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THE ENTREPRENEURIAL REGION
PATH DEVELOPMENT AND TECHNOLOGICAL CATCH-UP IN REGIONS ON THE KNOWLEDGE PERIPHERY

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The pursuit of a PhD is not only an academic rite of passage but also a personal journey.

During this journey, I have lived in Medellín, Colombia, Paris, France, Reggio Calabria, Italy, Utrecht, the Netherlands, and Boston, the United States, to conduct research on various topics related to economic geography, urban studies, public policy, and regional innovation governance. During this journey, I disseminated research results at conferences and workshops in Bratislava, Brighton, Brussels, London, Paris, Utrecht, Reggio Calabria, Trento, and Zagreb. During this journey I have become an expert in regional innovation governance and regional innovation policies publishing academic articles in peer-reviewed journals.

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DISCLAIMER

This disclaimer informs readers that the policy recommendations to create regional innovation agencies in regions located on the knowledge periphery expressed in this thesis belong solely to the author, and not to the author's employer, studied organizations, committee, advisors, or other group or individual. Any errors or omissions in this thesis are entirely my own.

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Abstract.

There is no "one-size-fits-all" regional innovation policy, as regional innovation systems (RIS) differ widely in terms of prior innovation capabilities, industrial base, and institutional contexts. Using Ruta N, a regional innovation agency in Medellín, Colombia, as a single, significant, critical, and high-impact case, this thesis investigates the strategies implemented by the municipally-owned intermediary organization to support new industrial path development. The thesis finds that there exists a "one-size-fits-many" regional innovation governance structure and institutional arrangement to upgrade RIS in a systematic manner. Ruta N has been created from the close institutional proximity between the public and private sectors to respond to specific innovation challenges in its RIS. The role of Ruta N is to continuously monitor its RIS, to find weaknesses in its RIS, and to find the solutions to upgrade its RIS while playing the role of a knowledge gatekeeper engaging in the "tropicalization" of extra-regional knowledge to support new industrial path development. Medellín's economic structure is transitioning from industrial towards more knowledge-based and service-based activities. During a period of regional structural change in the economy, the socio-institutional and the techno-economic structures are temporarily decoupled due to the relative inertia of the social, organizational, and institutional structures compared to rapid changes in the techno-economic structure. The lag in co-evolution between the socio-institutional and the techno-economic structures generates inefficiencies and instabilities in the RIS that requires policy interventions. Ruta N has devised programs to accelerate the co-evolution of the social, organizational, and institutional structure with the novel techno-economic structure. Finally, this thesis recommends a framework for designing such institutional arrangements in specialized and organizationally thick RISs that are located on the knowledge periphery to support new industrial path development and the technological catch-up process.

Keywords: Medellín, Path Development, Entrepreneurial State, Technological Catch Up, Institutional Arrangement, New Industrial Policy.

Abstract.

Non esiste una politica di innovazione regionale “unica”, poiché i sistemi di innovazione regionali (SIR) differiscono ampiamente in termini di capacità di innovazione, base industriale, e contesti istituzionali. Usando Ruta N, un'agenzia di innovazione regionale a Medellín in Colombia, come singolo caso significativo, critico e di grande impatto, questa tesi vuole indagare le strategie implementate dall'organizzazione intermediaria di proprietà comunale per supportare il nuovo sviluppo industriale. La tesi rileva l’esistenza di una struttura di governo dell'innovazione regionale “taglia unica” e un accordo istituzionale per aggiornare i SIR in modo sistematico. Ruta N è nata dalla stretta vicinanza istituzionale tra il settore pubblico e quello privato per rispondere a specifiche sfide di innovazione nei suoi SIR. Il ruolo di Ruta N è quello di monitorare continuamente i propri SIR, di rilevare i punti deboli nei propri SIR e di trovare soluzioni per aggiornarli, mentre svolge il ruolo di “custode della conoscenza” impegnandosi nella “tropicalizzazione” delle conoscenze extra-regionali, al fine di supportare nuovi sviluppi del percorso industriale. Medellín sta evolvendo da città industriale a città maggiormente basata sulla conoscenza e sui servizi. Nel periodo di cambiamento strutturale nell’economia, le strutture socio-istituzionali e tecno-economiche risultano temporaneamente divise a causa dell’inerzia delle strutture sociali, organizzative e istituzionali, rispetto ai rapidi cambiamenti nella struttura tecno-economica. Il ritardo nella co-evoluzione tra le strutture socio-istituzionali e tecno-economiche genera inefficienze e instabilità nel SIR richiedendo interventi politici. Ruta N ha ideato programmi per accelerare la co-evoluzione della struttura sociale, organizzativa e istituzionale, con la nuova struttura tecno-economica. Per concludere, questa tesi suggerisce un quadro per la progettazione di tali accordi istituzionali, in SIR specializzati e strutturalmente spessi che si trovano alla periferia della conoscenza, supportando lo sviluppo di nuovi percorsi industriali ed il processo di accelerazione tecnologica.

Keywords: Medellín, Sviluppo del Percorso, Stato Imprenditoriale, Accelerazione Tecnologica, Accordo istituzionale, Nuova politica industriale.

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ACI	Agencia de Cooperación e Inversión de Medellín
ACOPI	The National Association of Micro, Small and Medium-Sized Companies
ANDI	Asociación Nacional de Empresarios de Colombia
APEC	Asia-Pacific Economic Cooperation
ARTI	Agenzia Regionale per la Tecnologia e l'Innovazione
ASEAN	Association of Southeast Asian Nations
BCN	Bloque Cacique Nutibara
BITS	Building on Information Technology Strengths
CDN	Business Development Center
CDNBio	Business Center in Biotechnology
CEDEZO	Centros de Desarrollo Empresarial Zonal
CEO	Chief Executive Officer
CIDET	Centro de Investigación y Desarrollo Tecnológico
CIIEN	Centro de Investigación e Innovación en Energía
COMFAMA	Caja de Compensación Familiar de Antioquia
CONVIVIR	Servicios Especiales de Vigilancia y Seguriadad Privada
COP	Colombian Peso
CTA	Centro de Ciencia y Tecnología de Antioquia
CUEE	Comité Universidad Empresa Estado
DAPI	Digital American Pipeline Initiative
DARPA	Defense Advanced Research Projects Agency
DEA	Drug Enforcement Agency
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
ECSIM	Centro de Estudios en Economía Sistémica
EDU	Empresa de Desarrollo Urbano
EEG	Evolutionary Economic Geography
ELN	Ejército de Liberación Nacional
ENIAC	Electronic Numerical Integrator And Computer
EPM	Empresas Públicas de Medellín
EU	European Union
FARC-EP	Fuerzas Armadas Revolucionarias de Colombia—Ejército del Pueblo
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GEA	Grupo Empresarial Antioqueño
GPT	General Purpose Technology
GREMI	Groupe de Recherche Européen sur les Milieux Innovateurs
HDI	Human Development Index
HP	Hewlett Packard
IADB	Inter-American Development Bank
IBM	International Business Machines
ICIPC	Instituto de Capacitación e Investigación del Plástico y del Caucho
ICT	Information and Communication Technologies
IMF	International Monetary Fund

IRPA	Institute for Robotic Process Automation
KET	Key Enabling Technology
KPI	Key Performance Indicator
LEED	Leadership in Energy and Environmental Design
MIT	Massachusetts Institute of Technology
NAFTA	North American Free Trade Agreement
NEG	New Economic Geography
NGT	New Growth Theory
NTT	New Trade Theory
NYC	New York City
OCAD	Collegiate Bodies of Administration and Decision
OCyT	Observatorio Colombiano De Ciencia y Tecnología
OECD	Organisation for Economic Co-operation and Development
PEPES	Perseguidos por Pablo Escobar
PhD	Doctor of Philosophy
PLANEA	Strategic Plan for Antioquia
PMO	Project Management Office
POT	Plan de Ordenamiento Territorial
PRIMED	Programa Integral de Mejoramiento de Barrios Informales
R&D	Research and Development
RIA	Regional Innovation Agency
RII	Regional Innovation Initiative
RIS	Regional Innovation Strategy
RIS	Regional Innovation System
RITTS	Regional Innovation and Technology Transfer Strategy
RTP	Regional Technology Plan
RUEDA	Red Unificada de Emprendimiento de Antioquia
S3	Smart Specialization Strategy
SBIR	Small Business Innovation Research
SIC	Superintendencia de Industria y Comercio
SIN	System Integration Networking Model
SME	Small and Medium Enterprise
SMP	Sociedad de Mejoras Públicas
SPRI	Sociedad para la Transformación Competitiva
STEM	Science, Technology, Engineering, and Mathematics
STI	Science, Technology, and Innovation
STIF	Science, Technology and Innovation Fund
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TRL	Technology Readiness Level
UN	United Nations
UNDP	United Nations Development Programme
US	United States
USD	United States Dollar
USSR	Union of Soviet Socialist Republics
WSJ	Wall Street Journal

Introduction.

Path Development: A Regional Innovation Governance Perspective.

Motivation. How can regions on the knowledge periphery catch-up? This is the question that has been guiding this thesis. In the European Union (EU), this question is more relevant than ever due to the growing divergence between core and peripheral regions despite the efforts of EU Cohesion Policy to address this issue in different programming periods. Peripheral regions and regions on the knowledge periphery are often offered a "one-size-fits-all" type of policy from policymakers who usually come from and have studied in top innovation hubs around the world, and have thus, a limited understanding of the unique regional context of peripheral regions and of regions on the knowledge periphery. The author is originally from Paris and has studied in innovation hubs around the world, namely Boston, Milan, Paris, and São Paulo. The unique opportunity to pursue a PhD program in Reggio Calabria offered the author a unique perspective on the complexity and multifaceted context of peripheral regions. For the course of his PhD, the author lived from January to November 2016 in Reggio Calabria, Calabria, which despite its dazzling landscape, generous people, and mild climate, is one of the poorest regions in Italy and in the European Union, with a GDP per Capita of €16,600 compared to €35,700 in Lombardy and to €29,000 on average for EU-28 in 2016 (Eurostats, 2017). The region ranks at the bottom in many different development indicators, such as quality of government, the regional unemployment rate for recent graduates, and in science and technology (Charron, Dijkstra, & Lapuente, 2014; European Union, 2017). There is a clear sense of desolation in the City of Reggio Calabria where economic development is neither genuinely pursued nor seriously hoped for. Catching-up with the North of Italy or the rest of the European Union is an electoral promise that is instantaneously ridiculed, and who would want to be like the North of Italy anyway? The problem is that the vast majority of young Calabrians have to leave to the North of Italy or to global innovation hubs to have the prospect of finding a decent job opportunity, which further contributes to the peripheralization of the region. This unflattering description of Calabria can be applied to many other peripheral regions around the European Union and the world. The motivation for writing this thesis lies in supporting the economic transformation of peripheral regions and regions on the knowledge periphery around the world. This thesis provides an instrument, the Regional Innovation Agency, through which, peripheral regions and regions on the knowledge periphery can catch-up by fostering new industrial regional path development within a market-based economy.

Hypothesis. The research question that guides the thesis is:

"*How can a Regional Innovation Agency foster new industrial regional path development in a region located on the knowledge periphery?"*

Regional innovation agencies (RIAs) are being created in diverse regions around the world in terms of their prior innovation capabilities and institutional contexts to serve as change agents in their RIS through delivering targeted regional innovation policies (Fiore, Grisorio, & Prota, 2011; OECD, 2011a). A RIA is a regional innovation governance structure and institutional arrangement that can support new industrial regional path development by upgrading the regional innovation system (RIS) of regions located on the knowledge periphery. New industrial regional path development refers to

the process for a region of moving into higher value-added industrial activities. New industrial path development consists of path creation and branching (Trippl, Grillitsch, & Isaksen, 2017). While path branching refers to the creation of paths based on related regional industrial activities, path creation involves the creation of a new industry in a region (Boschma & Frenken, 2006; Boschma, Minondo, & Navarro, 2013; Neffke, Henning, & Boschma, 2011). Regional path development follows a branching logic since regional industries that are technologically related evolve from pre-existing regional industrial activities (Boschma, Minondo, & Navarro, 2013; Neffke, Henning, & Boschma, 2011). The process of path branching and path creation is seen as the result of path-dependent processes that can be enabled by platform policies (Asheim, Boschma, & Cooke, 2011; Boschma, Balland, & Kogler, 2015). Regions differ, however, in their capacity to branch into or to create new regional industrial path development due to their institutional structures (Dawley, 2014; Rodríguez-Pose, Di Cataldo, & Rainoldi 2014), their industrial varieties and knowledge base (Asheim, Boschma, & Cooke, 2011), their capacity to attract agents of structural change (Neffke et al., 2018), or their regional elites (Acemoglu & Robinson, 2012; Grabher, 1993). Some regions that have robust urbanization economies due to their highly diversified knowledge base, such as Paris and London, are highly resilient in branching into and in creating new industrial path development (Boschma & Lambooy, 1999; Frenken, Van Oort, & Verburg, 2007).

The concept of regions located on the knowledge periphery is different from the concept of peripheral regions. While peripheral regions are regions located on the knowledge periphery, the concept is too narrow to be used in the global South. The concept of peripheral regions has mostly been applied to thinly populated regions in the European Union that lack dynamic clusters and support organizations (Tödtling & Trippl, 2005). The concept of knowledge periphery is much broader since it not only encompasses peripheral regions but also all the regions outside the knowledge core. That is, regions on the knowledge periphery refer to regions that are geographically distant from regions with significant knowledge flows and/or production. Regions in the knowledge core can have for proxy regions with substantial patenting activities, such as the Top-100 cluster by patent filing in the world, the regions that are geographically proximate (within a 200 kilometers radius) from the Top-100 cluster by patent filing in the world, and the regions receiving significant knowledge flows from regions in the Top-100 cluster by patent filing in the world (see Bergquist, Fink, & Raffo, 2017 for the list of Top-100 cluster by patent filing in the world). In contrast to core regions, regions on the knowledge periphery are remote from some of the main sources and users of knowledge, have limited extra-regional knowledge linkages, knowledge infrastructures, and have limited capacity to absorb extra-regional knowledge (Grillitsch & Nilsson, 2015; Isaksen, Tödtling, & Trippl, 2018; Martin et al., 2018).

The central hypothesis that underlies the research question is that regions located on the knowledge periphery have more obstacles than core regions to generate new industrial regional path development due to their specific regional contexts. Regions located on the knowledge periphery face a number of obstacles hindering new industrial path development due to various evolutionary structures that lock regional path development into specific inferior technological trajectories due to the nature of scientific and technological knowledge that is path dependent, mutually dependent, self-reinforcing, and cumulative (Arthur, 1988; Boschma & Lambooy, 1999; David, 1985; Dosi, 1988). In addition to having more difficulties to access extra-regional knowledge due to its spatial nature, regions on the knowledge periphery have a lower capacity to acquire,

absorb, and diffuse extra-regional knowledge (Anselin, Varga, & Acs, 1997; Audretsch & Feldman, 1996; Rodríguez-Pose, & Crescenzi, 2008a). The specific nature of scientific and technological knowledge hinders, as a result, the capacity of regions on the knowledge periphery to trigger the "principle of interlocking, circular inter-dependence within a process of cumulative causation" to foster new industrial path development (Myrdal, 1957, p. 23).

The second hypothesis that underlies the research question is that regions on the knowledge periphery have to become entrepreneurial. The entrepreneurial region applies the concept of the "entrepreneurial state" to the regional scale to emphasize the importance of the state to partner with the private sector to support regional structural change in the economy (Mazzucato, 2015). The role of the entrepreneurial region and regional institutional capacities are fundamental in regions on the knowledge periphery since the sole allocation of more funds cannot provide sustainable regional economic development. In the European Union, the growing divergence between core and peripheral regions raises questions about the relevance of interventions within EU Cohesion Policy (Farole, Rodríguez-Pose, & Storper, 2011; Rodríguez-Pose, Di Cataldo, & Rainoldi, 2014). While the concept of smart specialization presumes the existence of a smart region to implement the policy-strategy, the literature on path development presumes path-dependent processes limiting thus, the process of technological catch-up for regions located on the knowledge periphery (Asheim, Boschma, & Cooke, 2011; Boschma, Balland, & Kogler, 2014; Charron, Dijkstra, & Lapuente, 2014; Rodríguez-Pose, Di Cataldo, & Rainoldi, 2014). The literature on smart specialization and path development points out the importance of the role of the government and policies to support structural changes in regional economies. Regions on the knowledge periphery often have, however, lower regional institutional capacities and quality of governments, which further hinder the possibility to structurally transform their economies and to catch-up technologically with regions in the knowledge core (Marques & Morgan, 2018; Rodríguez-Pose, 2013; Rodríguez-Pose & Di Cataldo, 2014). Indeed, government interventions have been essential in promoting the economic transformation of East Asian countries, namely Taiwan, Singapore, and South Korea, and this is too important to ignore (Amsden, 1989; Rodrik, 2008; Wade, 1990).

Moving beyond the orthodox economic paradigm, the neo-classical theory, that offers little to no help in understanding the process of economic transformation and the generation of new industrial path development, the author combines different perspectives, such as that of Schumpeterian growth models, new industrial policies, institutional economics, and transition studies, in order to frame the process of regional technological catch-up. The Schumpeterian growth models insist on the importance of technological innovations for economic growth (Schumpeter, 1934, 1939, 1942), its evolutionary nature (Nelson & Winter, 1982), and its importance for economic geography (Boschma, & Frenken, 2006). New industrial policies stress the importance of the role of the government to partner with the private sector in supporting the technological innovation process, calling for an "experimental", "smart", and "entrepreneurial" state (List, 1856; Mazzucato, 2015; Rodrik, 1995, 2004, 2008). Institutional economics point out the importance to capture the contextual nature of economic life (Hodgson, 1998; North, 1990, 2005). Transition studies show that the process of technological change is embedded in larger structural changes (Kemp, 1994; Geels, 2002, 2004, 2005; Perez, 1983, 2004, 2010). As pointed out by Friedrich List, the German catch-up theorist, "in order to allow freedom of trade to operate naturally, the

less advanced nation (Germany) must first be raised by artificial measures to that stage of cultivation to which the English nation has been artificially elevated" (List, 1856, p. 207). In this perspective, catching-up for regions located on the knowledge periphery can be supported through new industrial policies promoted by the entrepreneurial region to encourage technological innovations within the regional context while at the same time facilitating larger structural transitions.

The case selected to answer the research question and validating the hypothesis is:

The Regional Innovation Agency, Ruta N Medellín or Ruta N.

The case selected is the regional innovation agency Ruta N in Medellín, which was purposefully sampled for three reasons. First, the City of Medellín has been implementing unorthodox economic policies under 'a post-Washington consensus approach to local economic development' within a market-based economy (Bateman, Duran Ortĩz, & Maclean, 2010). Second, Ruta N and the City of Medellín have been hailed as best-practices in Latin America (OECD, 2015a). Third, Medellín is a secondary city that is transitioning from an industrial into a knowledge city and is located in the global South on the knowledge periphery with limited links with regions in the knowledge core. Ruta N was created in 2009 to support Medellín's transition from an industrial city into a knowledge city. The major actors that participated in the creation of the organization are, the municipal government, the municipal-owned multi-utility company EPM-UNE, Proantioquia, and the Centre for Science and Technology of Antioquia (CTA). Ruta N is in charge of implementing the Science, Technology, and Innovation (STI) Plan 2011-2021 that was drafted by more than 250 regional leaders and aims to position the city as the 'most innovative city in Latin America' (Pineda & Scheel, 2011). The STI plan was adopted as a public policy by the Medellín Council through the Municipal Agreement 024 of 2012, which granted, for the period 2011-2021, 7% of EPM ordinary profits to Ruta N to conduct investments and to support companies and research organizations in science, technology, and innovation (Concejo de Medellín, 2012). The STI Plan identified and prioritized three regional industrial path developments, information and communication technologies (ICTs), energy, and health, that were selected based on prior regional capabilities and potential growth. Ruta N has also supported path creation in three other sectors: nanotechnology, digital animation and video games, and biotechnology.

The case provides a framework for policymakers in regions located on the knowledge periphery to design their own version of a regional innovation agency to support new regional industrial path development and to promote technological catch-up. The case, which gives a rich description of Colombia, Medellín, its RIS, Ruta N, and its specific context, provides policymakers with all the elements to consider whether similar policy-responses are appropriate to replicate in their RIS and what is the most appropriate course of action to pursue such policy-strategy. Indeed, the framework developed in this thesis is flexible in allowing policymakers to incorporate or disregard elements to better respond to the contexts of their RIS. Institutions are context-specific. For that reasons, decision-makers should listen to a wide range of experts and should not blindly follow best-practices when reforming their institutions (Dixit, 2009). Policymakers should merge elements of international best-practices with context-specific features to reform or to design successful institutions (Dixit, 2009). Finally, the case is highly important for the new programming period 2021-2027 of EU Cohesion Policy, as the case offers an

instrument to strengthen the institutional quality and innovation capacities of regions on the knowledge periphery, such as Southern and Eastern European regions (European Commission, 2018).

Research Focus. The process of catching-up for peripheral regions is a highly complex and multidimensional phenomenon. This research focus is supported by an ambitious literature review. Indeed, the literature review is not limited to a particular discipline and comes from economics, namely evolutionary and institutional economics, regional economics, and economic geography; innovation studies, namely neo-Schumpeterian; sustainability studies, namely transition studies; sociology, namely urban sociology; business management, namely entrepreneurship studies; public management, namely new industrial policies; and urban studies and planning.

Outline of the Thesis. In line with the research focus and the motivation underlined above, the thesis is articulated into two main parts. The first part, based on a literature review, has the objective to design the conceptual framework in which to analyze the case study. The second part delves into the case study by providing the research design and the methodological approach to highlight the specific factors of the entrepreneurial region in supporting the technological catching-up process. The literature review examines the importance of technological innovations in the process of divergence, the multiple aspects of technological innovations, the importance of tacit knowledge and proximity in the innovation process and in anchoring spatially this process, the perspective of evolutionary economics, the different territorial innovation models, the role of governments in supporting the innovation process and the new industrial policies, and the importance of external knowledge and absorptive capacity to generate technological innovations. Finally, a framework that recombines previously discussed elements that are involved in the generation of technological innovations within the larger socio-institutional structure is developed. The case study analysis is supported by the methodology and the research design as well as the challenges, limitations, and ethical issues that the research faces. The analytical description of the historical context in Colombia, in Medellín, and in the creation of Ruta N. It gives the readers all the descriptive elements to understand the case, the role of the organization, and the programs that have been implemented to support the process of catching-up. Finally, the case is analyzed within the framework developed in the literature review. The third part explains the results and outlines the conclusions. The results are discussed to provide readers and policymakers with policy recommendations to successfully design their own regional innovation agency. The conclusions summarize the findings, the policy implications, the research limitations, and future research directions.

Part I
The Conceptual Framework: Outlining the Process of Technological Catch-up

1. Literature Review.

1.1. Technological Innovations and Regional Divergence.

The academic literature provides, both across nations and over time, a solid theoretical background linking technological innovations to the progress of countries, regions, cities, and firms (Aghion & Howitt, 1990; Akcigit, Grigsby, & Nicholas, 2017; Fagerberg, 1988, 1994; Freeman, 1987; Mokyr, 1990; Rosenberg, 1982a, 2004; Schumpeter, 1934; Solow, 1957; and many more). The OECD (2015b) argues that "innovation provides the foundation for new businesses, new jobs and productivity growth and is thus an important driver of economic growth and development" (p. 13). Technological innovation drives productivity growth as well as the quality and quantity of jobs, which are critical to improve standards of living (OECD, 2011a). Indeed, technological innovation is considered to be a dominant force in economic growth and in a post-2008 era characterized by low economic growth, innovation is seen as a transformative force for developed and developing economies (Metcalfe & Ramlogan, 2008; OECD, 2015b; Rosenberg, 2004; Solow, 1957). Technological innovations also have the capacity to address pressing social and global challenges, such as demographic shifts, resource scarcity, and climate change, while supporting more productive, resilient, and higher-income economies (OECD, 2015b).

From the work of Cobb and Douglas (1928) and Solow (1957), there are only two ways to increasing the output of the economy: an economy can either increase the number of inputs that go into the productive process, which include land, labor, and capital, or an economy can innovate in thinking of new ways in which the economy can get more output from the same number of inputs (Rosenberg, 2004). The impact of technical progress on economic growth was first synthesized into a coherent empirical whole by Solow (1957) from the work of Abramovitz (1956) who measured the growth of the output and the growth of inputs of the American economy between 1870 and 1950. Solow (1957) used a modified production function, $Y=f(K, L, t)$, in which K is capital, L is labor, and t represents technical change over time. The measured growth of inputs (i.e., in capital and labor) accounted for about 15% of the actual growth in the output of the economy, and 85% was an unexplained statistical residual, in other words, technical change. Solow (1957) discovered that technical change was responsible for 87.5% of economic growth when deriving estimates of the United States total factor productivity between 1909 and 1949. Although later works have debated the actual residual contribution to economic growth, it is taken as axiomatic that innovation is the single, most important, component of long-term economic growth (Cameron, 1996; Rosenberg, 2004).

Economic growth, however, as economists knew it, might be over (Ayres, 2006; Gordon, 2012). Indeed, perpetual economic growth is an extrapolation from history and a pious hope for the future, not a law of nature (Ayres, 2006). There are many drivers of past growth in industrialized countries that are now showing signs of saturation or exhaustion (Ayres, 2006). Growth optimists argue that technological change, especially in emerging sectors, such as artificial intelligence, information technology, nanotechnology, biotechnology, and robotics, can secure a lasting high economic growth (Ayres, 2006). The driver for technological innovations and economic growth are General Purpose Technologies (GPT), which are technologies—such as the electricity or information and communication technologies (ICT)—that are pervasive and spread to many sectors, have

a high rate of improvement, make it easier to invent or produce other innovations, and affect the entire economy (Bresnahan & Trajtenberg, 1995; Mazzucato, 2015, Ruttan, 2001). As discovered by Kondratieff (1984) and later supported by Schumpeter (1939), the occurrence of major technological transitions is associated with cycle of economic expansion, which allows the process of creative destruction to take place. Pavitt and Soete (1981) confirmed this observation by pointing out that there exists a strong relationship between phases of economic growth and different patterns of innovative performance. In other words, the introduction of breakthrough innovations facilitates the emergence of new industries and innovative actors, while at the same time, replacing incumbent industries and former innovative actors.

The economy is going through successive phases of development, also referred as cycles or waves, that simultaneously occur with the introduction of breakthrough technologies or General Purpose Technology (Kondratieff, 1925; Rosenberg, 1982; Schumpeter, 1942). According to Gordon (2012), there have been three industrial revolutions. The first industrial revolution, which spanned from 1750 to 1830, was triggered by the invention of the steam engine and railroads. The second industrial revolution, which lasted from 1870 to 1900, made mass-production possible with the invention and use of electricity, internal combustion engine, running water, indoor toilets, communications, entertainment, chemicals, and petroleum. The third industrial revolution, which began in the 1960s, was centered around the diffusion of microelectronics, building on the sequential discoveries of the transistor (1947), the integrated circuit (1957), the planar process (1959), the semiconductors (1960s), the microprocessor (1971), the personal computers (1970s and 1980s), the Internet (1990s), and smartphones (2000s) (Castells, 1994; Gordon, 2012). The third industrial revolution began around 1960 and reached its peak in the dot.com era of the late 1990s. The impact of the third industrial revolution on labor productivity happened in the 1970s and 1980s when computers replaced tedious and repetitive clerical labor. Since 2000, inventions are made on entertainment and communication devices that are smaller, smarter, and more capable, but do not fundamentally change labor productivity or the standard of living in the way that electric light, motor cars, or indoor plumbing did (Gordon, 2012). Two unique features characterize the third industrial revolution. First, knowledge is the fundamental feature of the third industrial revolution. While information and knowledge have been two essential features of every industrial revolution, the difference with the latest industrial revolution is that "information and knowledge are not only its raw materials but also its outcomes" (Castells, 1994, p. 13). Second, the main developments of the innovations in the third industrial revolution are on process rather than on product innovations (Castells, 1994, p. 14). Some authors believe that the world is at the commencement of a fourth industrial revolution (see Schwab, 2016). The fourth industrial revolution is "characterized by a much more ubiquitous and mobile internet, by smaller and more powerful sensors that have become cheaper, and by artificial intelligence and machine learning" (Schwab, 2016, p. 7).

The third industrial revolution has been dubbed the "knowledge-based economy" in which capitalist economies are going through an economic transition towards a "post-Fordist," "post-industrial," or "post-modern" economy (Amin, 1994; Castells, 1996; Drucker, 1994). The transition is characterized with the emergence of technological, market, social, and institutional forces that are very different from those which dominated the economy after the Second World War (Amin, 1994, p. 1). The term knowledge-based economy recognizes the importance of knowledge as the driver of

productivity and economic growth, emphasizing the role of information, technology, and learning in economic performance (OECD, 1996; OECD, 2001a). In the third industrial revolution, knowledge is paramount since it is the factor of production that is increasingly undermining and overtaking the traditional factor of production, land, capital, and labor, as the main source of profit (Drucker, 1998a). Although, technology and knowledge are closely interrelated since technology is "the use of scientific knowledge to specify ways of doing things in a reproducible manner," knowledge is paramount today since "knowledge feeds upon knowledge itself in order to generate higher productivity" (Castells, 1994, p. 10). The knowledge-based economy can be defined as the production of products and services that rely on intellectual capabilities rather than on physical inputs or natural resources characterized by an accelerated pace of technical and scientific advance and rapid obsolescence (Powell & Snellman, 2004). The knowledge-based economy can also be defined as an economy and thus its economic growth that is based on the creation, distribution, and use of technology embodied in physical and human capital (Feldman & Link, 2001).

The revolutionary nature of Information Communication Technologies was the trigger of the third industrial revolution, which differs not because of "the centrality of knowledge and information, but the application of such knowledge and information to knowledge generation and information processing / communication devices, in a cumulative feedback loop between innovation and the uses of innovation" (Castells, 1996, p. 32). The knowledge-based economy is characterized by increasing returns to scale (Arthur, 1996; Maskell & Malmberg, 1999a; Prahalad & Hamel, 1990; Temple, 1999). Indeed, knowledge is different from other inputs of production in that, it is extremely durable, its use does not reduce its stock, in fact, its use often creates new knowledge (Prahalad & Hamel, 1990). Indeed, knowledge can be sold again and again without reducing his stock (Maskell & Malmberg, 1999a). The increasing return to scale nature of knowledge does not generate equilibrium but instability (Arthur, 1996). Indeed, as shown by Arthur (1996, p. 100) "if a product or a company or a technology—one of many competing in a market—gets ahead by chance or clever strategy, increasing returns can magnify this advantage, and the product or company or technology can go on to lock-in the market". Increasing properties are characterized by market instability, multiple potential outcomes, unpredictability, market lock-in, possible inferior technological outcomes, and a winner-takes-all economy (Arthur, 1996; Rosen, 1981). Knowledge-based innovations differ as a result, "from all others in the time they take, in their casualty rates, and in their predictability, as well as in the challenges they pose to entrepreneurs... They have, for instance, the longest lead times of all innovations... To become effective, innovation of this sort demands not one kind of knowledge but many" (Drucker, 1998a, p. 6).

Knowledge-based companies are the primary actors of the knowledge-based economy. They are traditionally defined regarding their research and development (R&D) intensity, their proportion of scientists, and their proportion of professional engineers and technicians in the workforce (Aydalot & Keeble, 1988, p. 60). The OECD (1999) defines knowledge-based industries as "industries that use technology and/or human capital intensively." The knowledge-based industries include not only R&D intensive industries but also communications, finance, insurance, real estate, business services, community, social and personal services industries. Knowledge-based industries aim to remain competitiveness not through cost-reduction but through the generation of quasi-rents through enhanced knowledge creation (Maskell & Malmberg, 1999b; Porter, 1990). In

the knowledge-based industries, product life-cycles are shorter and the need for continuous innovation may lead to having process innovation to follow more rapid product innovation than in the traditional Abernathy-Utterback curves (Aydalot & Keeble, 1988; Freeman & Soete, 2004). The increased complexity of technology has forced knowledge-based industries to adopt new organizational strategies such as: "functional integration versus functional specialization, flexibility versus rigidity, customization versus product standardization, exploitation of economies of scope versus traditional economies of scale, just-in-time input organization versus investment in inventory, concentration of strategic and planning power and transfer of intermediate responsibility at the plant level, external collaboration for innovation versus internal development, continuing innovation and declining product maturity, decreasing scope for international selective decentralization of production phases" (Aydalot & Keeble, 1988, p. 60).

The third industrial revolution has also encouraged a complex transformation which concerns simultaneously the social, economic, organizational, institutional structures (Amin, 1994; Castells, 1994). The third industrial revolution has initiated the economic transition toward a "post-Fordist," "post-industrial," or "post-modern" economy (Amin, 1994). While the concept of post-Fordism is associated with economic and institutional change, the concept of post-modernism is related to changes in the realm of consumption, aesthetics, culture, and lifestyle (Amin, 1994). The shift in paradigm, however, encompasses both post-Fordism and post-modernism simultaneously. In other words, the transition into post-Fordism that was initiated by Information and Communication Technology innovations is concomitant with social, organizational, and institutional changes.

The third industrial revolution, as with previous industrial revolutions, is characterized by the process of creative destruction (Schumpeter, 1939). Many academics argue, however, that this latest transition is different, and that jobs are being destroyed at a much faster rate than is job creation (see Brynjolfsson & McAfee, 2014; Drucker, 1994; Ford, 2015). Indeed, the advent of the Internet, the ubiquitous of software, automation, and information and communication technologies have profoundly transcended society and the labor market. Developed countries are confronted with an increase in non-standard employments and jobs polarization in the labor market, which is characterized by an increasing demand for both high-skilled and low-skilled jobs and a "hollowing out" in middle-skilled ones (Acemoglu & Autor, 2011; Autor, 2014; Autor, Levy, & Murnane, 2003; Brynjolfsson & McAfee 2014; Cowen, 2013; Goos & Manning, 2007; OECD, 2015c). Non-standard employment, which includes: self-employment, temporary or fixed-term contracts, and part-time work, represents one-third of total employment in the OECD countries (OECD, 2015c). In the knowledge-based economy, work ethics has evolved to emphasize the importance of passion, freedom, and the pursuit of meaningful projects blurring the boundaries between leisure and work (Himanen, 2010; Mitchell, 1995). At the same time, wealth distribution is increasingly being skewed towards the superstars, people who dominate the activities in which they engage in, contributing to a winner-takes-all economy (Rosen, 1981).

The knowledge-based economy is not only a multidisciplinary academic concept but also a policy concept. The academic interest for innovation studies came into being in the 1980s and 1990s, at a time, where developed countries experienced an increased competition from low-cost labor emerging countries due to the process of globalization

(Freeman & Soete, 2004). Innovation studies aimed to conciliate the process of globalization with the theory of comparative advantage. Developed countries could, as a result, continue to enjoy high-growth rates and high-income per capita by moving up to higher value-added activities through innovation due to the nature of knowledge (Maskell & Malmberg, 1999a; Porter, 1990; Prahalad & Hamel, 1990). The increased policy recognition of technological innovations as the primary determinant for long-term international competitiveness and trade performance has reduced "the economist's cartel argument in support of all trade liberalization" (Freeman & Soete, 2004, p. 334). Developed and emerging countries are, as a result, in an innovation race. In this race for innovation, China is transitioning rapidly into a knowledge-based economy compared to other developed and developing economies (Zhou & Leydesdorff, 2006). European countries are lagging behind the United States in producing technological innovations. Although the European Union countries are leading in top-level scientific outputs compared to the United States, they have not been able to transform these outputs into wealth-generating innovations. Dosi, Llerena, and Labini (2006) argue that this "European Paradox" is due to a weaker system of scientific research and a lower capacity of European Union's innovative companies to successfully transform scientific outputs into successful technological innovations. In 2000, the European Union has made innovation a priority with the Lisbon Agenda (2000) and Europe Horizon 2020 strategy, which sets a target for 3 per cent of the EU's GDP to be invested in R&D, along with a diverse range of innovation policies to close its technological gap with the United States and thus, to become "the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion" (Hagemann, 2008; European Parliament, 2000).

Neoclassical growth theory assumes that technical change is "exogenous" and proceeds at a steady state. This is the so-called "manna from heaven" view of technology, where technology is a public good, accessible by all and at any time (Cameron, 1996). Science and technology is approached for neoclassical economists as a "black box" (Rosenberg, 1982). Neoclassical theories have, as a result, little to contribute to understanding technological innovations. However, the neoclassical thoughts are so pervasive in economic life and in guiding government interventions that it requires some discussion. The traditional neoclassical growth theory suggests that per capita growth rates should be inversely related to initial levels of income (Solow, 1956). The neoclassical model incorporates labor and capital mobility in regional development, to the extent that, given identical production functions in all regions, labor will flow from low-wage to high-wage regions, and capital will flow in the opposite direction (Barro & Sala-i-Martin, 1992). The neoclassical model assumes that over time wages and growth will be the same between regions within the same country (Barro & Sala-i-Martin, 1992). The theory implies that income levels and growth rates of national economies and regional economies should converge over time (Barro & Sala-i-Martin, 1992).

The theory on convergence between regions has not shown to be consistent with the facts (Islam, 2003). The long-run growth indicates divergence in productivity and income between the richest and poorest countries since the industrial revolution (Landes, 1998). The clear predictive limitations of the neoclassical growth theory led to the emergence of several theories, such as New Growth Theory (NGT), New Trade Theory (NTT), and New Economic Geography (NEG), to correct these limitations. Some neoclassical economists (see New Economic Geography: Fujita, Krugman, & Venables 2001; Krugman, 1991; see New Trade Theory: Krugman, 1985; see New Growth Theory:

Lucas, 1988; Romer, 1986; Romer 1994; Rosenberg, 1994) have tried to correct the limitations of the neoclassical growth model relating to the understanding of innovation. Rather than being exogenous, the endogenous growth theory attempted to endogenize the role of innovation in the growth process. Learning by doing (Romer, 1986), investment capital (Romer, 1986), human capital (Amable, 1993; Lucas, 1988), infrastructure (Amable, 1993), or R&D (Romer, 1994) are thus some of the determinants of technical change that are being incorporated in the growth model to better reflect the reality of the innovation process. Increasing returns to scale and knowledge externalities make continuous growth and productivity growth possible (Amable, 1993). The endogenous growth theory, however, lacks in capturing organizational change or the relationships between institutional, technical, and investment change (Freeman, 1994). The theory does not explain how technological innovation emerges and how it affects economic growth and development (Freeman, 1994). The endogenous growth theories demonstrate that differences in production structures arise because of differences in underlying characteristics without explaining why those characteristics appear in the first place (Ottaviano & Puga, 1998).

Neoclassical economic models have a limited interest for policymakers designing innovation policies, as they single out the institutional structure of the research systems of advanced industrial economies. Innovation is treated as a "black box" whose characteristics and internal processes are ignored (Mowery & Rosenberg, 1991). Neoclassical models assume that R&D decisions result from calculated returns on investment objectives made by rational profit-maximizing firms (Arrow, 1962). Contrary to the orthodox economic approach that is derived from neoclassical economics, the unorthodox economic approach emphasizes that international differences in technological capacities largely explain divergence in terms of income, trade, and standard of living (Dosi, Pavitt, & Soete, 1990). Additionally, the unorthodox approach points out that: general equilibrium mechanisms have limited predictive capabilities; technological knowledge is not a free good but is cumulative, path-dependent, localized, and specific; and international trade is highly relevant (Dosi, Pavitt, & Soete, 1990). Neoclassical economics suggests that outcomes are static under a general equilibrium theory; evolutionary economics in contrast, suggests that outcomes are ongoing with partial equilibrium models (Hodgson, 1998). The evolutionary approach, which was adopted in this thesis to describe technological innovation and economic growth, will be explained in details in the literature review.

The realization of the importance of the regional dimension in the process of innovation comes from the numerous examples of regional divergence within the same countries; for instance, the Third Italy versus the South of Italy, or Silicon Valley versus Route 128 in Boston (Asheim & Gertler, 2004; Bagnasco, 1977; Braczyk, Cooke, & Heidenreich, 1998; Saxenian, 1994). Success stories of highly specialized industrial agglomerations and clusters of regionally concentrated networks of Small and Medium Enterprises (SMEs) also significantly contributed to foster the interests of policymakers and scholars on regions as engines for growth and innovations (Baptista & Swann, 1998; Becattini, 1992; Feldman, 1994; Porter, 1990). The process of economic divergence is especially apparent between regions and city-regions within the same country, as demonstrated in the numerous case studies of prosperous regions, such as: The Third Italy; Silicon Valley; Orange County; Route 128; Baden-Württemberg; Haute Savoie; Regional Triangle Park; Cambridge, United Kingdom; and so on (Asheim & Gertler, 2004; Bagnasco, 1977; Becattini, 1992; Braczyk, Cooke, & Heidenreich, 1998; Camagni, 1991; Moretti, 2012;

Porter, 1990; Putnam, Leonardi, & Nanetti, 1994; Saxenian, 1994; Storper, 1995, and many more). In the European Union, while there is a trend towards long-term convergence in productivity and income at the national level, regional-level analysis either shows little change in patterns of dispersion or a tendency towards divergence (Cappelen, Fagerberg, & Verspagen, 1999; OECD, 2001b).

There is an economic divergence not only between widely historically disparate city-regions, such as North-South Italy but also between successful city-regions, such as Los Angeles and San Francisco. In the past decades, the two cities have diverged: while Los Angeles has experienced the loss of its aerospace industry, a rise in low-skilled immigrants from Latin America, and government failure, San Francisco has become the technology innovation center of the information age (Storper, Kemeny, Makarem, & Osman, 2015). The emergence of regions where both wages and employment are expanding, such as Silicon Valley in California, Research Triangle in North Carolina, and Cambridge in the United Kingdom, may seem surprising and even paradoxical in a world increasingly dominated by global telecommunications (Audretsch & Thurik, 1999). Regional divergence is mostly the outcome of the differences in regional innovative capacities due to the nature of technological innovations (Akcigit, Grigsby, & Nicholas, 2017). Indeed, the cumulative nature of technology combined with the geographical concentration of innovation over time due to specific, local, tacit, and only partly appropriable nature of knowledge are contributing to the perpetuation of technology gaps in regions that are enjoying a technological advantage (Faberberg, 1994). The concentration of technological innovation and wealth in a few metropolitan regions is due to, first, the necessity for a threshold in knowledge to trigger the "principle of interlocking, circular inter-dependence within a process of cumulative causation" (Myrdal, 1957, p. 23); second, the capacity of the metropolitan region to absorb and use external knowledge spillovers (Anselin, Varga, & Acs, 1997; Audretsch & Feldman, 1996; Rodríguez-Pose, & Crescenzi, 2008b); and third, the spatial dimension of knowledge spillovers that limit the development of regions on the knowledge periphery (Gertler, 2003; Rodríguez-Pose, & Crescenzi, 2008b).

Scholars and pundits have proposed that the revolution in ICT and the process of globalization is leading to, a "flat world" (Friedman, 2005), the "end of geography" (O'Brien, 1992), the "death of distance" (Cairncross, 1997), a "space of flows" (Castells ,1996), or a "weightless economy" (Quah, 1999). This view, also shared by technological utopians like Mitchell (1995), has not, however, occurred. While ICT and globalization have greatly enhanced the mobility of goods, labor, capital, and knowledge, it has not undermined the need for urban agglomeration; in fact, it has greatly contributed to the emergence of "urban and regional mountains" in which wealth, economic activity, financial flows, and innovative capacity concentrate (Ohmae, 1995; Rodríguez-Pose, & Crescenzi, 2008b; Sassen, 2001; Scott, 2001). Some authors argue, as a result, that regions, and not nations, have become the central unit of governance (Florida, Adler, & Mellander, 2016; Ohmae, 1995; Scott, 1998). Ohmae (1995) and Brenner (2004) suggest that despite the emergence of large supranational political institutions, the sub-national scales, namely metropolitan-regions, are increasingly becoming the critical strategic institutional arenas. The devolution of power to metropolitan regions are caused by upwards and downwards trends: the rise of supranational institutions such as the European Union, United Nations, NAFTA, ASEAN, APEC, and the rise transnational companies; and the devolution of power to regional and local authorities and organizations due to the disintegration of federal and centralized states. For some

authors, nation-states are seen as obsolete and no longer the optimal unit for organizing economic activity (Ohmae, 1995). Metropolitan-regions are emerging as the key organizing unit for innovation, creativity, and entrepreneurship (Florida, Adler, & Mellander, 2016).

The devolution of power to sub-national institutional levels and the redistribution of significant socioeconomic assets are re-concentrated within the most globally competitive urban regions and industrial districts, which has contributed significantly to the process of divergence between metropolitan regions and peripheral regions (Brenner, 2004; Veltz, 2000). Indeed, from the 1960s to today, urban governance has shifted from a Fordist-Keynesian welfare approach to an entrepreneurial and competitiveness oriented approach (Brenner, 2004; Harvey, 1989). In the 1960s, centralized governments introduced spatial policies to reduce intra-national regional divergence (Brenner, 2004). In the 1980s, there was a policy shift from comparative advantage to competitive advantage in which metropolitan regions were increasingly viewed as dynamic growth engines through which national prosperity could be secured (Brenner, 2004; Porter, 1986; Stimson, Stough, & Roberts, 2006). In the 1990s, the impact of globalization and the revolutionary nature of the ICTs were changing the nature and location of production, resulting in greater specialization or clustering (Dicken 1992; Stimson, Stough, & Roberts, 2006). National, regional, and local governments introduced place-based institutions and policies, such as enterprise zones, urban development corporations, airport development agencies, training and enterprise councils, inward investment agencies, and development planning boards in order to enhance socioeconomic assets within cities, which became the privileged target for major spatial planning initiatives and infrastructural investments (Brenner, 2004).

Regional governments have, as a result, taken a more active role in shaping innovation policies (OECD, 2011a). Two concurrent phenomena can explain the increasing importance of urban and regional governments in shaping innovation policy. First, the recognition by national policymakers that urban centers and regions have an essential role to play in formulating innovation policies, and thus, to foster regional growth; and second, the paradigm-shift toward decentralization (OECD, 2011a). Additionally, from a policy perspective, it is more relevant to look at innovation strategies at the urban and regional scales than at the national scale since: regional innovation systems follow varied development paths; divergences in growth are sometimes more pronounced within countries than between countries; R&D and patenting are mostly concentrated in key regions in top OECD innovative countries; new regions are emerging as knowledge hubs; regional collaboration and networks are becoming increasingly relevant for innovation; and creative industries are strongly shaped by regional features (OECD, 2011a). In the European Union, the Regional Technology Plans (RTP), Regional Innovation Strategies (RIS), and Regional Innovation and Technology Transfer Strategies (RITTS) are tools that are frequently used to affect regional innovation capabilities in order to promote convergence objectives for lower-income regions within the European Structural and Investment Funds (European Commission, 2014; Henderson, 2000). From 1989-1993, approximately 4% of the regional policy funds were devoted to innovation (OECD, 2011a). The share of innovation-related spending for the period 2007-2013 is projected to be approximately 25% of the regional policy funds (OECD, 2011a).

There is, however, no “one-size-fits-all” regional innovation policy. Cities and regions are not countries on a small scale. Urban and regional policymakers have to consider

three dimensions that vary considerably between regions, such as the local institutional context, which indicates the degree of regional and urban power to shape innovation policies; the local and regional innovation system; and the strategic choices made for supporting an innovation-driven model of growth (OECD, 2011a). Moreover, local and regional governments do not exercise control over a complete innovation system or have a comprehensive institutional framework. As a result, local and regional innovation strategies are embedded and interdependent with higher levels of governments, which are needed to carry out innovation strategies. There are three strategic priorities for cities and regions, which are: to build on current advantages (science push, technology-led, or a policy-mix); to support socio-economic transformation (reconversion or new specializations); and to catch-up (through the creation of knowledge-based capabilities and upgrading of absorptive capacity) (OECD, 2011a).

1.2. The Multiple Aspects of Technological Innovation.

The concept of technological change is a broad concept that encompasses technological invention, innovation, and diffusion of a new product, process, system, or device (Ashford & Hall, 2011; Freeman & Soete, 2004; Schumpeter, 1939, 1942). As a result, there are two distinctions to make, between invention and innovation, and between innovation and diffusion to fully comprehend the full spectrum of technological change.

Schumpeter (1939, pp. 84-86), made a clear distinction between invention and innovation, when he stated: “the making of the invention and the carrying out of the corresponding innovations are, economically and sociologically, two entirely different things. They may, and often have been, performed by the same person; but this is merely a chance coincidence which does not affect the validity of the distinction. Personal aptitude—primarily intellectual in the case of the inventor, primarily volitional in the case of the businessman who turns the invention into an innovation— and the methods by which the one and the other work, belong to different spheres”. An invention is defined as “an idea, a sketch or model for a new or improved device, product, process, or system. Such inventions may often be patented but do not necessarily lead to technical innovations. In fact, the majority do not” (Freeman & Soete, 2004, p. 6). Schumpeter (1934, pp. 65-66) suggests that an innovation is the “carrying out of new combinations.” Innovation, is to some extent, the recombination of physical and conceptual resources that are already in existence. For Schumpeter (1934) and evolutionary economists, equilibria are constantly disrupted by innovations (Arthur, 2010). The idea of recombination is elegantly stated by Arthur (2010, p. 170) when he stated: “every novel technology is created from existing ones, and therefore that every technology stands upon a pyramid of others that made it possible in a succession that goes back to the earliest phenomena that humans captured.”

An innovation can be defined as “the first commercial transaction involving the new product, process, system, or device” (Freeman & Soete, 2004, p. 6). Inventions can take place during the innovation process and more innovations can be made during the diffusion process. Many international organizations, think-tanks, and academics have given definitions of technological innovation, and among the most frequently quoted are the ones from the European Commission (1996) and the OECD (2005). The European Commission (1996, p. 54) defines innovation as, “the commercially successful exploitation of new technologies, ideas or methods through the introduction of new products or processes, or through the improvement of existing ones. Innovation is a result

of an interactive learning process that involves often several actors from inside and outside the companies". The Oslo Manual (OECD, 2005) defines innovation as: "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" (p. 46). The Oslo Manual (OECD, 2005) defines innovation activities as, "all scientific, technological, organizational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations" (p. 46). At the regional level, innovation is measured with innovation indicators, such as R&D expenditure, labor productivity, patents, and citations, which have some clear limitations (OECD, 2005).

Diffusion is the subsequent widespread adoption of an innovation beyond those who developed it (Ashford & Hall, 2011). The diffusion process of a technological innovation seems to be highly relevant for economic growth. In the 1950s and the 1970s, as reported by Freeman and Soete (2004), the OECD (1963, 1971) recognized that the rate of technical change and of economic growth depended more on the diffusion process than coming up with new inventions. Technological innovations contribute to the process of creative destruction (Schumpeter, 1942). During the process of creative destruction, Schumpeter (1942) noticed that firms in the newest industries had exceptionally high rates of profit, while other firms in older industries experienced the erosion or disappearance of profit. Indeed, technology development follows a technology S-curve, which posits that the rate of progress in performance will be slow in the early stage. In the second stage, as the technology becomes better understood, controlled, and diffused, the rate of technological improvement will accelerate exponentially (Christensen, 2013). Finally, in the mature stage, a greater and greater amount of time or inputs of engineering effort will be required to achieve an increasingly slower rate of progress in performance. The goal of strategic technology management is "to identify when the point of inflection on the present technology's S-curve has been passed, and to identify and develop successor technologies" (Christensen, 2013, p. 44).

In innovation studies, models have been developed to explain the innovation process. The academic literature frequently categorizes innovation models into two groups: the linear model of innovation and the non-linear model of innovation. Although it has largely been discredited today, the linear technology push and demand pull model of innovation has remained influential up to the early 1980s (Jankowski, 2001; Rothwell, 1992, 1994). The non-linear models of innovation include the doubling model; the integrated and System Integration and Networking model (SIN); and the Kline-Rosenberg model (Rothwell, 1992, 1994).

The linear model of innovation was widely adopted after World War II as the prevailing model of innovation in which research leads to development, development to production, and production to marketing (Kline & Rosenberg, 1986). It is not a coincidence that the linear model of innovation became popular at the peak of the Fordist era, at that time, it seemed that even abstract theoretical concept could follow the ideation of an assembly line. The concept of the linear model of innovation was introduced in Vannevar Bush's (1945) influential report titled *Science, the Endless Frontier*, which was requested by President Roosevelt to understand how the lessons learned from the wartime organization of science and engineering could be applied in times of peace (Jankowski, 2001). The breakthrough innovations that occurred during World War II, such as the atom bomb, radars, and penicillin, suggested that innovations were the outcomes of the

following cause and effect relationships: basic research made in large universities or government research institutes or private R&D laboratories, followed by innovation, and later followed by diffusion for military or civil uses. The Vannevar Bush's report pointed out the necessity for "government sponsorship of undergraduate scholarships and graduate fellowships to help develop scientific talents, and for the provision of federal incentives to industry to conduct R&D with their own funds" (Jankowski, 2001, p. 6). In the linear model of innovation, the innovation process is affected by the science push or technological push model, which refers to the idea that a new innovation begins in scientific research. This linear process of innovation suggests that the higher the investment in R&D, the higher the innovative capacity, and the higher the economic growth. The appealing and simplistic linear model of innovation was widely adopted by governments, which in turn, tried to foster innovations with technology push and investments in R&D. Although extremely simplistic, the linear model of innovation is still very influential today, which emphasizes the limitations of more recent models of innovation (Kline, 1985). As Thomas Kuhn (1967) argued in his much-praised book, *The Structure of Scientific Revolutions*, researchers and scientists completely abandon a model on a complex situation when a more complete model comes up. The concept of a paradigm-shift refers to the adoption of a new model replacing the prevailing paradigm (Kuhn, 1967). As a result of the linear model of innovation, the United States Federal government could justify expenditures to basic scientific and academic research to support scientific and technological innovations (Jankowski, 2001). Since the mid-1980s however, the Federal government has increasingly been more supportive of commercially-oriented R&D and is intervening through indirect rather than direct funding incentives (Jankowski, 2001).

The non-linear models of innovation were the responses to the shortcomings and overly simplistic linear model of innovation. The linear technology push and demand pull was the dominant model in the 1960s and early 1970s (Rothwell, 1992, 1994). The coupling model was the dominant model in the late 1970s and early 1980s (Rothwell, 1992, 1994). The System Integration and Networking model (SIN) was the dominant model in the late 1980s and early 1990s (Rothwell, 1992, 1994). The Kline-Rosenberg model of innovation is the dominant model since the early 1990s (Kline & Rosenberg, 1986).

The coupling model is the integration of demand pull and technological push models (Edosomwan, 1989; Rothwell, 1992). The coupling model involves feedback loops between the innovation process and push/pull combinations. The innovation model focuses on integrating R&D and marketing interface (Rothwell, 1992). Indeed, the innovation process is affected on both ends by two forces, market pull and technology push. The innovation process is constrained on the one hand, by the market or demand pull forces since it involves the recognition of a need or a potential market for a new product or new process (Freeman & Soete, 2004; Langrish, Gibbons, Evans, & Jevons, 1972). On the other hand, the innovation process is constrained by technology or science push forces, the availability of technological, scientific, and technical knowledge, resulting from research activities (Freeman & Soete, 2004; Langrish, Gibbons, Evans, & Jevons, 1972). Technology push starts with scientific discovery, which leads to technological development, manufacturing, commercialization, and diffusion in the marketplace. Market pull, however, begins with the identification of a market opportunity, which leads to development, manufacturing, and commercialization. Mowery and Rosenberg (1979) suggest that there are complex interactions between the supply side with R&D laboratories, scientific and technical institutions, and so on, and

the demand-side with potential and actual users, marketing organizations, and so on. Technology push or market pull is more or less relevant depending on the industry. In the pharmaceutical or chemical industry, for instance, large in-house R&D programs or sponsor R&D activities in universities and public or private research institutes or firms are crucial for producing innovations (Malerba, 2005; Pavitt, 1984). In other industries, such as computer operating systems, automobiles, machine tools or telecommunications, responding to changing demand through incremental innovations around dominant design and locked-in systems is more frequent (Utterback & Suarez, 1993; Malerba, 2005).

The integrated model deviates from the concept of the innovation process as a sequential process with activities shifting from function to function to considering the innovation process as a parallel process involving simultaneously elements of R&D, prototype development, and manufacturing (Rothwell & Zegveld, 1985; Rothwell, 1992, 1994). The innovation model focuses on integrating R&D and manufacturing interface, and on horizontal and vertical collaborations (Rothwell, 1992). Rothwell (1992) introduces the Systems Integration and Networking model (SIN) and adds conceptual elements to the integrated model with elements such as the fully integrated parallel development, the expert systems and simulation modelling in R&D, the strong linkages with leading-edge customers, the strategic integration with primary suppliers, the horizontal linkages, the emphasis on corporate flexibility and speed of development, the increased focus on quality, and other non-price factors. The Systems Integration and Networking model (SIN) aims to react to more and more relevant activities in the innovation process, such as inter-firm integration (networking); technological accumulation (technology strategy); integrated product and manufacturing strategies (design for manufacturability); flexibility (organizational, product, manufacturing); product quality/performance; the environment; and speed to market (Rothwell, 1992).

Kline and Rosenberg (1986) recognized the complexity of the innovation process when they stated that “there are many black boxes rather than just one” (p. 280). On this fact, Kline and Rosenberg (1986) develop the chain-linked model of innovation to highlight the feedback mechanisms between the different parts of the innovation process and flow paths of information and cooperation. The chain-linked model has five significant pathways that are important in the innovation process—potential market, invent and/or produce analytic design, detailed design and test, redesign and produce, and distribute and market—which includes numerous feedbacks and coordination not only with the central pathway but also with side-links to research and knowledge (Kline & Rosenberg, 1986). The innovation process is a highly complex, disorderly, hard to measure, and uncertain endeavor (Kline & Rosenberg, 1986). Technological innovation is controlled by two forces—technology push and demand pull—that interact with one another in subtle and unpredictable ways (Kline & Rosenberg, 1986).

Rothwell (1992) argues that technology and the innovation process are dynamic in that not only is technology changing rapidly but also is the innovation process (Rothwell, 1992). The level of interactions in the innovation process has been increasing exponentially both in scope and in intensity. The evolving models of innovation from linear to non-linear to chain-linked grasp this continually increased level of interactions. In the linear model of innovation, which was elaborated after the second world war, interactions were mostly confined within institutions, and the progressive breakdown of organizational models led to increasing interactions both within and between

organizations. Indeed, innovation increasingly requires "complex physical, virtual, and computational resources, as well as access to diverse collaborators" from around the world (Bulovic & Fiona, 2014, p. 4). The innovation process is faster than in the past and involves considerably more actors, to the extent of often being a multi-firm networking process (Rothwell, 1992). Additionally, in the non-linear view of innovation, both demand and supply can be determinant of innovation. Supply-side's view of innovation policy can include instruments working from the demand-side, such as laws, regulations and standards—that is, institutions—influencing suppliers for the product that is developed and produced. Demand-side also includes public technology procurement as an innovation policy instrument, which can trigger innovation, create new markets, lead to the fulfillment of previously unsatisfied needs, and solve pressing socio-economic and/or environmental problems (Edquist, Hommen, & Tsipouri, 2000; OECD, 2001b). Moreover, technological innovations imply more than technological change,as it is frequently accompanied by: organizational innovation, new venture division, management innovations, a new inter-functional liaison system, production innovations, a quality control circle, and commercial/marketing innovations, new financing arrangements, a new sales approach or leasing arrangement (Rothwell, 1992). The concept of innovation systems fits well with the non-linear model of innovation since it stresses interdependence and non-linearity (Edquist, 1997). Firms do not innovate in isolation but through interactions with other innovative actors through complex relations often shaped by formal and informal institutions. In the innovation system literature, technological innovation is the result of complex interactions between a wide range of actors, factors, and institutions (Edquist, 1997; Freeman, 1995; Lundvall, 1992; OECD, 1997). As a result, the understanding of the linkages among those actors and institutions is key to improving technology performance.

A technological innovation can be examined according to its range (incremental, radical, sustaining, or disruptive), its configuration (intrinsic or architectural), and its purpose (product or a process). The Oslo Manual (OECD, 2005) distinguished between four types of innovations: product innovations, process innovations, marketing innovations, and organizational innovations.

Technological innovations can be divided into two purposes: product and process innovations. A product innovation is defined as "the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user-friendliness or other functional characteristics" (OECD, 2005, p. 48). A process innovation is defined as "the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software" (OECD, 2005, p. 49). Process innovations can either be intended to decrease unit costs of production or delivery, or increase quality, or produce or deliver new or significantly improved products (OECD, 2005). A process innovation refers to an improvement of the way a product is manufactured without significantly changing the overall characteristics of the product. Additionally, product innovations dominate in the "high-tech" and knowledge-based sectors, process innovations dominate in the less advanced and more mature sectors (Edquist, Hommen, & McKelvey, 2001). Edquist, Hommen, and Mckelvey (2001) argue that process versus product innovations have different impacts on employment. Indeed, while product innovations tend to have a positive impact on employment, process innovations tend to have a negative impact on employment.

Utterback and Abernathy (1975) and Utterback (1994) provide, with the case-studies of the typewriter industry, automobile industry, television industry, transistor manufacturing industry, and integrated circuit industry, some important lessons with regards to product and process innovation within the product lifecycle perspective. Utterback and Abernathy (1975) suggest that the early stage of an innovation, or the fluid phase, is highly uncertain and the focus is placed on rapid product innovation. The fluid stage is characterized by radical product innovations that determine the product's dominant design. In the early days of the automobile industry, for instance, there was a variety of automobiles, including electric and steam-driven cars (Utterback, 1994). In the second stage, the product innovation reaches its dominant product design, which shifts the focus from product innovation to process innovation (Utterback & Abernathy, 1975). Once the dominant product design emerges, the basis of competition changes radically since firms adopt similar designs (Utterback, 1994). In this transitional phase, the rate of major product innovation slows down and the rate of major process innovations speeds up (Utterback, 1994). Finally, in the mature phase, both product and process innovations are incremental. The mature stage is prone to disruption that initiates a new fluid stage cycle. In the mature phase, "the ecology of competing firms changes from one characterized by many firms and many unique designs, to one of few firms with similar product designs" (Utterback, 1994, p. 24).

According to Arthur (2010), there are four different innovation mechanisms. Innovations can be incremental, radical, architectural, or disruptive. As stated by Arthur (2010, p. 164), "innovation consists in novel solutions being arrived at in standard engineering—the thousands of small advancements and fixes that cumulate to move practice forward. It consists in radically novel technologies being brought into being by the process of invention. It consists in these novel technologies developing by changing their internal parts or adding to them in the process of structural deepening. And it consists in whole bodies of technology emerging, building out over time, and creatively transforming the industries that encounter them". In *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle,* Schumpeter (1934) was the first to make the distinction between radical and incremental innovations. An incremental innovation concerns an existing product, service, process, organization or method whose performance has been significantly or partly upgraded (OECD, 2005). It refers to technological innovations that involve minor changes in technology or minor improvements in benefits and that develop in a cumulative evolutionary process of change (Sorescu, Chandy, & Prabhu, 2003). In contrast, a radical innovation refers to a technology that is discontinuous in its development (Rothwell, 1992). A radical innovation is an innovation that has a significant impact on a market by offering customers and users higher benefits relative to existing products, services, or processes, and, as a result, significantly impacts the economic activity of firms in that market (OECD, 2005; Sorescu, Chandy, & Prabhu, 2003). While incremental innovations can be introduced using processes, radical innovations will often require significant organizational and procedural adaptations (Rothwell, 1992). Schumpeter (1934) argues that radical technological innovations create major disruptive changes and have the capacity to challenge existing power structures and monopolies. Utterback (1994) shows that there are discontinuities in technological trajectories, for instance, in the ice cube industry: it went through harvested ice, machine-made ice, electromechanical refrigeration, and now aseptic packaging. Radical product innovations eventually end with the emergence of a dominant design when the marketplace has formed its expectations for a product regarding features, form, and capabilities (Utterback, 1994).

In his much-praised book, *The Innovator's Dilemma*, Christensen (2013) introduces the concept of disruptive and of sustaining innovations. Disrupting innovations, however, "disrupted or redefined performance trajectories" (Christensen, 2013, p. 10). Christensen (2013) describes the timeline of the disruptive innovation as the following: first, the innovation results in worse product performance in the near-term; second, the innovation brings to the market a different value proposition; third, the innovation appeals to a few fringe customers due to being cheaper, simpler, smaller, and more convenient to use; fourth, the disruptive innovation becomes mainstream and results in the failure of incumbent companies. Sustaining innovations refer to technologies that improve product performance in a continuous technological trajectory (Christensen, 2013). As a result, sustaining innovations can be radical or incremental in character. Radical innovation refers for Christensen (2013) as a discontinuous jump in technology within a product technological trajectory. In the literature, radical innovation and disruptive innovations are often used interchangeably

Incumbent companies have some limitations when it comes to forecasting the market potential of radical or disruptive innovations, as those four examples show: in 1876, an internal memo at Western Union, the telegraph monopolists, said, "the telephone has too many shortcomings to be considered as a serious means of communication." In 1927, a year before the movie *The Jazz Singer* was released, the head of Warner Brothers said, "who the hell wants to hear actors talk?" In 1943, Thomas Watson, then president of IBM, said, "I think there is a world market for maybe five computers." Lastly, in 1981, Bill Gates said in defense of the capacity of the first floppy disks, "640 kilobytes ought to be enough for anyone" (as quoted in Gordon, 2012, pp. 15-16). Radical or disruptive innovations, however, are usually not profitable for a long time after their inception. For instance, the company that invented the radio, the Marconi Company, did not receive any dividend from the launched of the radio in 1897 until 1910 (Freeman & Soete, 2004, p. 163). General-Purpose Technologies (GPTs), such as the steam engine, the combustion engine, nuclear power, electricity, and information and communication technologies, were, when first adopted, lowering productivity and economic growth due to problems of integration and restructuring, but are in the long run improving productivity levels and ultimately economic growth (Mokyr, 1990).

Incremental, radical, or disruptive innovations rely on different kinds of knowledge interactions (Tödtling, Lehner, & Kaufmann, 2009). The type of innovation widely differs from sector to sector. Some sectors are characterized by radical innovations and others by incremental innovations. High-technology sectors are characterized by the pursuit of radical innovations while low- and medium- technology sectors are pursuing incremental innovations. Incremental innovations, whether it is of an existing process or product, often come from the production engineers, the technicians, and the shop floor (Freeman, 1995; Freeman & Soete, 2004; Hollander, 1965). Incremental innovations also arise from the interactions with the market and with related firms, such as sub-contractors, suppliers of materials and services innovations (Freeman & Soete, 2004). Incremental innovation is taking place most effectively in an institutional environment where "learning" is fostered through intensive information exchange between organizations; and where there are stable and high-trust relationships between organizations (Lundvall, 1992; OECD, 2001b). Distance limits or enables incremental and radical innovations. Indeed, incremental innovations are triggered by frequent and repeated user-producer interactions (Lundvall, 1992, p. 57). As a consequence, being

close to advanced users provides a comparative advantage for the producers, and vice versa (Lundvall, 1992, p. 57). For radical innovation, geographical and cultural distance might play an even more important role than in the case of incremental innovation. Indeed, subjective elements in user-producer relationships, for instance, mutual trust and even personal friendship, are relevant (Lundvall, 1992, p. 58). Radical innovations are likely to occur along distant weak ties. The cognitive distance needs to be large enough to support recombination of novel information and knowledge (see Granovetter, 1973; Nooteboom, 1999). Radical innovations are more inclined to use scientific knowledge generated in universities and research organizations, which tend to be highly tacit and exchanged during intensive face-to-face interactions at the local or regional level. Indeed, in the early stages of radical innovations, the contribution of scientific and technical institutions, namely R&D organizations, are significant (Lundvall, 1992, p. 182). Incremental innovations and the adoption of new technologies, however, tend to occur during interactions with partners from the business sector at higher spatial levels (Tödtling, Lehner, & Kaufmann, 2009). Radical innovations are, thus, highly localized whereas incremental innovation can be less localized.

Freeman and Soete (2004) point out that the industry, firm size, technology, and history matter for generating technological innovations. In reviewing the literature on the innovation process, Dosi (1988) proposes five stylized facts on innovation; they are: innovation involves a fundamental element of uncertainty; technological innovation is more and more contingent on advances in scientific knowledge; the complexity of research and innovative activities favor formal organizations than individual inventors; a significant numbers of innovations are initiated through "learning", namely by doing and by using; and that technological knowledge is cumulative. In *The Economics of Industrial Innovation,* Freeman and Soete (2004, p. 202) summarize the characteristics of what make a successful innovative company in the twentieth century as having: a strong in-house professional R&D; a capability for conducting or connections with other institutions conducting basic research; the use of patents to gain protection and to bargain with competitors; a large enough size to finance fairly heavy R&D expenditure over long periods; shorter lead times than competitors; a readiness to take high risks; an early identification of a potential market; a careful attention to the potential market and substantial efforts to involve, educate and assist users; an entrepreneurial spirit to coordinate R&D, production and marketing; and a good communications with the outside scientific world as well as with customers. It is, however, highly difficult to measure technological innovation and, even more so, to measure innovation propensity, and for that three reasons. First, the proxies that are used cannot possibly capture all aspects of technical change. Second, there are wide differences within industries. Third, the firms that have a defensive innovation strategy may choose not to patent but are keeping up with competitors (Dosi, 1988). As a result, technological innovations are either measured by: the inputs used in the innovation process, such as R&D expenditures or venture capital investments; the intermediate outputs created, such as the number of patents; or by some final measure created, such as the number of new products (Carlino & Kerr, 2014). The OECD Frascati Manual, which provides the standard practice for measuring research and development, recognizes that R&D is only one of the scientific and technical elements that contributes to technical change (OECD, 1963). Innovation can be measured with diverse proxies, such as R&D spending, patenting, technological balance of payments, machinery imports, and diffusion, as well as the pervasive effect of technological spillovers between firms, industries, and countries (Cameron, 1996). Most researchers tend to use R&D spending or patent data as their measure of technical

change, usually because R&D spending and patent data are compiled by large international organizations and thus are the easiest and most reliable to work with (Cameron, 1996).

In the literature, it is frequently stated that while small firms or outsiders are introducing radical innovations, large incumbent firms tend to solidify their leadership with incremental innovations (see Christensen, 2013). Chandy and Tellis (2000) find that over a period of 150 years, small firms and non-incumbents have introduced slightly more radical product innovations than large firms and incumbents. While small firms and outsiders proportionally introduce more radical innovations in the United States than in Western Europe and Japan, incumbent firms in Western Europe and Japan proportionally introduce more radical innovations than in the United States (Chandy & Tellis, 2000). The discrepancy lies in differences between institutions, venture capital investments, and entrepreneurial culture between the United States and Western Europe and Japan (Chandy & Tellis, 2000). In *Socialism, Capitalism and Democracy,* Schumpeter (1942) argues that larger firms tend to spur more innovation than smaller firms. This assumption referred as the Schumpeterian hypothesis has contributed to a numerous and rich literature on firm size and innovation, whose underlying objective is to attempt to confirm or refute this aforementioned hypothesis. In the academic literature, the debate on firm size and innovation is far from being settled since compounding factors such as the type of industry or the historical context have an impact on firm size in innovation. Freeman and Soete (2004) suggest some stylized facts about technological innovations and firm size, such that outsiders play an important role at the beginning of technological revolutions by fostering new technologies, small firms make a large contribution to less capital-intensive industries, there is a process of concentration as technology matures, dominant design triggers a process of lock-in, large companies play an important role in process innovations and in capital-intensive industries, and that bootlegging resources by engineers can lead to radical innovations. The elements that constitute the innovation process vary greatly between sectors and over time. For Schumpeter (1942), outsiders and small firms are extremely important in the innovation process, since an entrepreneur is a person or group of persons, who has the capacity, motivation, and willingness to transform an idea into an innovation and thus employs "the gale of creative destruction" to replace inferior innovations and thus incumbents. Risk and uncertainty are some major components of the innovation process. The conventional wisdom in R&D management often refers to a 10 percent to even a 1 percent success rate (Freeman & Soete, 2004, p. 242). The success rate in R&D obviously depends on factors such as the R&D stage of development and R&D internal selection procedures (Freeman & Soete, 2004). Risk and uncertainty are powerful incentives in allocating a firm's resources to innovations. Empirical studies found out that R&D is heavily concentrated in the less uncertain projects rather than the more radical type of product innovation, which encompasses both technical and market uncertainty (Freeman & Soete, 2004). As a result, the bulk of R&D effort will be allocated to imitative innovations, product differentiation, and in-house process innovations where a market already exists (Freeman & Soete, 2004). Transaction costs such as informational asymmetries, monitoring problems, and possibilities of opportunistic behavior have an impact on R&D in innovative activities (Williamson, 1975). As emphasized by Dosi (1988), research activities generally imply (a) incomplete specifications of contracts, given the uncertainty about the research outcomes; (b) lack of adequate protection of proprietary information; (c) possibilities of "lock-in" phenomena with research suppliers, who can subsequently earn rents from that asymmetric advantage; (d) weak incentives to least cost performance; and (e) monitoring

costs.

Much research has tried to systematically approach the process of innovation. One of those researches was the project SAPPHO, which was carried out at the Science Policy Research Unit during the 1970s (Rothwell, Freeman, Horlsey, Jervis, Robertson, & Townsend, 1974). The SAPPHO project attempted to substantiate or refute generalizations about technical innovation (Freeman & Soete, 2004). As summarized by Freeman and Soete (2004, p. 222), the finding from the project SAPPHO suggested that companies performing little or no R&D were doomed to stagnate or disappear; intensive and R&D offensive companies experienced, in some case, a high growth rate; while a variation in R&D intensity shows no statistical association with growth for defensive companies reacting to highly innovative firms. Radical innovations require large investment in R&D and a higher tolerance of firms for uncertainty since radical innovations have a lower chance of success. Incremental innovations require less effort and follow a specific technological trajectory, which caps uncertainty and risk. As a result, the rationale to pursue innovation projects compared to alternative investment strategies is influenced by instincts, proclivities, and emotions or to what John Maynard Keynes (1936) referred to as the "animal spirits". Freeman and Soete (2004, p. 252) argue that the coping decisions to deal with the uncertainty related to the innovation process is likely to be restricted to the following cases: a small-firm's gamble, a small-firm's existential threat impelling it to innovate, a large-firm that uses a portfolio approach to R&D with the less risky projects taking the lion's share of the portfolio, a large-firm's that uses subjective measures in project selection, the animal spirits, the enthusiasm of inventors or researchers in large- and small- firms that willingly or unknowingly accept a high degree of uncertainty, government-sponsored firms that assume the high uncertainty due to pressing national or international events (war, environmental catastrophe), or due to deliberate national innovation policy strategies, government-sponsored firms that accept grossly over-optimistic estimates of future returns and where failure does not pose a serious threat to the decision-makers (i.e. Concorde airplane), and bootlegging individuals who initiate unofficial projects without the prior knowledge of their management. Radical product innovations will be more likely to be generated in a certain market, such as a government-sponsored market, rather than in a competitive market. National innovation strategies can reduce both the technical and the market uncertainty and thus provide a very powerful stimulus to industrial innovation, as private firms are constrained by two factors when allocating resources for innovations: profit maximization behavior and short-time horizon (Freeman & Soete, 2004). As the result of the high uncertainty and long-term nature of radical product innovations, private firms' underinvestment will prevail in long-term research and innovation, namely in fundamental research and the more radical product innovations (Arrow, 1962; Nelson, 1959).

Technological innovations result from the interactions between scientific and technological knowledge. The most important feature of science and technology is their cumulative nature (Dosi, 1984, 1988; Price, 1965; Rothwell, 1992). The cumulative nature of science and technology implies that an innovative region or firm today will most likely be innovative tomorrow (Dosi, 1984; Rothwell, 1992). Dosi (1988) points out that the specificity, cumulativeness, and tacitness of technological knowledge imply that the capacity and capabilities to pursue current and future innovations are, to a large extent, firm-specific and localized. This self-reinforcing cycle of technological and scientific knowledge accumulation allow for a large multiplier effect in already

technologically advanced areas (Rodríguez-Pose, & Crescenzi, 2008b; Verspagen, 1997). Scientific and technological knowledge, however, have their separate cumulative structures and develop quite independently from one another (see Figure 1). In investigating citation patterns in both scientific and technological journals, Price (1965) found out that science and technology progress quite independently of one another. Novel technologies are built from previous technologies rather than from the interactions between science and technology (Price, 1965). Technology and science tend to independently build upon themselves (Price, 1965). There is no continuous progression from basic research to applied research to development. Technology advances independently of any link with the scientific frontier, and often without any necessity for an understanding of the basic science which underlies it (Price 1965). As a result, "science builds on prior science; technology builds on prior technology; and utilization grows and spreads in response to needs and benefits" (Allen, 1977, p. 49). Some studies on the interactions of science and technology found that there exists a lag between science and technology of 15 to 20 years (Battelle, 1973; Sherwin & Isenson, 1967). The path from science to technology requires, as a result, a long time. There are feedback mechanisms between science and technology (Marquis & Allen, 1966). Engineers have access to scientific knowledge through formal channels, such as peer-reviewed articles, books, conference, textbooks journal, and informal channels, internal reports, reports of other companies, government reports (Allen, 1977). Science and technology have been more or less separated in history except during World War II where scientists were working not as basic researchers but as technologists (Price & Bass, 1969). Nelson (1993) shows that science and technology is increasingly intertwined. Knowledge in one technology can be leveraged into knowledge of another technology. Countries that lead in science often lead also in technology, as basic science allows for the creation of startups and nascent ventures (Arthur, 2010).

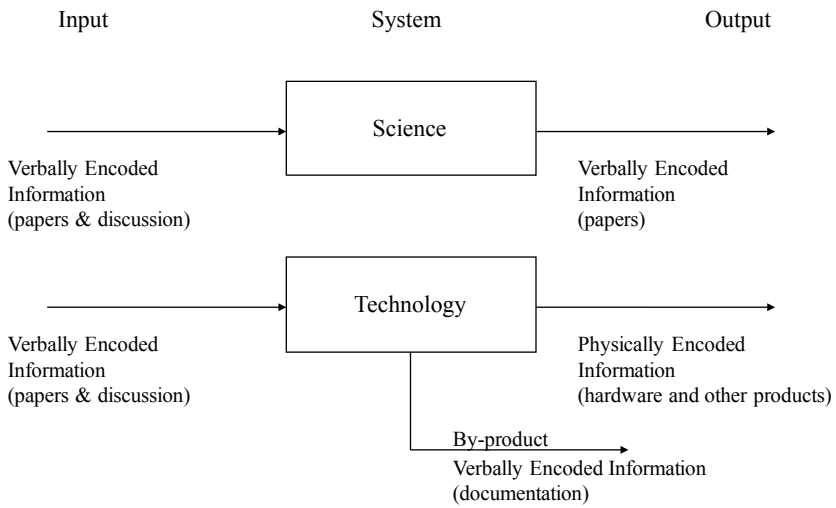


Figure 1. Information Processing in Science and Technology. Source: Allen (1977, p. 4).

Scientific research is frequently divided between applied and basic research, that is useful knowledge (applied) as opposed to a purely disinterested search for new knowledge (basic) (Rosenberg, 1990). It is, however, difficult to distinguish between basic and applied research. Indeed, scientists such as Jansky, Carnot, or Pasteur believed to perform applied research when they discovered a fundamental breakthrough (Rosenberg, 1990). Basic research is conducted in the United States within the university community and in research centers in the European Union (Rosenberg, 1990). Firms that

perform basic research are more likely to absorb and to have access to knowledge created in universities and research centers (Rosenberg, 1990). Rosenberg (1990) asks the question: "why do firms do basic research with their own money? Basic research makes a significant contribution to productivity growth but is seldom carried out by private companies since its social returns are much greater than its private returns (Rosenberg, 1990). Private basic research is carried out in a limited number of industrial sectors and by a limited number of large firms with significant market powers within these sectors (Rosenberg, 1990). In new fields, such as biotechnology, basic research is performed by small firms (Rosenberg, 1990). The monitoring of and the interaction with scientific knowledge are important strategies for in-house basic research (Price & Bass, 1969). Interactions between scientists and technologists can be indirect, passive, direct, or through the gatekeeper function (Price & Bass, 1969). The knowledge gatekeeper is able to partly understand articles published in peer-reviewed journals and then translates the information into terms that are understandable for the average engineers (Allen, 1977).

1.3. The Role of Tacit Knowledge and Proximity in Innovation.

In 1890, British economist Alfred Marshall published *The Principles of Economics,* in which he described the concept of agglomeration economies, a form of external economies, which can be defined as services or disservices rendered without compensation by one producer to another one (Scitovsky, 1954). External economies, or agglomeration economies, exist when a firm located in a specific urban environment has an enhanced productivity (Rosenthal & Strange, 2005). Marshall (1890) describes how an agglomeration, or cluster, of firms, such as those in Lancashire and Sheffield, fostered the development of external economies. In a much-quoted paragraph, Alfred Marshall (1890) described one effect of agglomeration economies on technological innovation, namely knowledge spillovers, when he stated:

> "when an industry has chosen a locality for itself, it is likely to stay there long; so great are the advantages which people following the same skilled trade get from near neighborhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed; if one man starts a new idea, it is taken up by other and combined with suggestions of their own; and thus it becomes the source of further new ideas. And presently subsidiary trades grow up in the neighborhood, supplying it with implements and materials, organizing its traffic, and in many ways conducing to the economy of its material" (Marshall, 1890, p. 271).

Marshall (1890) suggests that agglomeration economies can be classified into three categories, those arising: from labor market interactions, which allow better matching between an employer and a worker; from linkages between intermediate- and final-goods suppliers, which enable internal increasing returns; and from knowledge spillovers, which allow for workers to learn from each other. External economies are crucial in understanding the process of cumulative causation and some principles in evolutionary economics, such as lock-in effects and self-reinforcing principles. Agglomeration economies involve a mechanism of cumulative causation, which suggests that an initial advantage will cause a lock-in effect generating further growth

and multiplier effects (Malecki, 1997; Myrdal, 1957). Agglomeration economies and cumulative causation suggest that the diffusion of new technologies are first adopted in larger and richer cities. Knowledge, skills, and capital, once acquired, do not vanish, but become an endogenous source of future endowments (Malecki, 1997).

In economic geography, knowledge spillovers have and are still being extensively studied. There are two types of knowledge spillovers: pure knowledge spillovers or non-pecuniary spillovers, and pecuniary spillovers (Scitovsky, 1954). Pure knowledge spillovers are positive externalities, in which knowledge flows between adjacent producers and/or users of innovation, that occur without monetary transactions (Scitovsky, 1954). In the case of pure knowledge spillovers, knowledge created by one agent can be used by another either without compensation or with compensation that is less costly than the value of the knowledge (Montobbio & Kataishi, 2014; Scitovsky, 1954). Pure knowledge spillovers, which can be defined as a spatial public good, are knowledge that leak to other economic agents, thus generating positive externalities and fostering innovative activities (Breschi & Lissoni, 2001; Griliches, 1979). The mobility of highly-skilled workers, for instance, represents a strong mechanism for knowledge spillovers (Döring & Schnellenbach, 2006). In contrast, a pecuniary knowledge spillover occurs through monetary transaction, for instance, when one firm purchases R&D inputs or capital equipment (Montobbio & Kataishi, 2014; Scitovsky, 1954).

Knowledge spillovers—that is, the knowledge created in one firm but used by another without pecuniary compensation—occur due to the fact that knowledge is not a normal good, in that, it is, for a large part, a non-rival and non-excludable good (Romer, 1990; Teece, 1986). Knowledge, due to its non-rival and non-excludable characteristics, can potentially be rapidly diffused across regions and countries. The neoclassical interpretation even considers knowledge to be a "public good", that is, a good that is non-excludable and non-rival; and, as such, is accessible for everybody free of charge (Arrow, 1962; Fagerberg, Srholec, & Verspagen, 2010). Private firms aim, however, to maximize the rents from technological innovation through appropriability mechanisms. Appropriability refers to the tools and strategies that allow a firm to protect technological innovations, to varying degrees, as rent-yielding assets against imitation from competitors (Dosi, 1988). Dosi (1988) lists (a) patents, (b) secrecy, (c) lead times, (d) costs and lead time required for duplication, (e) learning-curve effects, and (f) superior sales and services efforts, as appropriability devices. As a result, the properties of technological knowledge, of markets, and of the legal environment, favor and protect, to varying degrees, technological innovations (Dosi, 1988). There is a high level of knowledge spillovers when appropriability is low (Spence, 1986). In the classical and Schumpeterian traditions, the level of appropriability of a technological innovation is both the incentive and the outcome of the innovation process (Dosi, 1988). All knowledge is partially excludable to varying degrees. Indeed, even codified knowledge that is widely available in the public domain in the form of patents, publications, and blueprints, cannot be accessed and exploited at no cost (Montobbio & Kataishi, 2014). Costs, such as communication and transport costs, depend on geographical, technological, cultural and institutional variables (Montobbio & Kataishi, 2014). Innovative companies, as a result, fail to obtain the real economic returns from an innovation, while customers, imitators, and other industry participants benefit due to the non-rivalry nature of knowledge (Tassey, 2001; Teece, 1986). Researchers frequently use sectoral concentration of firms; human capital characteristics; R&D activities; and patents and patent citations as proxies to study the strength of knowledge spillovers from

a geographic perspective (Rosenthal & Stange, 2005).

The academic literature identifies two types of agglomeration economies, namely urbanization and localization economies, both of which are widely debated as to their respective knowledge spillovers effects (Van der Panne, 2004). Specialization, also known as localization economies or MAR (Marshall-Arrow-Romer) externalities, named after Marshall (1890), Arrow (1962), and Romer (1986), and later formalized by Glaeser, Kallal, Scheinkman, and Schleifer (1992), refers to the hypothesis that the localization of similar industries in a metropolitan area is beneficial to innovation. Localization economies suggest market power favors innovation since local monopoly power restricts the flow of ideas to others firms and maximizes the innovating firm's capability to appropriate the innovation rents (Glaeser et al., 1992). Diversification, also known as urbanization economies or Jacobian externalities, refers to the hypothesis that the diversity of economic activities within a metropolitan region will be beneficial to innovation. Jacobs (1969) argues that knowledge spillovers between diverse economic agents might be complementary and, thus, facilitate search and experimentation in innovation. Ports, junction points, markets, or *entrepôt* cities are more likely to be creative and innovative than cities on the edge of the world (Hall, 1998; Jacobs, 1969; Vance, 1970). While some scholars favor specialization to diversification, and vice versa, the academic literature suggests that both localization and urbanization economies positively affects the innovation process (Andersson, Quigley, & Wilhehmsson, 2005; Paci & Usai, 1999; Shefer & Frenkel, 1998). In Israel, Shefer and Frenkel (1998) find that, while both specialization and diversification externalities positively affect the rate of innovation in high technology sectors, they do not affect the rate of innovation in the low technology sectors. Other studies find that diversification fosters economic growth in cities (Glaeser, Kallal, Scheinkman, & Schleifer, 1992); diversification, rather than specialization, fosters innovation in cities (Duranton & Puga, 2001; Feldman & Audretsch, 1999; Harrison, Kelley, & Gant, 1996); specialization favors innovation (Ellison, Glaeser, & Kerr, 2010; Porter, 1990; Van der Panne, 2004); and that specialization and diversification matter depending on the firms' product lifecycle (Duranton & Puga, 2001).

It is undisputed in the academic literature that R&D activities, patenting, and major product innovations are concentrated in metropolitan regions (Feldman & Audretsch, 1999). Knowledge spillovers have some specific features, such as their spatial concentration, their decaying nature with distance, their lead time to leak to other firms, and their tendency to be enhanced with density. Distance greatly affects knowledge spillovers (Audretsch & Feldman, 1996; Baptista & Swann, 1998; Jaffe, Trajtenberg, & Henderson, 1993). Indeed, patent citations are highly spatially concentrated, with citations 5 to 10 times as likely to come from the same metropolitan region as control patents. In regions in the European Union, knowledge spillovers are not traveling more than a 200 kilometers radius from the largest and most dynamic metropolitan regions (Moreno, Paci, & Usai, 2005). In the United States, knowledge spillovers barely exceed the boundaries of metropolitan regions (Anselin, Varga, & Acs, 1997; Sonn & Storper 2008). Arzaghi and Henderson (2008) show that in the advertising industry of Madison Avenue in Manhattan, the knowledge spillovers decay extremely rapidly with distance (approximately 750 meters). Overall, knowledge spillovers tend to be strongly localized, especially between university research centers and corporate patents (Acs, Audretsch & Feldman, 1992; Cameron, 1996; Jaffe, 1989). Knowledge spillovers rapidly decline with distance when looking at the spatial concentration of educated workers (Rosenthal &

Strange, 2004). Moreover, patents and patent citations are heavily concentrated in a relatively small number of urban centers (Jaffe, Trajtenberg, & Henderson, 1993). Knowledge spillovers from university–industry collaboration, however, can take place over longer distance (Ponds, Van Oort, & Frenken, 2010). Acs and Audretsch (1988) find that product innovations are even more concentrated in space than patents. This is pointing out that ideas and knowledge spillovers may be more important in very innovative sectors than in the manufacturing sector (Ellison, Glaeser, & Kerr, 2010). Knowledge spillovers also take time to diffuse. In a survey of 100 American firms with R&D spending over $1m in 1981, Mansfield (1985) highlight the time for spillovers to leak between firms. Mansfield (1985) shows that rivals were informed of new process or product innovations on average within about 12 to 18 months after it was made, with process innovations, the leaking out was somewhat slower than product innovations. The rate of diffusion is longer between US to European firms than within American firms (Mansfield, 1985). Finally, density greatly enhances knowledge spillovers (Akcigit, Grigsby, & Nicholas, 2017; Carlino, Chatterjee, and Hunt, 2007; Glaeser, 1999; Glaeser & Maré, 2001). Workers acquire skills by interacting with one another, and dense urban areas increase the speed of interactions (Glaeser 1999). Moreover, Jacobs (1969) and Krugman (1980) suggest that the size of the metropolitan region tend to enhance agglomeration economies, namely, urbanization economies. Empirical studies confirm the relations between knowledge spillovers and density in showing that densely-populated and geographically-connected states in the United States are more inventive (Akcigit, Grigsby, & Nicholas, 2017).

Proximity affects the intensity of knowledge spillovers. It is widely agreed in the academic literature that proximity has a positive impact on learning, knowledge creation, and innovation (see Agrawal, Kapur, & McHale, 2008; Amin & Wilkinson, 1999). Proximity is especially important for knowledge-based industries where tacit knowledge plays a fundamental role in the generation of innovative activities, which appears to be at the early stages of the industry life cycle (Audretsch & Feldman, 1996). The concept of proximity has been developed in the 1990s by a French research group of economists and sociologists, to investigate the process of industrial agglomeration, such as an industrial district, scientific park, or "innovative milieu" (Gilly & Torre, 2000). Building on the work of Gilly and Torre (2000), Boschma (2005) distinguishes between five dimensions of proximity: cognitive, organizational, social, institutional, and geographical proximity. Boschma (2005) suggests that for each dimension of proximity, there exists an optimal state, between too little and too much proximity, that provides the best innovation outcomes.

Economic geographers have extensively studied the impact of geographical proximity on knowledge transfer, interactive learning, and innovation. Geographical proximity strongly affects the intensity of knowledge spillovers. Knowledge, especially the knowledge that gives a competitive advantage to a firm, is highly tacit, and thus necessitates face-to-face interactions to be rapidly transferred (Storper, 2013). Empirical studies confirm the relationship between firms' innovative performances and spatial proximity due to the presence of knowledge spillovers (see Audretsch & Feldman, 1996; Jaffe et al., 1993). According to the industry or cluster life-cycle hypothesis, geographical proximity is critical in the early stages of an industry development whereas in later stages, when the industry matures, economic activities become more geographically dispersed (Audretsch & Feldman, 1996; Menzel & Fornahl, 2010; Tödtling, Lehner, & Trippl, 2006). Geographic proximity externalities can be divided

into three distinct spatial concepts (Jonhansson, 2005). First, intra-district, which refers to interactions between a district and a functional urban region. Second, intra-regional, which refers to interactions inside a functional urban region. Third, inter-regional, which refers to interactions between regions (Jonhansson, 2005). Gibbons (2000) shows, for instance, that although an expensive choice, companies decide to locate themselves as close to Hoover tower, the center of Stanford University, as possible, to take advantage of valued interactions with high-quality students and academics. Additionally, Abramovsky and Simpson (2011) find out that firms' R&D labs tend to locate themselves near highly rated and industrially relevant university research departments. Geographical proximity to skilled individuals facilitate the acquisition of skills and the diffusion of ideas, knowledge, and learning (Bikhchandani, Hirshleifer, & Welch, 1998; Glaeser, 1999; Jovanovic & Rob, 1989; Vives, 1997). Boschma (2005) argues, however, that geographical proximity has to be examined in relation to other dimensions of proximity since geographic proximity is not the only condition for effective learning to take place.

Cognitive proximity is also an important type of proximity in order for the exchange of knowledge to occur. Nooteboom (1999) argues that knowledge diffusion is constrained by the "cognitive distance" between actors. There is an optimal cognitive distance, where people have neither a too large nor too small cognitive distance, to generate unconventional, new ideas, and innovations. Indeed, actors need to have a cognitive distance large enough to share different ideas but small enough for the collaboration to happen. Knowledge cannot be completely appropriated and therefore may spillover, especially when the cognitive distance is small (Boschma, 2005). Nooteboom (1999, p. 153) argue that firms must make a tradeoff between cognitive distance and cognitive proximity to maximize their absorptive capacities. Indeed, the knowledge that is already known is useless, as it is, for knowledge that cannot be understood (Boschma, 2005). A diversity of backgrounds, experience, and knowledge trigger new ideas and creativity (Cohendet & Llerena, 1997; Jacobs, 1961). Due to the cumulative nature of science and technology, the cognitive base of actors, which depends on their absorptive and learning capacities, differ significantly and tend to persist over time due to the tacit nature of knowledge (Boschma, 2005). Actors and organizations need to possess a knowledge threshold to absorb new knowledge. The capacity of actors or firms to absorb new knowledge depends on some cognitive proximity (Boschma, 2005). As a result, cognitive proximity facilitates communication but may be detrimental to learning and innovation if actors and organizations are too closely proximate cognitively (Boschma, 2005).

Knowledge creation also depends on organizational proximity, that is, the capacity of actors and organizations "to coordinate the exchange of complementary pieces of knowledge owned by a variety of actors within and between organizations" (Boschma, 2005). Organizational proximity strongly affects transaction costs between and within organizations (Boschma, 2005). Hansen (2001) shows that strong ties between units in a multiunit organization stimulate the transfer of complex knowledge in product development projects.

Social proximity will also affect the creation of knowledge. Actors and organizations are embedded in a specific social context, which affects technological trajectories and, thus, economic outcomes (Granovetter, 1985; Polanyi, 1944). Trust-based social relationships facilitate the exchange of tacit knowledge (Maskell & Malmberg, 1999b). However, embedded relationships may lock members of a social network into sub-optimal choices

and established ways of doing things at the expense of innovation and learning (Boschma, 1995; Uzzi, 1997). Outsiders, which are critical for spurring radical innovations, may be denied entry (Boschma, 2005). Social proximity is positive for knowledge generation up to a certain threshold (Boschma, 2005).

Institutional proximity also affects the generation of knowledge. Institutional proximity adds a collective dimension since it refers to the common spaces of representation and the similar incentives and constraints of a specific legal and economic environment that face individuals (Vicente, Dalla Pria, & Suire, 2007). Edquist and Johnson (1997, p. 46) define institutions as "sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups". Institutions not only influence the actions of actors and organizations but also participate in reducing uncertainty and lowering transaction costs faced by such agents. As a result, institutions are "enabling or constraining mechanisms" that affect the level of knowledge transfer and interactive learning (Boschma, 2005).

As shown by Boschma (2005), the five dimensions of proximity are closely intertwined and feedback loops exist between one another. For instance, social proximity may decrease the cognitive distance between partners over time. Geographical proximity stimulates social proximity since it facilitates informal relationships through face-to-face interactions, which in turn, contribute to building trust (Audretsch & Stephan, 1996). Additionally, too strong social or institutional proximities can lead to collective lock-in by preventing individuals or firms from searching from diverse sources of information (Vicente, Dalla Pria, & Suire, 2007). Proximity, for instance, facilitates screening for venture capital companies since it eases repeated interactions and lowers, as a result, asymmetric information and moral hazard (Carlino & Kerr, 2014). Venture capital companies need a critical mass of potential investments to be self-sustainable. Angel investing, for instance in Silicon Valley done by the Google millionaires, contributes to the self-reinforcing and cumulative feedback loop (Carlino & Kerr, 2014). There is a "proximity paradox" in that an optimal proximity between actors of innovation is needed to to lead to higher innovative performance (Boschma & Frenken, 2010, p. 120). The level of optimal proximity to foster the best innovative performance seems to depend on many factors, such as cultural differences and the industry lifecycle (Boschma & Frenken, 2010). Policymakers have to find the right balance between too little and too much proximity in order for interactive learning and innovation to be the most effective (Boschma, 2005). Indeed, while too little proximity can favor problems in coordination and control, too much proximity can lead to lock-in system failures (Boschma, 2005). As a result, policymakers have to promote proximity while ensuring openness, flexibility, and diversity to avoid system failures (Boschma, 2005). Metropolitan regions offer knowledge-based actors with geographical, cognitive, social, organizational, and institutional proximity as well as the required resources to generate significant externalities (Diez, 2002). The specific characteristics of metropolitan regions, in terms of proximity, explain to some extent that despite the globalization process making companies more footloose than ever before, knowledge-based companies are increasingly tied to a particular location (Porter, 2000).

Proximity facilitates knowledge spillovers due to the specific nature of knowledge. In his book, *The Tacit Dimension*, Michael Polanyi (1966) disseminates the concept of tacit knowledge, when he observed: "We can know more than we can tell... The skill of a driver cannot be replaced by a thorough schooling in the theory of the motorcar; the

knowledge I have of my own body differs altogether from the knowledge of its physiology" (p. 4). The tacit dimension of knowledge is a component of human knowledge distinct from, but complementary to, codified knowledge (Polanyi, 1966). Tacit knowledge refers to the knowledge, ideas, concepts, shared beliefs, skills, competences, or insights that individuals possess but cannot be fully expressed since tacit knowledge is ill-defined, context-dependent, uncodified, unpublished, but can, nonetheless, be to some extent shared with collaborators and colleagues who have a common experience (Autor, 2014; Dosi, 1988; Morgan, 2004; Pinch, Henry, Jenkins, & Tallman, 2003; Polanyi, 1966). In each technology, there is an element of tacitness that can only be interpreted internally due to cumulatively augmented abilities and skills (Dosi, 1988). Tacit knowledge cannot be easily written down in a "blueprint" (and therefore be easily diffused), either in the form of public or proprietary information (Dosi, 1988). In contrast to tacit knowledge, codified knowledge consists of information and facts that can be expressed in various forms such as codes, standards, and rules, which, as a result, can be rapidly disseminated over the world (Cowan, David, & Foray, 2000; Pinch et al., 2003).

Tacit and codified knowledge is exchanged locally by "being there" (Gertler, 1995), "local broadcasting" (Owen-Smith & Powell, 2002), "noise" (Grabher, 2002), and "buzz" (Storper & Venables, 2004) and internationally through pipelines (Bathelt, Malmberg, & Maskell, 2004; Owen-Smith & Powell, 2004). Storper and Venables (2004) emphasize the importance of local buzz, which Bathelt, Malmberg, and Maskell (2004) define as "the information and communication ecology created by face-to-face contacts, co-presence and co-location of people and firms within the same industry and place or region". Buzz allows for continuous upgrading of information through constant formal and informal face-to-face interactions between users and creators of information. For Bathelt, Malmberg, and Maskell (2004), the coexistence of a high level of local and international interactions in a cluster provide the firms located within the cluster a competitive advantage compared to outsiders. Storper (2013, p. 34) provides a list of the advantages of face-to-face interactions, such as functioning as communication technology with high frequency, rapid feedback, visual and body cues, functioning as a mechanism for trust and incentive with the detection of lying, and co-presence of a commitment of time, functioning as a mechanism for screening and socializing with loss of anonymity, judging and being judged, and acquiring shared values, and functioning as a mechanism for rush and motivation with performance as display. As a result, face-to-face encounters provide an efficient technology of transaction under these circumstances by contributing to the building of trusts as well as permitting a depth and speed of feedback that is impossible in other forms of communication (Coleman, 1988; Storper, 2013).

One of the most important characteristics of tacit knowledge is its localized nature. Indeed, tacit knowledge is person-embodied and context-dependent, making it spatially sticky (Morgan, 2004; Storper, 1997; Von Hippel, 1994). Knowledge or information is "sticky" when that knowledge or information is costly to acquire, transfer, and use (Von Hippel, 1994). Due to the localized nature of tacit knowledge, it frequently enters the debate of government expenditures in public policies for science, technology, and innovation (Cowan, David, & Foray, 2000). The frequent argument against public expenditures to support science is that foreign companies would free-ride the knowledge generated since information can freely flow between countries through the publications of basic discoveries in scientific journals. While this argument is, to some extent,

applicable to codified knowledge, it does not apply to tacit knowledge. Indeed, tacit knowledge is sticky information and is central to strategic innovation policies for the development of countries, regions, or cities (Von Hippel, 1994). Tacit knowledge does not travel freely and resides in the head of the engineers, scientists, and knowledge workers possessing it. The inherent stickiness of tacit knowledge allows firms and organizations to protect and appropriate the benefits deriving from research investments, at the condition of controlling the access to knowledge (Cowan, David, & Foray, 2000). The various types of knowledge, such as, tacit, codifiable, scientific, technological, cultural, aesthetic, expressive, and symbolic, are crucial for economic competitiveness, whether it is at the level of the firm, region, city, or nation-state (Pinch, Henry, Jenkins, & Tallman, 2003). Technological knowledge is highly tacit since it deals with "the specific and the particular," consists of "innumerable small increments" and is, as a result, costly, difficult, and slow to diffuse (Rosenberg 1976, p. 78). Tacit knowledge is seen as a result, as an essential component leading to technological innovation (Bathelt, Malmberg, & Maskell, 2004; Gertler, 2003; Howell, 2002; Morgan, 2004). The level of codification of a piece of knowledge increases with time due to the cumulative nature of science and technology (Saviotti, 1998). Knowledge that is newer and closer to the technology frontier is thus likely to be more tacit than older pieces of knowledge (Saviotti, 1998). As a result, the newer the industry or the technology, the more tacit it will be, and thus the more localized it will be.

Knowledge is neither completely tacit nor codified but is situated along a continuum between tacit and codified (Saviotti, 1998). Knowledge is created through continuous interactions between tacit and codified knowledge (Nonaka, 1994; Nonaka & Takeuchi ,1995; Saviotti, 1998). From an economist's perspective, Cowan, David, and Foray (2000) point out that all tacit knowledge can hypothetically be codified. Indeed, tacit knowledge remains tacit when the costs related to the benefits to do so are too high. The degree of tacitness and codification of knowledge vary a lot depending on the temporal, spatial, cultural, and social contexts (Cowan, David, & Foray, 2000). Indeed, what is tacit for someone, is codified for someone else and inversely. As a consequence, a varying degree of knowledge is necessary to interpret the codes properly. The conversion of tacit knowledge can take four different forms: from tacit knowledge to tacit knowledge; from codified knowledge to codified knowledge; from tacit knowledge to codified knowledge; and from codified knowledge to tacit knowledge (Nonaka, 1994). Interactions through shared experience allow the conversion of tacit knowledge into tacit knowledge. The process of creating tacit knowledge through shared experience is called "socialization" (Nonaka, 1994). The recombination of diverse varieties of codified knowledge can lead to new knowledge. The process of creating explicit knowledge from explicit knowledge is referred to as "combination" (Nonaka, 1994). Codified and tacit knowledge are complementary and can expand over time through a process of mutual interaction (Nonaka, 1994). The conversion of tacit knowledge into explicit knowledge is called "externalization" (Nonaka, 1994). The conversion of codified knowledge into tacit knowledge referred to "internalization" (Nonaka, 1994).

The Information Communication Technologies (ICTs) have greatly contributed accelerating the codification of knowledge and how knowledge is produced, stored, and diffused (Morgan, 2004). The "death of geography" thesis argues that ICT and globalization reduce knowledge to universally accessible forms of information (Morgan, 2004). Indeed, the marginal cost of transferring information across geographic space has been reduced to virtually nothing, which contributed to shifting economic activities out

of the high-cost locations in Europe to lower-cost locations in Eastern Europe and Asia (Audretsch & Thurik, 1999). Codification allows knowledge to be transformed into information, which can either be embodied in material goods or transmitted through ICT structures (Freeman & Soete, 2004). Maskell and Malmberg (1999b) refer to the concept of ubiquitification to describe the process of mass codification of previously tacit knowledge in an increasingly globalized world. The process of ubiquitification tends to undermine the competitiveness of firms in the high-cost areas of the world that rely on codified or easily codified knowledge (Maskell & Malmberg, 1999b). More tacit forms of knowledge are thus even more critical today for sustaining a competitive advantage (Maskell & Malmberg, 1999b). Morgan (2004) argues that even with improvements in ICT, it is highly unlikely that it will replace the diversity of spatial proximity, where the nuances of body language and face-to-face communication convey as much as, if not more than verbal communication. While ICTs have significantly reduced the cost of transferring codified knowledge, the cost of transferring tacit knowledge between economic agents is still relatively high. Indeed, tacit knowledge requires costly face-to-face communication, which results in making geographic spaces relevant for knowledge spillovers to take place (Audretsch & Lehmann, 2005; Audretsch, Lehmann, & Hinger, 2015).

Information and Communication Technologies (ICTs) facilitate the codification of knowledge, which has an impact on the job market. The Polanyi's paradox, referring to the polarization of the labor market (which is the simultaneous growth of high-education, high-wage and low-education, and low-wage jobs) can be explained because of the differences between tacit and codified knowledge (Autor, 2014). Indeed, computers rely on the skills of software developers to write successful programs. The job of a software developer is to meticulously codify knowledge into a series of steps required for the computer to perform a task (Autor, 2014). Autor (2014) shows that tacit knowledge is problematic to code into computer programs, especially when software programmers don't know the rules. While computers have been able to perform increasingly complex cognitive tasks due to the rapid advances in computer technology, they have been maladroit at mimicking human interactions. Deming (2015) argues that individuals with a high level of social and cognitive skills are being increasingly rewarded in the labor market. In a recent study, Frey and Osborne (2017) estimate that the rapid developments in computer technology could put in jeopardy 47 percent of total U.S. employment. Automation, the rapid development in software and ICT could even impact highly-skilled workers performing relatively tacit and non-routine tasks (Brynjolfsson & McAfee, 2014). In *The Second Machine Age*, Brynjolfsson and McAfee (2014) take the example of driving that was once supposed to be impossible to automate is now a reality. There has been little or no employment growth in high-paying jobs since 2000 (Acemoglu & Autor 2011). Indeed, Beaudry, Green, and Sand (2013) argue that there is even a "great reversal" in the demand for cognitive skill that began in the U.S. labor market in 2000. Lu (2015) points out that this great reversal for skilled labor is happening due to rapid advances in ICT that is redefining the meaning of routine jobs.

1.4. The Evolutionary Economic Perspective.

Nelson and Winter (1982) introduce the evolutionary economic perspective, which encompasses concepts from evolutionary biology and the Schumpeterian economic thoughts. Evolutionary economics is the response to the limitations of neoclassical economics in explaining economic growth (Nelson, 1995; Nelson & Winter, 1982);

technological change (Arthur, 1988, 1994, 2010; David, 1985; Dosi, 1982, 1988; Mokyr, 1990); technological evolution (Utterback, 1994; Utterback & Abernathy, 1975); the nature of competition and the role of institutions and routines in guiding individual behavior (Freeman, 1994; Hodgson, 1988; Nelson & Winter, 1982; Veblen, 1898). In evolutionary economics, the nature of the economic problem is fundamentally different from neoclassical economics since "the set of choices are not given and the consequences of any choice are unknown" (Nelson & Winter, 1982, p. 276). From an evolutionary perspective, technological change can be interpreted as "an irreversible, path-dependent and evolutionary process, stemming from the behavior of economic agents which explore only a limited part of the set of theoretically possible actions, that part which is strictly linked to previous innovation adoptions and to already acquired know-how" (Camagni, 1991, p. 125). The evolutionary paradigm differs markedly from the neoclassical paradigm, which views technological change as "a fast, flexible and optimal reaction to changing market conditions, choosing among a wide spectrum of perfectly known alternatives" (Camagni, 1991, p. 125). Evolutionary economists have criticized the underlying assumptions of neoclassical economics, such as utility-maximizing individual, perfect competition, perfect information, and profit-maximizing firms (Dosi, 1984). They argue that firms do not possess perfect information and that choices for locations have little to do with rational and conscious decision-making (Boschma & Lambooy, 1999). Schumpeter (1942) suggests that the concept of perfect competition is incompatible with technological innovation. The evolutionary assumptions expect a diversity of firm behavior and focus as a result, on dynamic models of change not on static equilibria (Boschma & Frenken, 2006; Nelson & Winter, 1982). While neoclassical economics is simplistic, evolutionary economics can be placed within a complex systems perspective upon the economy (Foster, 2000). Constrained optimization models cannot possibly capture the behavior of complex adaptive systems (Foster, 2000). Technological change in the production function framework is neither exogenous or endogenous but results from evolutionary forces (Nelson & Winter, 1982). The thought that economics should integrate evolutionary models first originated from Thorstein Veblen (1898), when he wrote an article asking "Why is Economics not an Evolutionary Science?" since in his view, the evolutionary theories could integrate both continuity and change, both inertia and novelty and thus, better understand the complexity of the economic reality.

The evolutionary economic perspective merges concepts from the Schumpeterian growth models and evolutionary biology. The evolutionary economic paradigm could also be called "neo-Schumpeterian" since it encompasses the Schumpeterian growth model assumptions such that long-term growth is the result of innovation, that innovation is the result of investments, and that innovation triggers the phenomenon of creative destruction (Aghion & Howitt, 1990). For evolutionary economists, technological change is better interpreted with concepts coming from evolutionary biology, namely Darwinian and Lamarckian theories of evolution, rather than with concepts emanating from neoclassical economics (Dopfer, 2005; Mokyr, 1990). The two main theories of evolution come from Jean-Baptiste Lamarck and Charles Darwin, two 19th century biologists, who respectively published, *Philosophie Zoologique* and *On the Origin of Species* (Koonin & Wolf, 2009). Lamarckism emphasizes the idea that evolution is the outcome of "non-randomly acquired, beneficial phenotypic changes" that are inheritable. In contrast, Darwinism suggests the importance of "random, undirected change that provided material for natural selection" (Koonin & Wolf, 2009). In Darwinism, adaptation, mutation, and variety occur within a large number of generations (Kooning & Wolf, 2009). Socio-economic adaptation, mutation, and variety, however, can occur

more rapidly, oftentimes within a lifetime. Although Lamarckism has been largely discredited in evolutionary biology (Nelson, 1995), in evolutionary economics, both Lamarckism and Darwinism are important theories to explain technological change (Dopfer, 2005; Nelson & Winter, 1982). In evolutionary economics, Lamarckism implies the importance of the process of learning and of the cumulative nature of innovation (Lundvall, 2016; Saviotti, 1996). Actors in innovation systems, learn behaviors, adapt their behaviors to external stimuli, and transform their environment to be beneficial to their needs (Saviotti, 1996). Learning can be inherited since learning can be seen as a process that can be passed on to future or other entities (Nelson, 1995). In evolutionary economics, Darwinism implies variety, chance, novelty, mutation, adaptation, selection, accumulation, path-dependency, and retention (Dopfer, 2005; Metcalfe, 2003). Nelson and Winter (1982) introduce three basic concepts of evolutionary economics. First, the concept of routine. Second, the concept of search to evaluate and replace routines. Third, the selection environment that is partly determined by conditions outside the firms in the industry or sector being considered (Nelson & Winter, 1982, p. 401). Firms have different genetic endowments in terms of technical routines, learning capabilities, procedures, and selection processes that often evolve gradually. The evolutionary economic paradigm accounts for the intrinsic learning nature of technological change both at the microeconomic and social-institutional learning processes, which in turn, constrain industrial path development along technological trajectories and long-term, cyclical waves (Dosi, 1982; Perez, 2004).

Learning is the mechanism through which firms accumulate scientific and technological knowledge. Firms can be seen as learning organizations for the acquisition, accumulation, and generation of scientific and technical knowledge (Malerba, 1992). From an evolutionary perspective, learning is similar to Lamarckism in that it is the process at the source of incremental technical change that facilitates adaptation (Malerba, 1992). Technical changes lie in cumulative learning (Camagni, 1991, p. 125). Economists see learning in a firm as a costless and automatic process that reduce the average labor costs. Firms learn in many different ways, which are consciously conducted and linked to different sources of knowledge (Malerba, 1992). Learning allows for the "enhancements in the stock of knowledge and technological capabilities of firms, which in turn generate a whole range of trajectories of technological advance and not just simple average cost reductions" (Malerba, 1992). Learning rarely develops spontaneously (Lundvall & Johnson, 1994). Indeed, learning processes are determined by the capability to learn and to expand the knowledge base. Learning refers to not only science and technology systems but also to the learning implications of the economic structure, the organizational forms, and the institutional set-up (Cooke & Schienstock, 2000).

Malerba (1992) summarizes six ways of learning, namely learning by doing, learning by using, learning from advances in science and technology, learning from inter-industry spillovers, learning by interacting, and learning by searching. Some learning processes are internal to the firm, such as learning by doing, learning by using, and learning by searching (Malerba, 1992). Other learning processes are external to the firm, such as learning from advances in science and technology, learning from inter-industry spillovers, and learning by interacting (Malerba, 1992). Wright (1936) examines the role of learning by doing in the airline industry, and consequently opens up the rich academic literature on learning. Hirsch (1952) conceptualizes learning by doing and learning curves. Arrow (1962) shows that learning-by-doing increases the efficiency of

production operations. Several authors have introduced additional learning processes and their effects not only on cost reduction but also on the innovative capacities of firms, namely incremental innovations (Rosenberg, 1976). Rosenberg (1982b) introduces learning by using, which increases the efficiency of the use of complex systems. Nelson and Winter (1982) and Dosi (1988) look at learning by searching, in which R&D is seen as a search process that generates cumulative technical advance in specific technological trajectories. Lundvall (1988) and Von Hippel (1988) have shown the importance of learning by interacting with suppliers or users, namely for product innovations. Kline and Rosenberg (1986) have emphasized the role of scientific knowledge in innovation and thus, learning from science and technology. Cohen and Levinthal (1989) show the role played by the stock of knowledge and capabilities in the absorption and generation of new technologies. In addition, learning from the behavior of others compel actors to learn due to powerful endogenous effects (Bikhchandani, Hirshleifer, & Welch, 1998; Manski, 2000; Vicente, Dalla Pria, & Suire, 2007). Endogenous effects such as the reflection problem (Manski, 1993), conformity (Asch, 1956), imitation (Tarde, 1903), norms (Sherif, 1935), and informational cascades (Bikhchandani, Hirshleifer, & Welch, 1998) are powerful determinants in learning from the behavior of others. Endogenous effects suggest that individuals imitate or conform, and thus learn from, the behavior of others due to information asymmetries, which compel individuals to follow the behavior of supposedly better-informed individuals.

The concepts developed in evolutionary economics are especially valuable in regional science for understanding the process of regional divergence. Boschma and Frenken (2006) introduce the concept of evolutionary economic geography (EEG) to analyze how spatial structures emerge from the micro-behavior of individuals and firms. Evolutionary concepts such as path dependency, routines, chance, increasing returns, and lock-in have the capacity to generate regional divergence and diversity, which tend to persist over time due to the process of cumulative causation (Boschma & Lambooy, 1999). The evolutionary approach is highly relevant in explaining the process of localized "collective" learning in a regional context, the adjustment problems that regions may be confronted within a world of increasing variation, and the spatial formation of newly emerging industries as an evolutionary process in which the spatial connotation of increasing returns may result in a spatial lock-in (Boschma & Lambooy, 1999). Additionally, historical events, historical accidents, and genius entrepreneurs can serve as catalysts in regional development (Moretti, 2012; Storper & Scott, 1990). Scientific and technological knowledge is mutually dependent, self-reinforcing, and cumulative in nature. These features create path-dependency, which propel regions in particular technological trajectories (Boschma & Lambooy, 1999; Dosi, 1988). Although many concepts of evolutionary economics are relevant to explain regional divergence, the most discussed concepts in the literature are chance, routines, diversity, path dependency, cumulative causation, and lock-in.

Boschma and van der Knaap (1997) point out that due to the discontinuous nature of radical innovations, the location of new industries can emerge in a window of locational opportunity or chance, which triggers path dependency and cumulative self-reinforcing feedback loops, which lead to the formation of a cluster. Chance can thus be the trigger of industrial clustering in specific regions due to the evolutionary nature of spatial development (Arthur, 1994; Boschma & van der Knaap, 1997). A chance factor, such as the appointment of Fred Terman as the dean of the School of Engineering at Stanford University, can change the technological trajectory of a whole region. Fred Terman,

considered as the father of Silicon Valley, was the main instigator of two cornerstones endeavors that completely transformed the regions. First, he encouraged his former students to start their own businesses, such as Hewlett-Packard and Fairchild Semiconductor Corporation, in which he also played the role of an angel investor (Gibbons, 2000). As a result, Stanford's Electric Engineering department became a magnet for students who wanted to later launch their startups. Second, he launched Stanford Research Park in Menlo Park to accommodate startups (Miller & Coté, 1987). Following this initiative, MIT built the MIT Technology Square in the early 1960s as an incubator of high technology startups (Miller & Coté, 1987). In evolutionary economics, the dynamism of an economic system rests upon the absorption of scientific and technological knowledge, the diffusion of innovations within the innovation system, and the generation of scientific and technological knowledge (Iammarino, 2005).

Nelson and Winter (1982) assume that innovative actors operate on the basis of behavioral routines due to bounded rationality. Simon (1955) introduces the concept of bounded rationality, which suggests that individuals and firms are subject to cognitive constraints, leading to routine, heuristics, and cognitive biases to reduce uncertainty. Nelson and Winter (1982) describe the process routine as heuristics in the local search process that firms pursue, which limit novelty in technologically-related products. Innovating agents engage in multiple simultaneous search and learning alternatives, which affect their ability to generate novelty and diversity (McKelvey, 1997). Routine affects the search process to a reduced number of alternatives, which restrict the ability of the firm to select an optimal outcome (McKelvey, 1997). Routines, through the retention and transmission of information, generation of novelty and diversity, and selection among alternatives, define evolutionary patterns of technical change, new industrial path development, and regional technological trajectories (McKelvey, 1997, p. 215). Cohendet and Llerena (1997) look at the mechanisms that generate diversity and, in particular, the complex relationship between diversity and learning. Evolutionary models look at the innovation process not as a random process but as an integrated part of economic activity. The diversity of a system is affected by mutations, competition, and selection mechanisms in such a manner that "diversity drives evolution, and evolution generates diversity" (Cohendet & Llerena, 1997, p. 227). Policymakers have a role in fostering diversity and maintaining a balance between diversity of competences and diversity of technologies (Cohendet & Llerena, 1997, p. 240).

The concept of path-dependency suggests that evolutionary patterns do not automatically lead to optimal outcomes (Arthur, 1988; David, 1985). Paul David (1985, 1992, 1994) and Brian Arthur (1988, 1994) have contributed to the definition of the concept of path-dependency. The concept of path-dependency refers to the non-linear, self-reinforcing, historical economic processes that shape technological innovations (Arthur, 1985, 1988, 1994; David, 1992, 1994). David (1985) argues that path-dependency in technological change has three determinants, namely, technical interrelatedness, economies of scale, and quasi-irreversibility. As shown by David (1985) with the QWERTY keyboard, path-dependency and technological trajectories are frequently spurred by temporally isolated events, which were provoked by chance elements rather than systematic forces. Indeed, as shown by David (1985) and Gould (1987), the QWERTY keyboard is an archetypal example of path-dependency that lock a technology into a suboptimal outcome. The QWERTY keyboard is the continuation of the typewriter's keyboard, which was before that, the keyboard used to write Morse codes for the telegraph (Stamp, 2013). Although the QWERTY keyboard is argued to be significantly less efficient than other keyboards'

configurations, it is still the keyboard dominant design due to the process of path-dependency (David, 1985; Gould, 1987). Additionally, Gould (1987) shows that both technology and biology evolutionary processes, such as the Panda's thumb or the QWERTY typewriter keyboard, can lead to suboptimal outcomes. At the metropolitan level, Martin and Simmie (2008) develop a four-phase model of path-dependency. The model consists of a pre-formation stage, a path creation phase, a path lock-in phase, and a path dissolution phase (Martin & Simmie, 2008). The new paths do not emerge in a vacuum but in the context of existing technological, industrial, and institutional arrangements (Martin & Simmie, 2008). The phenomenon of path-dependency can lead to system failure, such as regional lock-in into inferior technological trajectories.

Arthur (1988) introduces the concept of self-reinforcing mechanisms to demonstrate that small historical events shape the nature of technology. Technological trajectories, which can be defined as the paths by which innovations in a given field occur, that are being chosen are by no means optimal (Dosi, 1982). Indeed, the path-dependent nature and changing nature of learning processes may act as dynamic entry-barriers with respect to possibly more efficient alternative technologies (Camagni, 1991, p. 125). When the technology reaches a certain tipping point on a trajectory where the dominant design is accepted, the cumulative processes reinforces and perpetuates that choice, highly reducing the spectrum of possible outcomes and alternatives (Camagni, 1991; Utterback, 1994). Since technological change is cumulative and path-dependent, influenced by the prevailing technological paradigm and the evolution of technological trajectories, it can get "stuck" or "locked-in" within one technological trajectory, which would potentially lead to sub-optimal results (Arthur, 1994; David, 1985; Grabher, 1993; Nelson & Winter, 1982). Regions, to a larger extent than countries, are prone to "lock-in" (Cooke, Uranga, & Etxebarria, 1998; Grabher, 1993; Martin & Simmie, 2008). There is a strong cumulative process taking place in regions. Indeed, when a threshold of firms in the region has been reached, the region becomes more attractive for new firms to locate there, even if these firms have other locational preferences (Boschma & Lambooy, 1999). The cumulative nature of science and technology (Dosi, 1984; Price, 1965) combined with evolutionary notions of path-dependency and economics notions of increasing returns to scale result in a strong cumulative and self-reinforcing evolution of the spatial system (Boschma & Lambooy, 1999). Older regions, like Paris and London, that enjoy strong urbanization economies due to a highly diversified economic base, tend to possess a potential to develop new technologies again and again, and to keep up with new regions that base their fortune on new technologies (Boschma & Lambooy, 1999).

Evolutionary economics focuses on the processes and mechanisms that support an economy to transform itself from within (Witt, 2003). Theories on economic theories must be dynamic, must deal with irreversible processes, and must cover the generation and impact of novelty as the ultimate source of self-transformation (Boschma & Martin, 2010; Witt, 2003). Entrepreneurship plays an essential role in evolutionary economics as a source of novelty and in allowing the process of creative destruction (Schumpeter, 1934) and is seen as a driver of urban and regional economic development (Audretsch, Keilbach, & Lehmann, 2006; Stam, 2010). Newcomers to the economy have an important role to play in the evolution of economic systems. According to Schumpeter (1942, p. 83), entrepreneurs play a central role in the evolution of economic systems, when he states:

> "the fundamental impulse that sets and keeps the capitalist engine in motion

> comes from the newcomers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates… [This is a] process of industrial mutation—if I may use that biological term—that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism."

1.5. Territorial Innovation Models.

The concepts of "industrial districts" (Becattini, 1979); "innovative milieu" (Camagni, 1991; Maillat, 1998); "cluster" (Porter, 1990); "regional science" (Storper & Scott, 1988); "learning regions" (Florida, 1995; Morgan, 1997); and "regional innovation systems" (Cooke, 1992; Braczyk, Cooke, & Heidenreich, 1998) emphasize the regional dimension of technological innovations. Regional divergence is explained by the different levels of regional innovation capacities. Territorial innovation models have, over the years, converged with concepts in innovation studies, such as "flexible specialization" (Piore & Sabel, 1984); "Triple Helix" (Etzkowitz & Leydesdorff, 2000); "Mode 2" (Gibbons, Limoges, Nowotny, Schwartzman, Scott, & Trow, 1994); the "fifth generation innovation process" (Rothwell, 1994); and "Open Innovation" (Chesbrough, 2003), which are emphasizing the changing nature of learning and innovation in the knowledge-based economy. Piore and Sabel (1984) point out the transition from mass-production to new organizational model of productions characterized by flexible specialization and greater sophistication, promoting continuous innovation. Etzkowitz and Leydesdorff (2000) point out the necessity to reshape institutional arrangement to promote the triple helix model of innovation to support the interactions between the private sector, the public sector, and universities. The concept of Mode 2 points out the transition from "one mode of knowledge generated within disciplinary and primarily cognitive contexts to a mode of knowledge that is being created within broader, transdisciplinary social and economic contexts" (Gibbons et al., 1994, p. 2). The concept of a fifth generation innovation process emphasizes the importance of networking and the integrated nature of the innovation process (Rothwell, 1994). Chesbrough (2006) introduces the concept of open innovation as a paradigm that acknowledges the importance of inflows and outflows of ideas and tacit knowledge in the process of innovation.

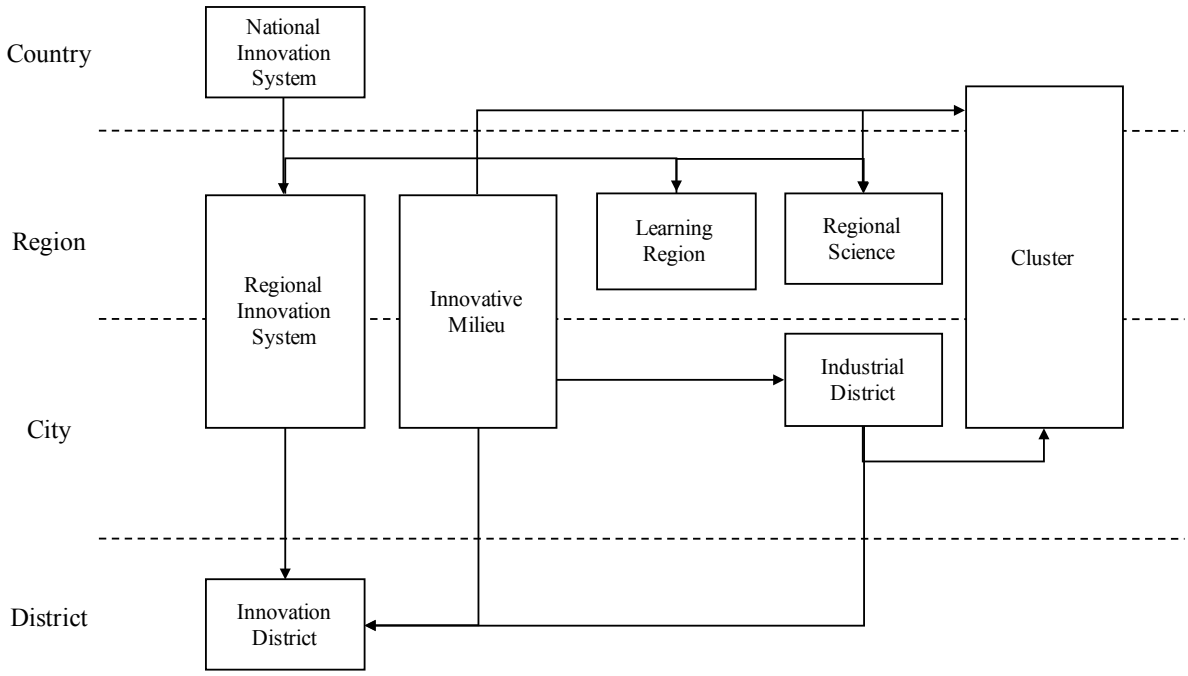


Figure 2. Territorial Innovation Models, their Scopes and their Relationships. Source: own design.

The concept of industrial districts emerged in the context of important transformations that developed countries were undergoing (Maillat, 1998). Most notably, as suggested by Piore and Sabel (1984), the resurgence of flexible production systems supplanting the Fordist mass-production model. The concept of industrial districts was adopted to explain the divergence between the Third Italy and the rest of the country (Bagnasco, 1977; Becattini, 1979; Pyke, Becattini, & Sengenberger, 1990). The concept of industrial districts can be traced back to the *Principles of Economics*, in which Marshall (1890) described how an agglomeration of small and medium-sized firms fostered the development of external economies (Becattini, 1979). An industrial district is defined as "a socio-territorial entity which is characterized by the active presence of both a community of people and a population of firms in one naturally and historically bounded area. In the district, unlike in other environments, such as manufacturing towns, community and firms tend to merge" (Becattini, 1990, p. 37). Becattini (1989) and Pyke, Becattini, and Sengenberger (1990) specify the fundamental features of an industrial district, such as: collaboration and competition between the firms; an industrial climate; workers' flexibility and entrepreneurial spirit; and frequent interactions between the relevant innovative actors. The rationale for industrial district rests on the creation of "external economies of scale" for small firms as a competitive alternative to the "internal economies of scale" of large companies (Asheim, 1996). External economies of scale reflect the economies that are external to the firm but internal to the specific location. Some examples of industrial districts are the textile industry in Carpi and Prato, the furniture industry in Brianza and Cascina, and the footwear industry in Vigevano and Puglia (Brusco, 1990).

The concept of innovative milieu was developed in the 1980s by a group of researchers at the Groupe de Recherche Européen sur les Milieux Innovateurs (GREMI) with the objective to understand and develop robust methodologies to analyze and to compare innovative regions (Camagni, 1991, Crevoisier, 2001, 2004; Maillat, 1998). The GREMI stresses the importance of non-pecuniary externalities, such exchanges of information,

knowledge, and experience, in the process of technological innovation that are facilitated in a localized innovative milieu (Camagni, 1991; Maillat, 1998). Camagni (1991, p. 3) defines the innovative milieu as "the set, or the complex network of mainly informal social relationships on a limited geographical area, often determining a specific external 'image' and a specific internal 'representation' and sense of belonging, which enhance the local innovative capability through synergetic and collective learning processes." The innovative milieu performs the following functions: a collective information gathering and screening function; a function of 'signaling' in the direction of the market of local firms, a collective learning process, mainly through skilled labor mobility within the local labor market, a collective process of definition of managerial styles and decision routines; an informal process of decision coordination (Camagni, 1991, p. 231). The innovative milieu is a set of relationships in a geographical area that includes a coherent socio-cultural whole, a production system, a technical culture, and a group of actors (Crevoisier, 2004; Maillat, Quévit, & Senn, 1993). The innovative milieu integrates dynamic technological development, organizational innovations, and the advantages of spatial proximity (Crevoisier, 2004). Technological development stresses innovation, learning, and know-how (Crevoisier, 2004). Organizational innovations refer to the importance of the role of networks, competition, and social capital (Crevoisier, 2004). Spatial proximity stresses that competition occurs between regions (Crevoisier, 2004). The literature on the innovative milieu emphasizes the importance of interactions between different innovative actors, of socially embedded processes, of a sense of regional cohesion, and of a sense of belonging (Crevoisier, 2001, 2004).

Porter (1990, 2008, 2011) introduces the concept of cluster. For Porter (2008), the two fundamental elements that define a cluster are interconnectedness and proximity. Indeed, firms in a cluster must be linked in some way. The links are both vertical (buying and selling chains) and horizontal (complementary products and services, the use of similar specialized inputs, and technologies or institutions, and other linkages) (Martin & Sunley, 2003). The geographic scope of a cluster can range from a city to a network of neighboring countries (Porter, 2008). The second element is that firms in a cluster are geographically proximate. Co-location encourages the formation of clusters and enhances the value-creating benefits of interactivity between firms (Martin & Sunley, 2003). Michael Porter (2008) defined clusters as "[t]he geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also cooperate" (p. 214). Porter (2008) introduces the diamond framework to analyze and affect the sophistication of a cluster. For Porter (1990), competition, such as in a cluster, is the most important determinant of generating and sustaining a competitive advantage. Indeed, clusters affect competition in three broad ways: first, by increasing the productivity of constituent firms or industries; second, by increasing their capacity for innovation and productivity growth; and third, by stimulating new business formation that supports innovation and expands the cluster (Porter, 2008).

Regional science has contributed to the rediscovery of the region as the most relevant space for the process of innovation. Most specifically, the Californian school of economic geography or regional science look at the influence of the process of globalization on the formation of new industrial spaces (See Saxenian, 1994; Scott, 1986; Storper, 1992; 1995, 1997; Storper & Scott, 1988). The process of globalization that implies vertical disintegration and the internationalization of production, reinforces the

importance of learning and innovation in regions with substantial industrial agglomeration, and have, as a result, strengthened the economic dominance and contributed to the emergence of new global hub of a number of key cities around the world (Scott, 1986; Storper, 1992). Castells (1989) considers the large bulk of global information flows being limited to some cities. Sassen (1991) signals the emergence of global cities concentrating power and influence. Amin and Thrift (1992) emphasize the concentration of power in regions that are able to provide information, innovation, knowledge, and institution-rich environments. Regional science explains the process of regional divergence and concentration as the outcome of untraded interdependencies that are "conventions, informal rules, and habits that coordinate economic actors under conditions of uncertainty" (Storper, 1997, p. 5), which allow innovative actors in some regions to travel or to travel faster along superior technological trajectories (Storper, 1995). The socio-institutional settings, inter-firm communication, and interactive processes of localized learning play decisive roles in innovation processes and growth (Stoper, 1997; Saxenian, 1994). Untraded interdependencies allow urban regions to be protected from low-cost competition from emerging countries (Storper, 1995).

Richard Florida (1995) and Kevin Morgan (1997) introduce the concept of a learning region, which participates in the convergence between the fields of innovation studies and economic geography. Morgan (1997, p. 492) suggests that the concept of the learning region is to "connect the concepts of the network paradigm—like interactive innovation and social capital—to the problems of regional development in Europe". The concept of learning regions emphasizes the significance of the role of regions to facilitate learning between individuals and organizations (firms, research institutes, universities, and economic development agencies). Indeed, regions are, for Florida (1995), the repository of knowledge and ideas, which are in the knowledge-based economy the most important sources of technological innovation (Florida, 1995; Morgan, 1997). At the center of the concept of the learning regions is the idea that tacit knowledge does not travel easily. Tacit knowledge is best shared through face-to-face interactions between persons who already share some basic similarities: the same language; common codes of communication; shared conventions and norms; personal knowledge of each other based on past history of successful collaboration or informal interaction (Gertler, 2003). The concept of the learning regions emphasizes the fact that agglomeration economies are not enough to explain regional divergence and that innovation requires a skilled and creative regional labor market operating under entrepreneurial conditions (Florida, 1995; Morgan, 1997).

The concept of the National System of Innovation (NSI), introduced by Freeman (1995), Lundvall (1992) and Nelson (1993), can be traced back to Friedrich List's book, *The National System of Political Economy,* published in 1856. In his book, List (1856) argued in favor of policies, among which the protection of infant industries and the creation of vocational schools, to accelerate the industrialization of Germany, and overtake England as the first European economic powerhouse. The concept of NSI originates from the wide disparities between national systems in fostering technological innovations, and thus, provides an answer to the divergence between countries "forging ahead", "catching up", and "falling behind" (Abramovitz, 1986; Durlauf & Johnson, 1992; Edquist, 1997; Freeman, 1995; Lundvall, 2007). Edquist (1997, p. 14) defines a system of innovation as "all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovation." Freeman (1987, p. 1) defines the national innovation system as "the network of institutions in the public and private

sectors whose activities and interactions initiate, import, modify and diffuse new technologies." Policymakers are mainly using the concept of a system of innovation in a descriptive manner. The concept has been used to describe and compare with case-studies, widely different national systems of different complexities regarding their national education systems, labor markets, financial markets, intellectual property rights, competition in product markets, and welfare regimes (Nelson, 1993). The concept of innovation systems encompasses the analysis of the determinants of and the actors participating in the innovation process, and hence the concept provides an enticing framework for governments and policymakers to experiment with policy analysis, research, and design to strengthen their innovation systems (Lundvall, 2007).

The concept of a regional innovation system (RIS) is based on the literature on regional innovation models and on innovation systems, namely the national systems of innovation, and, as a result, rests on the same assumptions, but in the context of a region (Doloreux & Parto, 2004). The concept of a RIS provides a robust analytical and descriptive approach to understand how the innovation process is shaped within a specific region. RISs mostly consist of two actors that interact with one another. The first and most important actors are the firms located in the region. The second actors are the regional institutional infrastructures that support the firms located in the region, such as research and higher education institutes, technology transfer agencies, vocational training organizations, business associations, and finance institutions (Asheim & Isaksen, 2002). Interactions are central in RIS. Innovation systems are based on evolutionary, non-equilibrium theories in which innovation is a result of interactive processes both internal and external to the firm (Freeman, 1995; Lundvall, 1992; Nelson, 1993). The innovation system approach emerged due to the accumulation of empirical studies at different levels of aggregation showing that innovation is the outcome of an interactive process (Rothwell, 1977; Lundvall, 1988; Kline & Rosenberg, 1986). Indeed, the innovation system approach suggests that technological innovations refer to the "introduction into the economy of new knowledge or new combinations of existing knowledge. This means that innovations are looked upon mainly as the result of interactive learning processes" (Edquist & Johnson, 1997, p. 42). The main addition of the literature on RISs compared to the literature on national innovation systems is the importance of the evolutionary perspectives in explaining regional dynamics. In RIS, innovation is fully endogenous and constitutes an important determinant of economic change. Innovation processes involve evolutionary economic change, which is not linear and certain. In comparison to traditional economic analysis, innovation system models never reach an optimal equilibrium (OECD, 2001b). Indeed, RIS has adopted conceptual elements of evolutionary economics and the new regional science, such as agglomeration, trust building, reciprocity, social network relationship, willingness to cooperate, institutions, and learning in regional systems (Braczyk, Cooke, & Heidenreich, 1998, Cooke, Uranga, & Etxebarria, 1998). RISs offer the assets to foster collective technological learning (Braczyk, Cooke, & Heidenreich, 1998; de la Mothe & Paquet, 1998; Diez, 2002). The regional collective learning capacities are associated with a wide variety of evolutionary dynamics that have the power to shape technological trajectories (Braczyk, Cooke, & Heidenreich, 1998).

The concept of RISs participates in the rediscovery by many scholars and academics of the importance of the regional scale and regional innovation policies in stimulating regional firms' innovative capacities (Amin, 1994; Asheim & Isaksen, 2002; Aydalot, 1986; Doloreux & Parto, 2004; Malmberg & Maskell, 2002; Ohmae, 1995; Porter, 1990;

Storper, 1995; and many more). RISs differ greatly between countries and within countries, making the region the most relevant unit in innovation systems to study (Braczyk, Cooke, & Heidenreich, 1998; Edquist, 1997; Fischer, Diez, & Snickars, 2013). The RIS approach combines elements of the national innovation systems (Edquist, 1997; Freeman, 1995; Lundvall, 1992; Nelson, 1993), regional science (Storper, 1995, 1997; Storper & Scott, 1988), with an evolutionary interpretation of the regional learning economy (Cooke & Morgan, 1998; Cooke, Uranga, & Etxebarria, 1998). Doloreux (2003) defines a RIS as "a set of interacting private and public interests, formal institutions and other organizations that function according to organizational and institutional arrangements and relationships conducive to the generation, use and dissemination of knowledge." There are two main sets of studies that have been used to analyze RIS. The first set is based on comparative empirical studies of various regions to explore desirable criteria upon which systemic innovation at the regional scale might occur. The second set of studies offers 'snapshots' of individual RISs by assessing them to determine the extent to which they correspond to a truly RIS (Doloreux & Parto, 2004). The research on regional innovation systems has, however, often focused on successful regions, such as Silicon Valley, Third Italy, and Baden-Württemberg (Bagnasco, 1977; Cooke & Schienstock, 2000; Malmberg & Maskell, 2002; Saxenian, 1994). The fact that so much research is based on "success stories rather than statistics," which provides lessons that are seldom applicable elsewhere, has been a source of criticism (Doloreux, 2003; Malmberg & Maskell, 2002).

RISs have been analyzed on a different scale since the regional scale can be described in different ways. First, regions can be described in terms of their shared normative interests with respect to some geographic, physical, social, or economic characteristics (Braczyk, Cooke, & Heidenreich, 1998; Malecki, 1997; Meyer, 1963). Second, regions can be defined according to their nodalities or polarizations around a central urban place (Malecki, 1997; Meyer, 1963). Thirdly, regions can be defined according to their administrative homogeneity or governance boundaries that correlate with political or state institutions and their distinct spheres of influence (Braczyk, Cooke, & Heidenreich, 1998; Malecki, 1997; Meyer, 1963). For Cooke (2001) and Cooke and Schienstock (2000), a region can either be defined within geographic and administrative boundaries in which innovative networks and institutions heavily interact with one another or within cultural boundaries in which specific cultural characteristics make the region a homogeneous space. For Ohmae (1995), a region is "an authentic community of interest", a region can be a metropolitan area, a county, a province or a federal state. The unit of analysis for regional innovation systems varies widely between scholars and academics. As the result of the imprecise definition of a region, RISs have been studied at the level of the city (Simmie, 2001), metropolitan regions, (Diez, 2002), and even districts within cities (Asheim & Isaksen, 2002). Moreover, regions are neither autonomous nor sovereign with regards to the nation-state or supranational organizations. Indeed, the regional institutional framework is embedded in larger multi-level governance structures (Braczyk, Cooke, & Heidenreich, 1998, p. 425).

1.6. The Role of the Government in the Innovation Process.

The role of government to stimulate technological innovations differs between the different theories of innovation and school of economic thoughts. The neoclassical economic approach, evolutionary economic approach, systems-of-innovation approach, industrial networks approach, social constructivism approaches, quasi-evolutionary

approach, or the large-technical-systems approach advocate for different levels of government intervention to achieve an optimal level of technological innovations. For neoclassical economists, technological innovation is treated as a black box and is exogenous (Rosenberg, 1982). Neoclassical economists advocate intervening to correct the market in avoiding market failures and thus, welfare losses (Bator, 1958). Technological innovation is for evolutionary economists, path-dependent and endogenous (Nelson & Winter, 1982). The role of government is to generate variation to avoid lock-in. The system of innovation approach highlights the importance of interactions and learning between different actors to generate technological innovation. The role of the government is to limit system failures (Metcalfe, 2005; Asheim et al., 2006). In the innovation system approach, policymakers have a central role in interacting with other actors in designing, implementing and evaluating innovation policies (Woolthuis, Lankhuizen, & Gilsing, 2005). Public policies can also capture evolutionary mechanisms, such as chance and increasing returns, by building up a favorable local environment to promote urbanization economies, and, as a result, prevent negative lock-in (Lambooy & Boschma, 2001). For evolutionary economists, some of the innovation policies that can be implemented are: the identification of emerging technologies of strategic importance; the promotion of technology diffusion across the entire economy; the promotion of the emergence of new industries; the support of technological upgrading of firms, the support for the diffusion of new standards and the installation of advanced communications networks; and the support of risk-taking Schumpeterian entrepreneurs; and the promotion of education and training in new areas of knowledge, competences, and skills (Amin, 1994, p. 26). Mazzucato (2015) argues that the State should not only intervene to reduce market and system failures but also to directly partner with the private sector in investing in uncertain and risky innovative endeavors that private actors are unwilling to pursue (Mazzucato, 2015). The State should lead the process of industrial development, "by developing strategies for technological advance in priority areas" (Mazzucato, 2015, p. 44).

Neoclassical economists argue that government interventions distort markets, and, as a result, decrease social surplus and impose a deadweight loss upon society. Neoclassical economists acknowledge, however, that governments should intervene only and only if there is a market failure (that is, in a situation in which the free market is not producing an efficient level of allocation) (Bator, 1958). There are four major types of market failures in which government intervention is frequent, they are: the lack of public goods, which are non-excludable and non-rival goods; the existence of natural monopolies; negative and positive externalities, also known as spillovers; and informational asymmetries (Pagano & Bowman, 1997). Governments should intervene only to limit market failures by correcting externalities, providing public goods, limiting asymmetric information, and promoting market efficiencies. Technological change, however, namely invention and innovation, is prone to market failures (Mokyr, 1990; Tassey, 2001). That is, the (free) market is unable to produce a desirable level of invention and innovation. In R&D activities, there are two major types of market failures. The first market failure relates to the difficulties for private firms to fully appropriate the returns on their investment since that knowledge—which is non-rival and partially non-excludable in nature—will spillover to other firms (Appelt, Bajgar, Criscuolo, & Galindo-Rueda, 2016). Indeed, once created, the use of scientific and technological knowledge does not reduce its supply to others, and it therefore has "a zero marginal cost" (Mokyr, 1990, p. 181). The public good nature of technological and scientific knowledge has encouraged policymakers to create instruments and devices in order to

postpone competition by protecting property rights, which are exclusive rights on intellectual creations in fields related to technology (patents), business (trademarks), and the arts (copyright) (Nooteboom & Stam, 2008). Technology embodies significant public good elements, such as the creation of new markets; the provision of infrastructures to other technologies; the economies of scope to other industries; the lower investment barriers; the knowledge spillovers; and the sophistication of users (Tassey, 2001, p. 67).

The second market failure in R&D activities relates to the difficulties for private firms in finding external finance, in particular for startup companies and uncertain projects (Appelt et al., 2016). Innovation is a highly uncertain activity with large information asymmetries between inventors and investors (Appelt et al., 2016). Technological innovation is, as a result, prone to underinvestment (Mokyr, 1990; Tassey, 2001). The four types of underinvestment that can occur are: aggregate underinvestment by an industry; underinvestment in applied R&D in new firms; underinvestment in new generations of existing technology or in radically new technology; and underinvestment in supporting technology infrastructures (Tassey, 2001, p. 52). According to Tassey (2001, p. 67), the three most important market failures are: underinvesting in longer-term, complex, and multidisciplinary technology research, especially in the early phases of the R&D life cycle due to uncertainty and technical risks; the shortening of R&D life cycles with resulting disincentives to undertake long-term and high-payoff radical innovations research, which result in a focus on product-line extensions and incremental process improvements; and the lack of infrastructures for increasingly system-based technologies.

The innovation systems approach set an additional rationale for government intervention. In addition to market failures, governments can intervene to promote collective learning and to limit dysfunctional interactions (Laranja, Uyarra, & Flanagan, 2008). In the innovation system approach, interactions between innovative actors are at the center of the innovation process (Edquist, 1997; Lundvall, 1992). The underlying premise of innovation systems is that interactions between many different actors that cooperate, collaborate, and learn from each other, are central to the process of innovation (Edquist, 1997; Lundvall, 1992). Innovation systems refer to the idea that innovation by firms cannot be understood in terms of independent decision-making at the level of the firms but rather, as a system of complex interactions prone to “system failures” (Smith, 2000). Systems failures, as a result, refer to the less than optimal interactions that result from the system. For some authors, system failures, rather than market failures, should be the starting point for policy intervention (Metcalfe, 2005; Asheim et al., 2006). Besides market failures, local and regional governments that pursue innovation strategies can design policies to limit “system failures” (Woolthuis, Lankhuizen, & Gilsing, 2005). Woolthuis, Lankhuizen, and Gilsing (2005) reviewed in the literature from Carlsson and Jacobsson (1997), Smith (1997), Malerba (1997), Johnson and Gregersen (1994), and Edquist (1997), to uncover the eight types of system failures, which are: infrastructural failures, transition failures, lock-in/path-dependency failures, hard institutional failures, soft institutional failures, strong network failures, weak network failures, and capabilities failures. System failures include infrastructural failures (communication, energy, and science & technology infrastructure), institutional failures (hard failures when they refer to technical standards and legal system, and soft failures when they relate to norms and values), interaction failure (weak network failure when it is connected to a lack of complementary relationships, and strong network failure when it is linked to wrong direction network guidance), and capabilities failure (lack of competences) (Woolthuis,

Lankhuizen, & Gilsing, 2005).

In the innovation system approach, the process of regional lock-in has been extensively studied (Grabher, 1993; Friedrichs, 1993; Maskell & Malmberg, 1999a; Tödtling & Trippl, 2005). The process of lock-in occurs due to the path-dependence nature of regional economic development and the cumulative nature of the specific regional capabilities, which combine human, physical, and institutional endowments that lock the regional industrial path development and firms' technological trajectories (Maskell & Malmberg, 1999a). Friedrichs (1993) for instance, shows that lock-ins can develop when local elites, such as corporate management, trade unions, and urban/regional managers or politicians, act to prevent structural changes in declining industries to protect their vested interests. The local elites tend, as a result, to prolong the period of crisis instead of proactively developing or attracting new types of economic activities. Lock-ins are most common in mono-industrial milieux dominated by large firms, for instance in the Ruhr region or Detroit (Maskell & Malmberg, 1999a). Grabher (1993) provides a framework to analyze lock-ins. Grabher (1993) identified three types of lock-ins. First, functional lock-ins, which refer to rigid hierarchical inter-firm networks, particularly between large enterprises and small and medium-sized suppliers that can reduce the need for suppliers to develop boundary spanning functions, such as research and development and marketing. Second, cognitive lock-ins, which refer to the homogenization of worldviews or mindset. Third, political lock-ins, which relate to strong intertwined relations between public and private actors that might hinder necessary industrial restructuring. Grabher (1993) points out that in the case of the Ruhr region, the lock-in was the result of functional, cognitive, and political lock-ins.

Innovation policies have to take into account specific system failures that can exist in specific regions. Tödtling and Trippl (2005) point out that peripheral regions may be at risk of organizational thinness, old industrial areas may be at risk of lock-in, and some metropolitan regions may be at risk of fragmentation. Organizational thinness refers to the lack of dynamic clusters and of support organizations. In some innovation systems, mostly peripheral due to lack of critical mass, key institutions, such as research institutes, educational centers, venture capital companies, and specialized suppliers may be missing or weakly developed (Camagni, 1995). Fragmentation refers to the lack of strong networks and interactive learning (Fritsch, 2003). Intra- and inter-firm collaborations are not developed and exchange of knowledge is limited, resulting in fragmentation failure. Organizations that are oriented towards old routines and specializations can suffer from inertia, undermining the ability to adapt and renew their activities (Tödtling & Trippl, 2005). The long-term industrial competitiveness of a region as a result, is related to "the ability of its firms to continuously upgrade their knowledge base and performance, rather than obtaining static efficiency through identification and exploitation of cheap resources and economies of scale" (Maskell & Malmberg, 1999a). While cumulativeness in knowledge, science, and technology tend to lock-in regions and firms, Maskell and Malmberg (1999a) argue that firms and regions need to remain open for radical changes and be ready to un-learn to sustain economic competitiveness. Un-learning refers to the process of removing and dissolving previously needed institutions that currently hinder further development (Maskell & Malmberg, 1999a). This process, which might jeopardize the vested interest of some elite groups, is indispensable to prevent the risk of a regional lock-in (Maskell & Malmberg, 1999a).

The role of the government to stimulate technological innovations can also generate suboptimal outcomes and lead to government failures. Indeed, there are also many rationales against government intervention to foster technological innovations. Government failures arise due to the context-specific, complex, and dispersed nature of knowledge (Nooteboom & Stam, 2008). Moreover, lobbies and vested interests can influence government decisions into sub-optimal policy choices. Because governments are extremely vulnerable to loss of reputation and are under continuous public scrutiny, policy responses to market and system failures take time to be formulated due to bureaucratic processes and administrative oversights (Nooteboom & Stam, 2008). The academic literature reviews a large number of government failures, such as regulatory capture, that result from increased government intervention (Dal Bó, 2006; Levine & Forrence, 1990). Regulatory capture, one of the most studied government failures, is "the process through which special interests affect state intervention in any of its forms" (Dal Bó, 2006). Regulatory capture for public regulators can take two forms. First, the revolving door phenomenon refers to the situation where a public regulator without electoral ambitions who might want to pursue a career in the private sector favors specific industries or companies in anticipation of future employment (Dal Bó, 2006). Second, a public regulator might be constrained by political and reelection motives or personal self-interest derived from his or her position rather than wider public interests (Levine & Forrence, 1990). The theory of regulatory capture suggests that public or private entities can funnel direct and indirect subsidies distributed through public intervention. At the local and regional level, government intervention can take many forms, taxes, zoning regulations, public procurements, or policies for innovation. Any of these previously mentioned interventions can be shaped to favor a monopoly, public officials, or a set of private companies, and thus distort public interest. In a narrower sense, regulatory capture refers to the influence of state monopolies on governmental agencies to introduce regulations that benefit them (Dal Bó, 2006; Stigler, 1971).

Regulations also affect the quality of entrepreneurship. As shown by Baumol (1996), there are two types of entrepreneurs: the productive entrepreneurs who create value and the unproductive ones who extract profits from the system. The type of payoffs and regulations will affect the relative size of both types of entrepreneurs. Public policies to offset market or system failures can have a negative effect, such as crowding out, when private firms reduce their funding with public funds. In some instances, government funding may be a cheaper source of finance than funding raised from capital markets (Lach, 2002). As shown by Lerner (2009, p. 84), regulatory capture can affect government initiatives for the promotion of entrepreneurship, as with the case of the Australian Building on Information Technology Strengths (BITS), an incubator launched in 1999, whose funding went mainly to compensated the managers and not the incubated firms; other examples included NYC Discovery Fund and Iowa Heartland Seed Capital Fun. Moreover, Djankov, La Porta, Lopez-de-Silanes, and Shleifer (2002) show that entry regulations—procedures, official time, and official costs—for startups in more democratic governments are lighter than in less democratic ones, suggesting that stricter entry regulations favor politicians and bureaucrats. As a result, in order to maximize public interest, a diverse range of stakeholders from the public and private sectors as well as the civil society should ponder whether the reduced system and market failures is more beneficial than an increased likelihood of government failures. The potential failures that exist in innovation systems do not always make government intervention required or desirable. Indeed, while there is a possibility that governments improve overall welfare, they do not always have the willingness, capacity, or resources to do so (Dixit, 1996).

Moreover, a policy failure, which is the failure for a policy to achieve its objectives, may arise due to the inadequate policy design, implementation, and governance. As shown by Cooke (2001), the European Union's innovation gap with the United States results from excess public intervention, which resulted in major government failures.

The idea that the State should step back from the economy to unleash the power of entrepreneurship and innovation in the private sector has become pervasive to the extent that it is virtually accepted by the public as a "common sense" truth. The neoclassical dogma of the self-regulating free market is, according to Karl Polanyi (1957), a myth. Indeed, for Polanyi (1957), there never was a truly free and self-regulating market system, when he said: "the road to the free market was opened and kept open by an enormous increase in continuous, centrally organized and controlled interventionism" (p. 144). Governments have always taken an active role in not only protecting their industries but also in stimulating new technologies. More recently, Mazzucato (2015) argues that the State has a central role to play in intervening in the innovation process. Governments should go beyond their roles of creating the conditions and business environments for innovation to directly intervene in the economy. Mazzucato (2015) takes the example of innovation policies in two liberal market economies, the United Kingdom and the United States, to show the importance of the State in the innovation process. The government should not only intervene to support market forces and entrepreneurship, which must remain the driver of technological innovations, but should also take a more proactive strategic and coordinating role to support the development of technological innovations, and in some cases, governments have the legitimacy to intervene in order to solve societal crises or to avoid future societal crises (Butter, 2002; Rodrik, 2007). Public policies as a result, often go much beyond their roles to simply offset market and system failures, by directly intervening in the innovation process.

Governments are frequently intervening to support public research (Block & Keller, 2016; Mazzucato, 2015; Ruttan, 2001). Public investment in scientific research is recognized as an essential feature of effective national innovation systems and benefits from various government strategies. Government procurements, namely done in the defense sector, and government contracts give a strong incentive to private firms to conduct basic research (Rosenberg, 1990). Public research undertaken by universities and public research institutions often are long-term and high-risk research that couldn't have been conducted by the private sector (OECD, 2015b). Government funding has allowed for the development of many radical or disruptive innovations (Freeman & Soete, 2004; Mazzucato, 2015). The invention of the computers, for instance, was financed with government funding. The University of Pennsylvania received financial support from the Department of Defense in order to build the Electronic Numerical Integrator And Computer (ENIAC), the first electronic computer, whose main purpose was to calculate trajectories of shells and bombs (Freeman & Soete, 2004). The Bayh-Dole Act encouraged the emergence of the biotechnology industry since the new biotech companies were new spin-offs from university labs with heavy state funding (Mazzucato, 2015). Block and Keller (2016) found that between 1971 and 2006, the large majority of innovations have taken advantage of Federal research supports, especially in the early stage of development. In the United States, the government has been proactive in establishing policies for the development of new technologies, such as the Defense Advanced Research Projects Agency (DARPA), the Small Business Innovation Research (SBIR), the Orphan Drug Act, and the National Nanotechnology Initiative (Mazzucato, 2015). The Pentagon created DARPA in 1958 as a response to counter the

Soviet technological breakthrough and advances in launching the satellite Sputnik in 1957 (Mazzucato, 2015). The Federal Department of Defense introduced the concept of "blue sky thinking" in R&D projects to promote forward thinking inventions that could only potentially produce results in 10 or 20 years (Mazzucato, 2015). The Reagan Administration built upon the success of DARPA and launched the Small Business Innovation Development Act (Mazzucato, 2015). The SBIR program required government agencies with large research budgets to designate a fraction of their research funding to support initiatives of small, independent, for-profit innovative firms, and startups (Mazzucato, 2015). Companies such as Apple, Compaq, and Intel, have received early stage financing through government funding programs like the SBIR (Mazzucato, 2015, p. 10). The major technological elements in the Apple's iPhone can be traced back to State investments, from the Internet, to the touch-screen display, to the new voice-activated SIRI personal assistant (Mazzucato, 2015, p. 10). Government's support is so pervasive in the innovation process that Ruttan (2001) argues that governments have systematically played a central role in the development of General Purpose Technologies (GPTs). Technological revolutions, such as the computer industry, the internet, the pharma–biotech industry, and the nanotech industry would not have occurred without the leading role of the State (Mazzucato, 2015). As shown by Ghosh and Nanda (2010), while venture capital firms enter in the capital at the stage of the idea vetting and pre-commercial testing, governments and universities enter in basic and applied research. Private venture capital and private equity companies invest in companies whose commercial viability is established within a 3-to-5-year period (Ghosh & Nanda, 2010). In biotechnology, nanotechnology, and ICT, venture capital companies started to invest in companies 15 to 20 years after the most important investments were made by public sector funds (Mazzucato, 2015, p. 31).

The field of regional development originated with the publications of Gunnar Myrdal's (1957) *Economic Theory and Underdeveloped Regions* and Albert Hirschmann's (1958) *The Strategy of Economic Development*. Metropolitan regions are increasingly seen as the most appropriate entities for designing supportive policies for science, technology, and innovation compared to nation states, which in an increasingly borderless world, are increasingly seen as dysfunctional (Cooke, 1997; Krugman, 1995; Ohmae, 1995). Local and regional innovation policies tend to be shaped by "best practice models," such as "growing the next Silicon Valley," derived from well performing regions and cities, which are then, applied indiscriminately to regions and cities around the globe (Miller & Coté 1987; Sturgeon, 2000; Tödtling & Trippl, 2005). There is, however, no "one-size-fits-all" regional innovation policies, as regions have widely different contexts (Tödtling & Trippl, 2005). The role of regions in Science, Technology, and Innovation (STI) policy development and implementation derives from the degree of devolution to regions of STI policy competences. Regions may have an active role in: setting the overall strategy and framework, developing policy, financing policy, implementing programs and instruments, and/or evaluating strategies, programs, and instruments (Cooke, Uranga, & Etxebarria, 1998; OECD, 2011b). In the OECD, some countries already have a long-standing regional plan of action for designing innovation policies, such as Canada, Germany, Spain, and the United States; in other countries, like new EU member countries, there is a strong trend to increase democratization, devolution, and decentralization (OECD, 2011b). The range and nature of competences devolved from central governments to regional governments will affect how regional innovation policies are designed. Countries, such as Belgium, Canada, Germany, Spain and the United States have granted many competences for science, technology, and innovation

(STI) policy to regions. At the other end of the spectrum, regions in small or centralized countries, such as Greece, New Zealand and Portugal do not have many competences in designing STI policies (OECD, 2011b). Some regions, such as Baden-Wurttemberg or Rhône-Alpes have pushed for greater autonomy to develop their innovation policies (Cooke, Uranga, & Etxebarria, 1998).

Regional innovation policies have evolved considerably in the past decades to respond to the unique conditions of the knowledge-based economy (Knight, 1995). In the late 1970s and the early 1980s, regional innovation policies involved large infrastructure development, most notably the creation of science parks and the relocation of research labs. The regional innovation policies were heavily influenced by the linear innovation model (OECD, 2011a). In the 1980s, regional innovation policies aimed at supporting technology transfer with the development of incubators and technology transfer agencies (OECD, 2011a). In the late 1980s and the early 1990s, regional innovation policies aimed at strengthening networks, with co-ordination innovation activities between regions and the identification of clusters (OECD, 2011a). In more recent years, regional innovation policies have prioritized research-driven clusters. In many cases, regions have taken on greater roles in basic science policy as a result of decentralization reforms (OECD, 2011a). Generic regional innovation instruments include but are not limited to: clusters and excellence hubs, incubators, science and technology parks, scholarships for post-graduate studies, public subsidies to private R&D, tax credits for private R&D, competitive research grant, promotion of scientific cooperation, funding via public development banks, public venture capital funds and guarantees, systemic initiatives in the form of networks, clusters, competitiveness poles and competence centers, innovation support services for existing SMEs, support for innovative start-ups, innovation vouchers, mobility and talent attraction schemes, and support for quality research infrastructure, innovation procurement schemes fiscal measures, technology extension services, and technology platforms (OECD, 2011a). Regional innovation policies have to be flexible and to constantly evolve to avoid: autarkic frameworks, which emerge due to lack of openness to outside sources of knowledge and ideas; lock-in with respect to decision-making, which refers to incapacity to change technological trajectories; ineffective multi-level governance, which refers to coordination problems between different level of governance; and innovation paradox due to limited institutional capacity (OECD, 2011a). Influenced by the new public management, metropolitan and regional governments are establishing regional innovation agencies to stimulate technological innovations and entrepreneurship. There is a great diversity among them regarding their sizes, missions, ownerships and funding structures, and activities (OCED, 2011b). There is, however, a gap in the academic literature in critically analyzing the role of the regional innovation agencies in their RISs. The only studies and academic literature to delve into the role of regional innovation agencies in their RISs are the OCDE (2011a) and Fiore, Grisorio, and Prota (2011).

1.7. The Importance of External Knowledge and Absorptive Capacity.

The concepts of “industrial districts” (Becattini, 1979); “innovative milieu” (Camagni, 1991; Maillat, 1998); “cluster” (Porter, 1990); “regional science” (Storper & Scott, 1988); “learning regions” (Florida, 1995; Morgan, 1997); and “regional innovation systems” (Cooke, 1992; Braczyk, Cooke, & Heidenreich, 1998), all point out the importance of external scientific and technological knowledge for the process of innovation. The role of external linkages as a catalyst for technological innovations is a

dynamic field in research in management, innovation studies, and regional studies (see Antonelli, 2000; Leonard-Burton, 1995; Penrose, 1959). Antonelli (1999) suggests that technological knowledge is the by-product of activities, such as learning, R&D, search and technological transactions and interactions with the scientific community, allowing firms to acquire the four knowledge inputs, such as internal and external, tacit and codified knowledge required to generate new technological knowledge. External knowledge is seen when recombined with internal knowledge as a source of knowledge creation (Antonelli, 2000; Saviotti, 2007). The complexity of new technologies and knowledge imply that the source of innovation relies more and more upon the integration and recombination of diverse sources of knowledge (Antonelli, 2000; Owen-Smith & Powell, 2007). For Dosi (1988), innovation is an uncertain problem-solving that blends internal with external knowledge. External sources of knowledge have been recognized to stimulate growth within a cluster (Bathelt, Malmberg, & Maskell, 2004; Camagni, 1991; Pyke, Becattini, & Sengenberger, 1990). Extra-regional knowledge can be carried into the region through the market, formal, and informal networks and partnerships (Amin & Thrift, 1992; Scott 1988; Camagni 1991; Becattini, 1979; Owen-Smith & Powell 2004; Trippl, Grillitsch, & Isaksen, 2017), through "brain circulation" of knowledge workers (Saxenian & Hsu, 2001), and/or through multinational corporations (Markusen 1996). In clusters, the inflow of external knowledge can come from external actors that are attracted to the regional innovation system or local actors that have access to external knowledge (Boschma & Iammarino, 2009). The process of globalization, the new international division of labor, and the revolutionary nature of information and communication technologies, all point out the importance of extra-regional connections (Castells, 1996; Fröbel, Heinrichs, & Kreye, 1980).

In RISs, the access and exploitation of external knowledge have two essential purposes. First, it limits the risk of technological, institutional, and organizational lock-ins since that external knowledge facilitates recombination processes leading to innovations (Arthur, 2010; Grabher, 1993; Hassink, 2005; Hodgson, 1998). Second, the access and exploitation of external knowledge can generate novel technological trajectories. Asheim and Isaken (2002) and Bathelt, Malmberg, and Maskell (2004) highlight the importance of place-specific local resources and external world-class knowledge to strengthen local firms' competitiveness. In a RIS, place-specific contextual knowledge, both codified and tacit, which are mostly geographically immobile, must be combined with highly dynamic external knowledge (Asheim & Isaksen, 2002; Bathelt, Malmberg, & Maskell, 2004; Storper & Venables, 2004). In the literature, local buzz, which refers to the information and communication ecology created by face-to-face contacts, co-presence, and co-location of people and firms within a RIS, facilitates the exchange of internal knowledge (Bathelt, Malmberg, & Maskell, 2004; Storper & Venables, 2004). The presence of local buzz, which facilitates the exchange of internal knowledge, must be combined with global knowledge pipelines, which facilitate the diffusion of external knowledge into the regional innovation systems. Innovation systems that are able to build and maintain a diverse number of global pipelines with relevant innovation hubs around the globe are more successful (Bathelt, 2001; Bathelt, Malmberg, & Maskell, 2004). Pipelines that connect the local innovation systems with external scientific and technological knowledge allow for the gradual dissemination of the new knowledge through leaking to other firms located in the metropolitan regions. The establishment of pipelines with distant firms and innovation systems is, however, a complex and expensive process (Bathelt et al., 2004). There are two challenges in establishing successful global pipelines. The first one relates to the identification of the pipelines to tap into (Bathelt,

Malmberg, & Maskell, 2004). The second one relates to the translation and assimilation of the information arriving through the pipelines (Bathelt, Malmberg, & Maskell, 2004). Morrison, Rabelloti, and Zirulia (2013) suggest that global pipelines are beneficial for clusters that have a high-quality local buzz and that are weakly endowed in terms of knowledge.

The presence of networks facilitates the acquisition of external knowledge (Castilla, Hwang, Granovetter, & Granovetter, 2000; Hagedoorn & Duysters, 2002; Lundvall, 1988; Powell, Koput, & Smith-Doerr, 1996). A network can be defined as "a set of nodes or actors (persons or organizations) linked by social relationships or ties of a specified type. A tie or relation between two actors has both strength and content. The content might include information, advice, or friendship, shared interest or membership, and typically some level of trust" (Castilla, Hwang, Granovetter, & Granovetter, 2000, p. 219). Ties that connect pairs of nodes can either be directed, for instance, one-directional, or undirected, and can be dichotomous or weighted (Borgatti & Foster, 2003). Cooke and Morgan (1993) point out that networking activities are not only including interactions between and within private firms but also include interactions between firms and public or quasi-public intermediary agencies. Intra-firm networking includes, for instance, the integration of R&D production. Inter-firm networking includes, for instance, close and long-lasting ties between producers and users, joint ventures, cooperation, and so on. Networks function also at the interregional and intraregional levels. The urban and regional government usually promote network with successful cities and regions to reproduce the success of those regions and cities. The networking capabilities can as a result, link innovation actors, resources, and activities in and between innovation systems (Cooke & Morgan, 1993). Innovation networks can be formal or informal. Formal networks emerge from formal investment decisions allocated by companies to the creation of strategic networks or from spontaneous and informal investment decisions by individuals (Westlund, 2009). Informal networks are, however, difficult to quantitatively study and necessitate as a result, qualitative network analysis as did Saxenian (1994) in the case of Silicon Valley and Route 128. Informal networks are based on trust, common rules, and norms, which are commonly referred as social capital (Putnam, 1993; Westlund, 2009) or a shared culture leading to a specific innovative milieu (Camagni, 1991; Saxenian, 1994). Formal and informal networks are important routes for the transfer of tacit knowledge between innovative actors (Castilla, Hwang, Granovetter, & Granovetter, 2000; Metcalfe, 1995; Saxenian, 1994). Networks improve the firm's search space and limit both bounded rationality and bounded vision (Carlsson & Jacobsson, 1997).

Benneworth and Dassen (2011) point out the necessity for regional innovation policies to take advantage of global networks. Local and regional networks must link global networks to enhance their learning capacity, innovativeness, and competitiveness. These local-global networks not only have to be harnessed by the private sector but also by the public sector in order to create networks of multi-level governance system (Benneworth & Dassen, 2011). In Silicon Valley, international linkages contribute to the innovative capacity of the cluster (Engel & del-Palacio, 2011). Networks of immigrants contribute to brain circulation between their home countries and Silicon Valley (Engel & del-Palacio, 2011; Saxenian & Hsu, 2001). The strength of the networks is also relevant. Indeed, Granovetter (1973) points out that weak ties can be extremely powerful for instance, when looking for a job. Gordon and McCann (2000) show that the concept of embeddedness developed by Granovetter (1973) in which actors cultivate a more

extensive set of weak ties, is more likely to produce innovation than strong and tight ties among a smaller number of like-minded people. Porter (2000) notes that highly embedded social networks may actually delay innovation since it can promote group-think and conformity, which reinforces routines, suppresses new ideas, and creates rigidities. Consequently, networks can facilitate system failures such as lock-in and path-dependencies scenarios when networks are too strong. The educational system and bridging institutions have an important role to play in limiting system failures by keeping the system open (Carlsson & Jacobsson, 1997). Moreover, it is difficult for firms to disengage from unfruitful networks. As Kim, Oh, and Swaminathan (2006) show, firms can face network inertia when attempting to dissolve old relationships and form new network ties.

Empirical studies confirm the importance of external knowledge in the innovation process. In a study of the biotechnology cluster in the Boston area, Owen-Smith and Powell (2004) emphasize the importance of global knowledge pipelines, which refer to communication and collaboration between local firms and research centers with inter-regional and international partners, for accessing new knowledge. Owen-Smith and Powell (2004) find that local buzz and international networks contributed to the success of the cluster. The inter-organizational networks at the local level and through proprietary alliances were critical to generate externalities and enhance the innovative capacity of the firms located in the biotechnology cluster in Boston. Rantisi (2002) studies the openness of the Garment district in New York City and shows how intermediary institutions facilitate the transmission of ideas between the Lower East Side of Manhattan and the Garment district. In studying the Chilean wine cluster, Giuliani (2005) shows that extra-cluster knowledge was important to forge the cluster's success. In the case of the textile cluster in New York City, Uzzi (1997) shows that over-embeddedness, in other words, close social relations, is detrimental to innovation. The importance of the weak ties in the innovation process (Granovetter, 1973; Hauser, Tappeiner, & Walde, 2007), the presence of international networks in cluster (Porter, 1990), all point out the importance of external knowledge for competitiveness. While SMEs can suffer from the lack of appropriate external networks to access external knowledge (Rothwell & Dodgson, 1991), large innovative firms have an enhanced capacity to access external knowledge (Lazerson & Lorenzoni, 1999). Coe and Helpman (1995) find the importance of R&D spillovers in open economies since that foreign R&D has beneficial effects on domestic productivity, and that these are stronger the more open an economy is to foreign trade. Katz and Allen (1982) show that in large R&D laboratory, scientists tend to neglect external knowledge, which the authors designate the phenomenon as the "not invented here syndrome".

At the firm level, the successful exploitation of external knowledge requires the creation within the firms of absorptive capacity, which is the capacity to understand externally sourced technology and apply it internally (Cohen & Levinthal, 1989, 1990). Wesley Cohen and Daniel Levinthal (1990) define the concept of absorptive capacity as "the ability of a firm to recognize the value of new, external information, assimilate it and apply it to commercial ends" (p. 128). The concept of absorptive capacity emphasizes the importance of external knowledge and of the needed internal capacities to translate that external knowledge. Zahra and George (2002, p. 186) define absorptive capacity as "a set of organizational routines and processes by which firms acquire, assimilate, transform, and exploit knowledge to produce a dynamic organizational capability". R&D and human capital investments are for firms the main tools to work around the absorptive

capacity constraint (Cohen & Levinthal, 1989, 1990; Lund Vinding, 2006; Mangematin & Nesta, 1999). Economists traditionally think of R&D as generating new information. Cohen and Levinthal (1989, p. 569) suggest that R&D not only generates "new information but also enhances the firm's ability to assimilate and exploit existing information." In studying the Chilean wine cluster, Giuliani and Bell (2005) suggest that the cluster's absorptive capacity derives from the level of the local knowledge to process extra-cluster knowledge. Giuliani (2005) suggests that the success of an industrial cluster depends on its absorptive capacity. Firms in clusters that forge ahead have the capacity to absorb extra-cluster knowledge and to diffuse it into the intra-cluster knowledge system (Giuliani, 2005). The concept of absorptive capacity is not only relevant for external knowledge but also for internal knowledge within a firm. The importance of intra-firm absorptive capacity is exemplified by the quote of Lew Platt, former chairman of Hewlett-Packard, when he stated, "if only HP knew what HP knows, we could be three times more productive!" (as cited in Gertler, 2003, p. 84). In the case of Xerox Corporation, Schoenberger (1999) provides a case that often highlights the incapacity of firms to absorb internal knowledge. The Xerox headquarter located in the East Coast of the United States was unable to commercially benefit from innovations produced in peripheral research sites, such as Xerox PARC in Palo Alto or Fuji Xerox in Japan. In the case of Xerox, Schoenberger (1999) points out that the absorptive capacity has not only economic determinants but also critical socio-institutional determinants, such as the fundamental distinct institutional framework and cultural contexts (Schoenberger, 1999).

Zahra and George (2002) distinguish between a firm's potential and realized absorptive capacity. While potential absorptive capacity involves knowledge acquisition and assimilation capabilities, realized absorptive capacity implies knowledge transformation and exploitation (Zahra & George, 2002). Zahra and George (2002) suggest that four organizational capabilities of knowledge, acquisition, assimilation, transformation, and exploitation build on each other to yield absorptive capacity. Acquisition refers to a firm's capability to identify and acquire externally generated knowledge that is critical to its operations (Zahra & George, 2002). Assimilation refers to the firm's routines and processes that allow it to analyze, process, interpret, and understand the information obtained from external sources (Zahra & George, 2002). Transformation denotes a firm's capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge (Zahra & George, 2002). Exploitation emphasizes the application of knowledge (Zahra & George, 2002). Potential absorptive capacity makes the firm receptive to acquiring and assimilating external knowledge but does not guarantee the exploitation of knowledge (Zahra & George, 2002). Realized absorptive capacity is a function of the transformation and exploitation capabilities, which reflects the firm's capacity to leverage the knowledge that has been absorbed (Zahra & George, 2002). Absorptive capacity requires learning capability and problem-solving skills. Learning capability is the capacity to assimilate knowledge for imitation and problem-solving skills to create new knowledge for innovation (Kim, 1998).

The concept of absorptive capacity, which was initially designed in the context of firm theory, has been extended to the study of complex institutions, such as nations and regions (Azagra-Caro, Archontakis, Gutiérrez-Gracia, & Fernández-de-Lucio, 2006; Caragliu & Nijkamp, 2012; Eaton & Kortum 1999; Keller 1996; Mowery & Oxley, 1995; Niosi & Bellon, 2002; Roper & Love, 2006). The regional absorptive capacity depends on broader macroeconomic policies and institutional factors that are set at the national level, such as barriers to trade, export embargoes, import quotas or foreign exchange

limitations, monopoly regulations, labor regulations, property rights, and institutional infrastructures, such as communication, banking, and taxation (Hurwicz, 1995). Regional absorptive capacity can be defined as the region's ability to identify, assimilate, and exploit external knowledge (Caragliu & Nijkamp, 2012). At the national and regional level, absorptive capacity is associated with the literature on international technology transfer (Keller, 1996). Technological knowledge flows can occur though through trade, through inward FDI, through consultancy, licensing, and franchising, and outward FDI, through reverse technology transfer (Narula, 2004). Indeed, technology transfer, foreign direct investment (FDI), intermediate goods, capital equipment, or licensing, may have little or no effect on economic growth without prior development of absorptive capacity (Narula, 2004). For Narula (2004), absorptive capacity includes the ability to search and select the most appropriate technology to be assimilated and the activities associated with creating new knowledge. Absorptive capacity reflects the ability of a country or region to select technologies that might set novel relevant technological trajectories (Narula, 2004). At the regional level, absorptive capacity depends on culture (Buch & Rivers, 2001; Caragliu & Nijkamp, 2012; Saxenian, 1994); human and cognitive capital (Caragliu & Nijkamp, 2012; Simon, 1998); labor market (Roper & Love, 2006); financial capital (Rostow, 1980); inward FDI (Ariffin & Bell, 1997; Borenzstein, Gregorio, & Lee, 1998); and prior scientific and technological knowledge (Cohen & Levinthal, 1989). For Caragliu and Nijkamp (2012), a region's absorptive capacity depends on the set of psychological and cognitive dispositions of regional agents towards socio-economic interactions. The capacity to absorb new knowledge depends on the set of cognitive skills, such as mutual trust, relational capital, sense of belonging, that are strongly place specific (Caragliu & Nijkamp, 2012).

RISs shape the regional absorptive capacity (Braczyk, Cooke, & Heidenreich, 1998; Narula, 2004). Narula (2004) suggests that the basic components of absorptive capacity in innovation systems are: basic infrastructures, advanced infrastructures, firms, formal, and informal institutions. As a result, the capacity to absorb external scientific knowledge depends on universities and research institutes, the capacity to access technical trained workforce, and to access financial capital (Guerrieri & Tylecote, 1997). In less sophisticated innovation systems, such as in the context of developing countries, the absorptive capacity is defined as "the ability to learn and implement the technologies and associated practices of already developed countries" (Dahlman & Nelson, 1995, p. 88). Keller (2004) found that as much as 90 percent of productivity growth can be attributed to foreign technology. International knowledge diffusion is considered a powerful driver for economic growth and catching-up (Montobbio & Kataishi, 2014). While the invention of new technologies is geographically concentrated, the production and innovation due to the global value chain is more spread out. In a cross-sectional analysis, Crescenzi (2005) shows that in the European Union, regional innovative activities play a significant role in determining differential regional growth patterns. In peripheral regions, the investment in innovative activities must be complemented with investment in human capital to be efficient. Kim (1997) suggests that "technological capability" explains the South Korean success in catching-up. Technological capability is defined as "the ability to make effective use of technological knowledge in efforts to assimilate, use, adapt and change existing technologies. It also enables one to create new technologies and to develop new products and processes..." (Kim 1997, p. 4). Capabilities not only refers to R&D but also other capabilities needed for the commercial exploitation of technology. There are three aspects of technological capability: production capability, investment capability, and innovation capability (Kim, 1997).

Mowery and Oxley (1995) highlight that national systems of innovation have a better capacity to acquire externally sourced technology than to exploit them. The national absorptive capacity relies on investments in the scientific and technological labor force, along with trade and economic policies that enforce competition among domestic firms (Mowery & Oxley, 1995). Absorptive capacity facilitates technological accumulation, which in turn, facilitates further absorptive capacity (Narula, 2004). There is a cumulative causation between absorptive capacity and technological accumulation.

The agents that facilitate a firm's absorptive capacity are called the knowledge gatekeepers. At the level of a firm, the exchanges of knowledge go through a two-step process, in which certain key individuals act as bridges linking the organization members to the outside world (Allen, 1977). The knowledge gatekeepers work as a medium between the creator of information and its users (Allen, 1977). The two-step process between the creator and the users of information is frequent in social sciences. For instance, Lazarsfeld, Berelson, and Gaudet (1958) found out, in a study of voter decisions during the 1940 presidential election campaign, that information from radio and newspaper did not influence the average voter directly, but rather "opinion leaders" who subsequently influenced the vote of friends and associates. External knowledge is distributed to technological gatekeepers before being further dispatched to sub-units of a firm (Bathelt, Malmberg, & Maskell, 2004). The knowledge gatekeepers are thus, able to operate within and transmit between two coding schemes (Allen & Cohen, 1969). Knowledge gatekeepers have a dual role: the acquisition of external knowledge and its translation (Allen, 1977). According to Allen (1977), knowledge gatekeepers are "a small number of key people to whom other frequently turned for information. These key people differed from their colleagues in the degree to which they exposed themselves to sources of technological information outside their organization" (p. 145). Knowledge gatekeepers have the following characteristics: they are frequently used for technical advice and consultation; they are better exposed to the scientific and technological literature; they have lot of informal contacts with members of the scientific and technological community outside of their own laboratory (Allen & Cohen, 1969). In RISs, knowledge gatekeepers play an important role in determining absorptive capacity and favoring collective learning process. Graf (2011), Morrison (2008), Giuliani (2005), and Lazaric, Longhi, and Thomas (2008) among others have used the concept of gatekeeper within the concept of innovation systems as agents acquiring external knowledge to diffuse it within the RIS. At the regional level, knowledge gatekeepers have the capacity to establish linkages with innovative actors from other regions (Graf & Krüger 2011; Breschi & Lenzi 2015). Knowledge gatekeepers are as such, seen as brokers of knowledge, allowing knowledge to flow between separate regions (Gould & Fernandez, 1989).

The presence of knowledge gatekeepers is associated with successful clusters, industrial districts, and regions (Giuliani, 2005; Graf, 2011; Morrison, 2008; Van Agtmael & Bakker, 2016). Morrison (2008) suggests that successful industrial districts, such as an Italian furniture district, have knowledge gatekeepers that are well-connected to external sources of knowledge but are nevertheless limited in their connections with firms within the industrial district. A limited number of anchor or leader firms in industrial districts are absorbing, using, and diffusing knowledge at the level of the industrial district. As shown by Morrison (2008), leader firms perform the role of translating knowledge and transferring it to smaller firms within industrial districts. The leader firms identify through searching external sources of knowledge, which is then translated from complex

tacit knowledge into useful codified knowledge to the firm and firms located in the industrial district (Morrison, 2008). The transfer of knowledge is, however, contingent on the leader firm's incentive to cooperate with local actors (Morrison, 2008). In the mechanical cluster of Brescia in Italy, Lissoni (2001) points out that it is mainly the world leader in the sector, the firm Lonati, that coordinate the industrial district's activities and access to knowledge. In the automatic packaging machinery industrial district in Northern Italy, Munari, Sobrero, and Malipiero (2011) find that focal firms, which have a larger size and innovation capacities than other firms within industrial districts, have an advantage in acquiring and transferring external knowledge, and act as a result, as technological gatekeepers boosting the speed of creation and diffusion of knowledge flows within industrial districts. The successful of exchange of knowledge to other actors within the cluster, regions, or industrial districts depends on the local buzz (Bathelt, Malmberg, & Maskell, 2004; Storper & Venables, 2004). Indeed, Morrison (2008) finds that firms located in industrial districts share similar values, rules, norms, and as a result, form a cohesive social environment, which favors trust and reciprocity and thus the informal exchange of tacit knowledge. As summarized by Morrison (2008), gatekeepers of knowledge constitute a small community of individuals; they are at the core of an information network; they are over-exposed to external sources of information; and they develop linkages with external actors that are mostly informal.

2. Conceptual Framework for the Entrepreneurial Region to Support Regional Technological Catch-up in Regions Located on the Knowledge Periphery

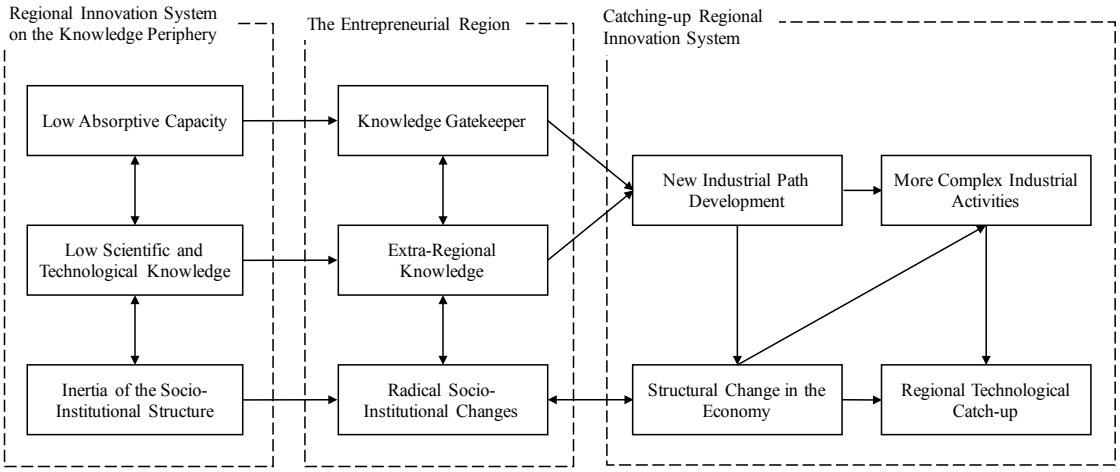


Figure 3. Conceptual Framework for the Entrepreneurial Region to Support Regional Technological Catch-up in Regions Located on the Knowledge Periphery. Source: own design.

The conceptual framework aims to analyze the role of the entrepreneurial region in promoting technological catch-up in regions located on the knowledge periphery (see Figure 3). One of the instruments of the entrepreneurial region to promote the innovation process is the regional innovation agency (RIA), which is a new trend in regional innovation governance to design and to deliver regional innovation policies (OECD, 2011a). RIAs are intermediary organizations that are being created in widely different regions in terms of their innovation capabilities and institutional contexts to serve as change agents in their regional innovation systems (RISs) (see Fiore, Grisorio, & Prota, 2011; Howells, 2006; OECD, 2011a; Rosenkopf & Nerkar, 2001). From the academic literature, regional innovation systems on the knowledge periphery suffer from, a low regional absorptive capacity, a lack of endowments in scientific and technological knowledge, and an inertia of their socio-institutional structures. The entrepreneurial region aims to reduce these structural problems by acting as knowledge gatekeepers to improve regional absorptive capacity, by increasing the amount of extra-regional scientific and technological knowledge to complement local knowledge capabilities, and by promoting radical socio-institutional changes to further increase regional absorptive capacity and extra-regional knowledge flows. The conceptual framework uses the concept of absorptive capacity applied to the RIS context, which can be defined as the capacity of a RIS to acquire, exploit, and diffuse extra-regional scientific and technological knowledge. The role of knowledge gatekeepers in regions on the knowledge periphery is thus fundamental. Knowledge gatekeepers have three functions: the acquisition of extra-regional knowledge, its contextualization, and its diffusion within their RISs. The entrepreneurial regions aim to support new industrial path development and to promote socio-institutional changes to affect structural change in the regional economy. In turn, structural change in the regional economy implies rapid path creation and path destruction that affects the socio-institutional structure. New industrial path development and structural change in the economy will lead to more complex, or

higher value-added, regional industrial activities, which will support the process of regional technological catch-up.

In the conceptual framework, the concept of a RIS is used to identify the actors, their relations, and their interactions in the region. In the RIS, the RIA is one of those actors. The RIS is analyzed using the framework developed by Liu and White (2001). RISs are anchored around five fundamental activities—R&D, implementation, end-use, education, linkage—which affect a system's structure and dynamics (Liu & White, 2001). Liu and White (2001) propose as a result, to focus "on system-level characteristics, including the distribution of these activities within the system, the organizational boundaries around them, coordination mechanisms, evolutionary processes, and the effectiveness of the system in introducing, diffusing and exploiting technological innovations". The use of categories such as "research institute", "firm" or "government" can generate more confusion than insights, since, in different national or industrial contexts, these may have very different meanings in terms of the range of activities they undertake (Liu & White, 2001). Research consists of basic, developmental, engineering research and development centers; implementation refers to multinationals, small and medium enterprises, and startups; end-use refers to the customers of the product or process outputs; linkage refers to the actors bringing together complementary knowledge; and education consists of universities, colleges, and vocational schools (Liu & White, 2001). The activities are divided into three elements: primary actors, secondary actors, and institutions (Liu & White, 2001). Primary actors are the organizations that perform one or more of the five listed activities (Liu & White, 2001). Secondary actors are organizations that affect the behaviors or the interactions between primary actors. The secondary actors directly or indirectly affect primary actors in setting operational plans, organizational targets, objectives related to any of the fundamental activities, or through the institutions that they create or shape (Liu & White, 2001). Institutions are the set of practices, rules and other disembodied organizations that guide or constrain an actor's behavior (Liu & White, 2001). RISs include primary and secondary actors that sometimes pursue competing interest (Liu & White, 2001). The RIA is, under Liu's and White's (2001) framework, a secondary actor that directly or indirectly affect the behavior of primary actors.

The conceptual framework moves beyond the firm-centric approach taken in the evolutionary economic geography (EEG) literature on new industrial path development (Asheim, Boschma, & Cooke, 2011; Balland, Boschma, Crespo, & Rigby, 2017; Neffke, Hartog, Boschma, & Henning, 2018; Neffke, Henning, & Boschma, 2011). Although firms and entrepreneurs are the most important in fostering new industrial path development, the entrepreneurial region can actively support new industrial path development. Several case studies have presented the role of regional policies in the creation of the media and biogas cluster in Sweden (Martin & Martin, 2017) or in the offshore wind industry in Northeast England and Scotland (Dawley, 2014). The main gap in the academic literature that this thesis explores is to provide a case on the role of the regional government in regions located on the knowledge periphery to support new industrial path development. The literature on path development points out the path-dependent process of path development enabled by platform policies and conducted by agents of structural change, namely firms and entrepreneurs (Asheim, Boschma, & Cooke, 2011; Neffke, Hartog, Boschma, & Henning, 2018). New industrial path development consists of path creation and path branching (Trippl, Grillitsch, & Isaksen, 2017). While path branching refers to the creation of paths based on related industries,

path creation involved the creation of a new industry in the region (Boschma & Frenken, 2006). Regional path development follows a branching logic since regional industries that are technologically-related evolve from the pre-existing regional industries (Boschma, Minondo, & Navarro, 2013; Neffke, Henning, & Boschma, 2011). The theoretical concept of new industrial path development is closely related to the policy concept of Smart Specialization Strategy (S3), which highlights the importance of regional governments in shaping strategic policies adapted to the regional context to build upon existing capabilities and industrial knowledge to diversify the regional economy into higher value-added industrial activities (Foray & Goenaga, 2013; OECD, 2016). The policy-concept emphasizes the importance of the public sector in being more agile, experimental, and entrepreneurial in an "age of austerity" (Marques & Morgan, 2018; Morgan, 2017).

The conceptual framework emphasizes the fundamental role of extra-regional scientific and technological knowledge for promoting structural change in the economy in regions located on the knowledge periphery. The acquisition of extra-regional scientific and technological knowledge is motivated by the search for capabilities, which firms in a peripheral innovation system might lack, and of the need to form alliances through which to build entirely new competences, and discovering new knowledge and innovations (Belussi & Sedita, 2010). In the technology gap theory, Posner (1961) argues that the acquisition of extra-regional scientific and technological knowledge can accelerate technological catch-up. In the innovation process, diffusion, and more importantly the speed of diffusion, matters more for economic development than innovation or invention (Ray, 1980). International technology diffusion determines productivity and growth differences, partly because only a handful of rich countries account for most of the world's creation of new technology (Keller, 2004). During the industrial revolution for instance, Britain was highly successful in diffusing inventions produced in Continental Europe (Mokyr, 1990). Indeed, not only the acquisition and development of knowledge through innovation and learning but also the diffusion and efficient utilization of this knowledge are relevant for economic growth (Narula, 2004). The role of extra-regional scientific and technological knowledge has been critical in the rapid economic development of Japan during the Meiji restoration (1869), the Four Asian Tigers, and China (Amsden, 1989; Caves & Uekusa, 1976; Dahlman & Nelson, 1995; Mokyr, 1990; Parto, Ciarli, & Arora, 2005; Rodrik, 2008; Wade, 1990). In Japan for instance, during the Meiji restoration (1869), between 1872 and 1892, the government invited more than 5000 foreign experts to help run the government-owned factories and to give training (Dahlman & Nelson, 1995). The industrial revolution in Europe benefited from inventions made in China or in the Middle East (Mokyr, 1990). Leibniz implored the Jesuit traveling to China "not to worry so much about getting things European to the Chinese, but rather about getting remarkable Chinese inventions to us; otherwise little profit will be derived from the Chinese mission" (as cited in Mokyr, 1990, p. 188). Regions on the knowledge periphery, however, lack the capacity to acquire, absorb, and exploit scientific and technological knowledge from regions located in the knowledge core (Ferretti & Parmentola, 2015; Keller, 2004; Mokyr, 1990).

The conceptual framework underlines the importance of regional absorptive capacity for supporting new industrial path development in regions located on the knowledge periphery. The acquisition and diffusion of extra-regional scientific and technological knowledge must be coupled with policies that aim to strengthen regional absorptive capacity in order to support regional actors to fully exploit extra-regional knowledge. In

analyzing trade data and regional growth in Italy, Boschma and Iammarino (2007) point out that the inflow of variety or similar knowledge did not affect regional economic growth. The paper suggests that attracting large inflows of extra-regional knowledge is not enough to affect higher economic growth (Boschma & Iammarino, 2007). It is only when firms have the capacity to absorb the knowledge that external knowledge leads to learning and innovation (Boschma & Iammarino, 2007). The academic literature points out that firms, industries, countries, and regions have to generate various "capabilities", such as "social capability" (Abramovitz, 1986), "technological capability" (Kim, 1980), "absorptive capacity" (Cohen & Levintal, 1990) and "innovation system" (Lundvall, 1992, Nelson, 1993, Edquist, 1997), to successfully exploit external technologies and thus escape the trap of lagging behind and low competitiveness. For Dahlman and Nelson (1995, p. 88), absorptive capacity in developing countries implies the ability to learn and to implement the technological knowledge that first originated in developed countries.

The conceptual framework stresses the role of the entrepreneurial region in supporting radical socio-institutional changes for that two reasons. First, the entrepreneurial region has to align the socio-institutional structure with the new industrial path development in order to support the RIS' absorptive capacity. Second, the entrepreneurial region has to limit transitional failure resulting from regional structural change in the economy. Regional structural change implies rapid path creation and path destruction that affects the socio-institutional structure, which, in turn, through cumulative causation will affect future path development. The socio-institutional structure refers to the evolutionary structures that co-evolve with the techno-economic structure. The socio-institutional structure involves three knowledge-driven structures: (i) the social structure that refers to informal institutions, (ii) the organizational structure that refers to organizational features within private organizations, and (iii) the institutional structure that refers to the organizations that implement and/or devise formal institutions.

The entrepreneurial region has to align the socio-institutional structure with the new industrial path development in order to support the RIS' absorptive capacity to fully exploit extra-regional knowledge. The socio-institutional structure can hinder or enable a RIS' absorptive capacity in fully exploiting extra-regional knowledge. New industrial paths development do not emerge in a vacuum but in the context of existing technological, industrial, and institutional arrangements (Chlebna & Simmie, 2018; Edquist & Johnson, 1997; Martin & Simmie 2008). Socio-institutional changes can be particularly favorable to the introduction and diffusion of new technologies (Lundvall, 1992, p. 183). Evolutionary patterns such as path-dependency, technological trajectories, imitation, inertia, lock-in, habits, routines, and cumulative causation can be applied to any knowledge-driven systems, such as the socio-institutional structure (David, 1994; Hodgson, 1998; Metcalfe, Foster, & Ramlogan, 2006; North, 1990; Saxenian, 1994; Setterfield, 1993). Regions accumulate different social, organizational, and institutional structures that are the outcomes of a specific regional context. Freeman (1991) developed the concept of "techno-economic paradigm" to emphasize the importance of institutional innovations to support technological innovations. The socio-institutional structure is cumulative, interdependent, and self-reinforcing. Organizations can directly create institutions (North, 1990). Organizations for instance, can construct standards and implement rules (Edquist & Johnson, 1997). Institutions can also directly create organizations. For instance, a government can enact a law that leads to the establishment of an organization (Edquist, 2001). New institutions are partly determined by pre-existing ones (Saviotti, 1997, p. 181). Technological, organizational, institutional, and

social innovations occur when the actors inside the firm or institutions have the willingness, the opportunity and motivation, and the capacity or capabilities to innovate (Ashford, 2000). Ashford and Hall (2011, p. 676) argue that changes can either be evolutionary or revolutionary, the latter being influenced by crises, tipping points, or visionary leadership.

The social structure refers to social features that favor the acquisition, diffusion, and exploitation of extra-regional knowledge into a RIS. The acquisition, diffusion, and exploitation of external scientific and technological knowledge are ultimately embodied in people. The social structure is connected to the concept of informal institutions and social capital. In the academic literature, there are numerous examples of how culture and social features contributed to technological innovation in innovation systems, such as in South Korea (Koo, 1995); in Western Europe (Mokyr, 2016); or in Silicon Valley (Saxenian, 1994). Culture and the social structure can also, be powerful constraints to technological innovation. Headrick (1988) looks at how technology transfer in former colonies was organized without the development of technological capability due to cultural features in the colonies. Ultimately, technology transfer in the former colonies failed to substantially increase the standard of living because governments were reluctant to adopt the cultural and social practices necessary to develop the knowledge, skills, and attitudes related to a particular product or process (Headrick, 1988). For Headrik (1988), the cultural diffusion of technology takes "a willingness to accept changes, a strong political cohesiveness, and a common vision of the future" (p. 13). Strong internal social structures, such as technological conservatism, tradition, custom, routine, can produce economic inertia, conformism, and as a result, be powerful obstacles to innovation and technological change (Mokyr, 1990, p. 155). Informal institutions also affect incentives and behaviors. Informal institutions affect entrepreneurship, for instance, with risk-taking, failure, status, and prestige (Edquist & Johnson, 1997, p. 53).

The social structure can either enable or restrict interactions within and across regional innovation systems. Camagni (1991) noted that social capital is "a process happening both at the intra-regional level in the form of collective learning processes, and through inter-regional linkages facilitating the firm's access to different, though localized, innovation capabilities" (Camagni, 1991, p. 8). Informal institutions refer "to the conventions and codes of behavior" (North, 1990, p. 4). More precisely, informal institutions are common law, customs, traditions, taboos, codes of conduct, work norms, norms of cooperation, conventions, practices, and so on (Edquist & Johnson, 1997, p. 46). Putnam (1996, p. 56) defines social capital as "the features of social life—networks, norms, and trust—that enable participants to act together more effectively to pursue shared objectives." Social capital encompasses the norms, values, and beliefs, which are shared in everyday interaction within social networks, and which enable the coordination of action to achieve desired goals (Bourdieu, 1980; Coleman, 1988; Putnam, 2001). Geographical proximity and social capital influence each other in both cumulative and counteractive ways. The repeated interactions between people within a regional innovation system create a "genius loci" or social capital that more or less facilitates the acquisition of external knowledge. Geographical proximity contributes to the divergence of social capital, which, in turn, contributes to group cohesion and reduces as a result, the interactions between groups already separated by space (Westlund, 2006). The stock of social capital differs greatly between cities and regions. And this, in turn, reflects the wide disparities in localized trajectories of economic, social, and cultural development (OECD, 2001b; Putnam, Leonardi, & Nanetti, 1994). In agglomeration economies, social

capital has two roles. First, it enhances the social capital of the firms and other actors within the agglomeration. Second, it enhances the social capital between the agglomeration's actors and the rest of the world. Internal social capital is, however, stronger than the external social capital since otherwise, the agglomeration would dissolve (Westlund, 2006, p. 40). Shared values, mutual trust, sense of belonging, and norms facilitate the creation and preservation of formal and informal relations, which in turn, contribute to collaboration and cooperation not only within an innovation system but also across relevant innovation hubs around the world (Brusco, 1982; Caragliu & Nijkamp, 2012; Saxenian, 1994). There are three main externalities of social capital. According to Maskell (1999, 2000), social capital increases mutual trust across actors of a system, which reduces in turn, transaction costs; it increases human capital through facilitating the exchange of knowledge; it increases the capacity of a system for common action.

In a RIS, the social structure affects the regional absorptive capacity. There are, however, different social processes at work in the acquisition, diffusion, and exploitation of external knowledge in a RIS. First, the acquisition of the external knowledge in a RIS will be facilitated by closeness across RISs (Boschma, 2005, 2008; Gertler, 1995). Closeness, which refers to frequent, effective, often unplanned interaction, and more broadly, to encompass common language, modes of communication, customs, conventions, and social norms, facilitate the acquisition of extra-regional knowledge (Gertler, 1995). The entrepreneurial region aims to connect its RIS with relevant innovation hubs around the world that have distinct social structures. The entrepreneurial region adopts programs to reduce the social distance between its RIS social capability with social capabilities of the newly-connected RISs to facilitate the acquisition of external knowledge. Indeed, a set of shared cognitive structures, language, and frame of reference are required to favor the acquisition of external knowledge (Boschma, 2005, 2008; Cohen & Levinthal 1990, Hall, 1998). Second, global pipelines need to be complemented with local buzz to diffuse the extra-regional knowledge within the RIS (Bathelt, Malmberg, & Maskell, 2004; Storper & Venables, 2004). Social features, such as mutual trust (Asheim, 1996; Maskell, 1999, 2000); norms (Gertler, 2005; OECD, 2001); networks (OECD, 2001; Westlund, 2006) informal relations (Brusco, 1982; Saxenian, 1994); shared values (Saxenian, 1994); social endogenous effects (Bikhchandani, Hirshleifer, & Welch, 1998; Suire, & Vicente, 2009); and high social capital (Westlund, 2006), favor the diffusion of extra-regional knowledge within the RIS. Third, the exploitation of the extra-regional knowledge in a RIS will facilitate social changes. Technological determinism suggests that technological changes, which is impinged on society from outside of society, cause social changes. As shown by Ogburn and Nimkoff (1964), technological innovations have important social effects when they suggested that the invention of the radio had more than 150 social effects. The exploitation of external knowledge will, as a result, contribute to cause social change reinforcing further acquisition of external knowledge. The social capital or informal institutions are likely to evolve in an incremental manner due to the embeddedness of informal constraints, such as customs, traditions, and codes of conduct, in societies (North, 1990).

The organizational structure refers to organizational features that favor the acquisition, diffusion, and exploitation of extra-regional knowledge in RIS. The organizational structure affects a firm's absorptive capacity (Liao, Welsch, & Stoica, 2003; Van Den Bosch, Volberda, & de Boer, 1999). The OECD (2005, p. 51) defines an organizational

innovation as "the implementation of a new organizational method in the firm's business practices, workplace organization or external relations". Organizational innovations can be intended to increase a firm's performance by reducing administrative costs or transaction costs, improving workplace satisfaction (and thus labor productivity), gaining access to non-tradable assets (such as non-codified external knowledge) or reducing costs of supplies (OECD, 2005). The access to non-codified external knowledge is, as a result, an important element of organizational innovation. Zahra and George (2002, p. 186) define absorptive capacity as "a set of organizational routines and processes by which firms acquire, assimilate, transform, and exploit knowledge to produce a dynamic organizational capability". Van Den Bosch, Volberda, and De Boer (1999) suggest that absorptive capacity has three components, such as the ability to recognize the value of external knowledge, assimilate it, and apply it to commercial ends. R&D and human capital investments are for firms the main tools to work around the absorptive capacity constraint (Cohen & Levinthal, 1989, 1990; Lund Vinding, 2006; Mangematin & Nesta, 1999). Levinthal (1994) points out that prior organizational competencies can trap companies in suboptimal developments. Firms can, for instance, expect to solve problems through existing regime and thus do not invest in radical innovations, which drive them to continue along existing paths and "technical trajectories" (Dosi, 1982). In a RIS, the firms' capacities to develop strong organizational capacities will determine their capacities to absorb external knowledge. Organizational determinants, such as organization forms and combinative capabilities, facilitate absorptive capacity (Van Den Bosch, Volberda, & De Boer, 1999).

In a RIS, the entrepreneurial region will adopt programs to facilitate the firms' ability to recognize, to identify, to acquire, to diffuse, and to exploit external knowledge. The external knowledge can be acquired in two forms: disembodied or equipment-embodied (Fischer, Diez, & Snickars, 2013). External knowledge from equipment-embodied knowledge spread in the economy through the purchase of technology-intensive machinery, such as computer-assisted systems (Fischer, Diez, & Snickars, 2013). External knowledge from disembodied knowledge may be transferred through descriptions of new products or production processes found in catalogs, publications, or patent applications, through seminars and conferences, through R&D personnel turnover or through mergers and acquisitions, joint ventures and other forms of inter-firm cooperation (Fischer, Diez, & Snickars, 2013). Networks and international linkages offer the possibility to identify and to acquire external knowledge. International linkages can take various forms, such as formal networks, informal networks, industry networks, production chain networks, global networks, university-firm networks, geographic clusters, and university-firm networks, migration, international trade, foreign direct investments (FDI), global value chains, and international R&D (Aghion et al., 2009).

External knowledge can be acquired through technology transfer. For Headrick (1988) technology transfer is a two-step process that occurs simultaneously, "first, the relocation, from area to another, of equipment and methods, along with the experts to operate them. The other is the diffusion from one society to another of the knowledge, skills, and attitudes related to a particular process or methods" (p. 9). Technology transfer is defined as "the processes and consequences of moving technological ideas, skills, processes, hardware, and systems across a variety of boundaries—national, geographic, social and cultural, or organizational and institutional" (Seely, 2003, p. 7). Foreign technology can be acquired from external firms through technology licensing, provided by foreigners through direct investments, acquired through indigenous efforts to translate

foreign technological knowledge into specific methods by foreign study or training, reverse engineering, copying (Dahlman & Nelson, 1995; Narula, 2004). Technological transfer involves technological learning; most importantly, the learning of human capital since technological capability is ultimately embodied in people, not machinery (Dahlman & Nelson, 1995, p. 97). Ultimately, the success of technology transfers rests on "the ability or willingness of the importing society to accept the technology than on the support of the exporting society" (Headrick, 1988, p. 11).

The diffusion of external knowledge has for determinants human capital, R&D expenditures, and prior scientific and technological knowledge (Cohen & Levinthal, 1989, 1990; Keller, 2004). The diffusion of external knowledge can result from labor mobility since labor is the main carrier of knowledge, employees moving from one firm to another will also transfer the knowledge (Florida, 2002; Romer, 1990; Simon, 1998). Mahroum (2000) argues that each group of mobile skilled migrants is driven by different push and pull factors. Managers, engineers, and technicians are driven by economic factors and the state of the national economy. Academics and scientists are driven by bottom-up developments in science, work conditions, and the institutional prestige of the university or research center. Entrepreneurs are driven by governmental policies, such as visa, taxation, regulations, financial facilities, and bureaucratic efficiency. Students are driven by the recognition of a global workplace, accessibility problems at home, and the intercultural experience. Economic migrants, however, mostly contribute to cultural diffusion rather than technology transfer (Headrick, 1988).

Technological innovations that can result from the exploitation of external knowledge affect the firm's organizational structure (Pini & Santangelo, 2010). The innovative firm can evolve from an entrepreneurial organizational structure to an organizational structure favoring larger-scale production of standardized offerings. Indeed, technological innovations can transform firms into more hierarchical, rigid, and formal organization focusing on structure, goals, and rules in which "major innovations—once the life-blood of the firm—are less and less encouraged; continuous incremental improvements become the order of the day" (Utterback, 1994, p. 84). Firms that tend to focus on creative and innovative pursuits generally de-emphasizes bureaucratic structures, fixed job responsibilities, and written communications formalized in fixed filing systems. Indeed, creativity seems to be enhanced when the organizational structure involves teams and job responsibilities aim to meet the exigencies of new problems rather than routine ones (Freeman & Engel, 2007). The innovative organizational structure is characterized by "a widening of technological options; enterprise restructuring (e.g., decentralization); enhanced scope and variety of technological cooperation (e.g., precompetitive R&D consortia; and university-industry cooperation); a trend towards the internationalization of R&D" (Galli & Teubal, 1997, p. 343). Innovative firms have to become ambidextrous organizations that are able to exploit innovations while exploring new innovation opportunities at the same time (O'Reilly & Tushman, 2004).

The institutional structure refers to the institutional features that favor the acquisition, diffusion, and exploitation of external knowledge in a RIS. The institutional structure consists of formal institutions and of the public organizations that directly implement the formal institutions. Formal institutions are the "rules that human devise" that affect transaction costs (North, 1990, p. 4; Williamson, 1979). Formal institutions are, for instance, laws, constitutions, law, government regulations, formal instructions, property rights, or the tax system that affect incentives to pursue innovation (North, 1990).

Property and intellectual property rights to knowledge and ideas such as laws and rules concerning patents, copyrights, and trademarks affect the level of appropriability of technological innovation, and, thus, affect the diffusion of knowledge (Edquist & Johnson, 1997). Public organizations are formulating and implementing "technology policy, regulatory agencies, organizations for higher education and research, technology support entities (training programs, industry-specific research organizations, extension services), standard-setting organizations, and patent offices" (Edquist & Johnson, 1997, p. 59). The institutional structure is path dependent and is shaped through feedback mechanisms by the individuals and the organizations pertaining to the institutional structure (North, 1990; Setterfield, 1993). Lobbies and vested interests can, as a result, through institutions slow down the regions in building the capacity to adopt new technologies and to reallocate resources to new industrial activities (Olson, 1982). Institutional innovation or public-sector innovation can be defined as the implementation by a public-sector organization of new or significantly improved products, services or ways of doing things, either within the structure of the public sector itself or in the way in which public services are provided. Innovations in the public sector can take different forms, such as service innovations, service delivery innovations, administrative and organizational innovations, conceptual innovations, policy innovations, and systemic innovations (Windrum, 2008). However, formal institutions are more prone to radical changes than informal institutions, since formal rules may change overnight, as a result of political or judicial decisions (North, 1990, p. 6). Institutional innovations occur for two reasons. First, social innovations push a group of people with enough political support to improve existing institutions or to invent new institutions. Second, the existing institutions cannot cope with current or former challenges or cannot longer function effectively because of changing circumstance (Lundvall, 1992, p. 183). At the level of the institutional structure in a RIS, the acquisition, diffusion, and exploitation of external knowledge favors the continuous transformation of formal institutions allowing the RIS to further acquire, diffuse, and exploit external knowledge.

Finally, the entrepreneurial region has to limit transitional failure resulting from regional structural change (see Figure 4). During structural change in the economy, such as during a Kondratieff cycle or during the introduction of disruptive innovations, the socio-institutional structure is briefly decoupled from the techno-economic structure due to its relative inertia and path-dependent nature compared to a period characterized by rapid increasing technological complexity and by the diffusion of technological disruptions (Antonelli, 2011; Freeman 1991; Geels 2002, 2004, 2005; Hall & Preston 1988; Kemp 1994; North 2005; Perez 1983, 2004, 2010). The decoupling between the socio-institutional structure and the techno-economic structure generates inefficient systemic interactions leading to transitional failure (Perez, 2010). Kondratieff long waves are the most vivid period of decoupling between the socio-institutional structure and the techno-economic paradigm since it affects the entire structure of society (Geels, 2002; Perez, 2004). Kondratieff long-wave can even disrupt regions in the knowledge core and give the opportunity to regions on the knowledge periphery to technologically catch-up (Hall, 1998; Markusen, 1985; Murmann, 2003; Perroux, 1955; Storper & Walker, 1989). Indeed, regions with the social, institutional, and organizational structures to support the dominant industries or certain types of innovations are less reactive to respond to the need of new industries due to political, cognitive, or functional lock-ins (Grabher, 1993; Hall, 1998; Hall & Soskice 2001; Markusen, 1985; Murmann, 2003). The Information and Communication Technology (ICT) revolution for instance, has completely transformed the innovation system to the point of triggering major structural adjustments,

such as the changing desired skills in the labor force, the emergence of new management structures and type of organizations, the emergence of new industrial relations, and the emergence of institutional regulation structures at the national and international level (Castells, 1996). The transition between two distinct techno-economic paradigms implies changes in ideas, behaviors, organizations, and institutions towards better alignment with the nature of the structural change in the economy (Perez, 2010). The inertia of the socio-institutional structure can even hinder structural change in the economy. In the 19th century, while Japan adopted Western technologies and successfully experienced a rapid economic transformation, China was not as successful in adopting Western technologies because it tried to preserve its old social and economic institutions (Mokyr, 1990). Fagerberg and Verspagen (2002, p. 1292) note that "technological catch-up is not a question of replacing an outdated technological set-up with a new one, but to continually transform technological, economic, and institutional structures." Saxenian (1994) suggests that the divergence between Silicon Valley and Route 128 lies in their different organizational and social structures, which made Silicon Valley more decentralized and fluid thus more conducive to the acceleration and diffusion of innovations. In regions located on the knowledge periphery that are undergoing structural change of their regional economies, the entrepreneurial region can facilitate the co-evolution of the socio-institutional structure with the new techno-economic by learning from regions located in the knowledge core at the technological frontier that have fitter socio-institutional structure. The entrepreneurial region has the role to acquire, to translate, and to diffuse extra-regional knowledge while at the same time facilitating the co-evolution of the socio-institutional structure to allow the extra-regional knowledge to be efficiently exploited by the greatest number of actors within their RISs.

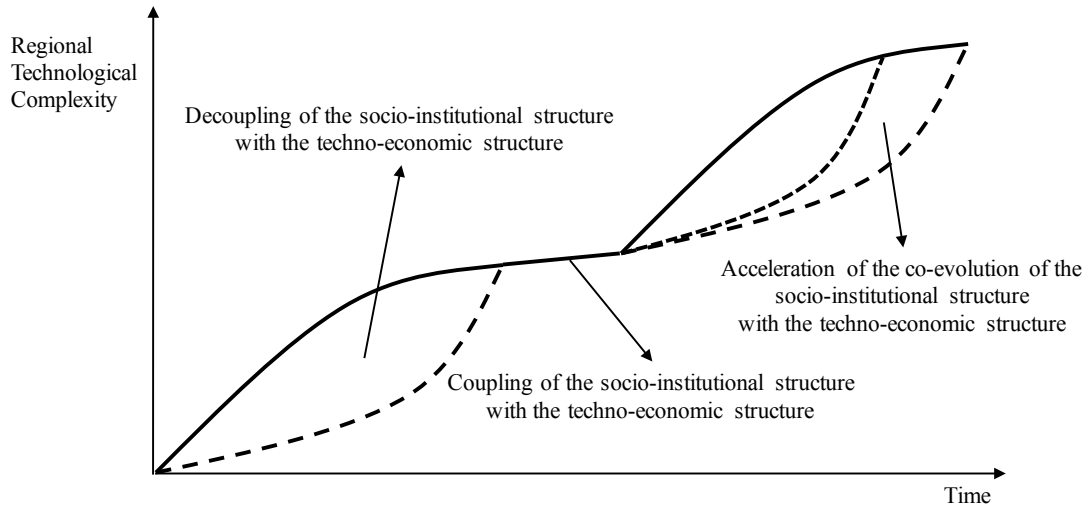


Figure 4. The Coupling and Decoupling of the socio-institutional structure with the Techno-economic Paradigm. Source: Own Design.

Part II
The Entrepreneurial Region: The Case of Ruta N Medellín

3. The Methodological Framework.

3.1. Purpose and Research Question.

The Philosophical Assumptions. The ontological assumption relates to the nature of reality and its characteristics. The ontological assumptions that have guided this thesis come from the intersections of regional studies, innovation studies, economic geography, and heterodox economics, namely evolutionary and institutional economics. Heterodox economic schools embrace the view that economic agents are embedded in larger structures that determine economic behaviors. The structures determining the agency of economic and social actors are path-dependent, cumulative, multiples, and mutually reinforcing (Boschma & Frenken, 2006; Hodgson 1998; Perez, 1983; 2004). This thesis approaches reality as a set of multiple realities that are layered upon one another.

The epistemological assumption relates to what counts as knowledge. This thesis approaches reality as a set of multiple realities that are layered upon one another. Knowledge can be obtained through the in-depth understanding of the context and in-depth interactions with the actors within that context. Knowledge, or subjective evidence, is thus assembled on individual views within the context studied. Knowledge can only be attained through multiple and repeated interactions in the field.

The axiological assumption relates to the role of values in a research. This thesis approaches reality as a set of multiple realities that are layered upon one another, in which knowledge can be obtained through the in-depth understanding of the context and in-depth interactions with the actors within that context. The values that the researcher is bringing to the study is that of a constructivist paradigm in which knowledge can be obtained through a qualitative approach.

Purpose and Research Questions. The purpose of this thesis is to uncover how the entrepreneurial region through a regional innovation agency can facilitate the process of technological catch-up in a region located on the knowledge periphery.

The rationale of this thesis is to understand the role of a regional innovation agency (RIA) located on the knowledge periphery in supporting new industrial path development and regional structural change. The intent of the research is to provide a framework for policymakers in regions located on the knowledge periphery to support the process of technological catch-up through new industrial path development and regional structural change.

The central question that guides the thesis is:

- How can a regional innovation agency foster new industrial regional path development in a region located on the knowledge periphery?

The sub-questions that further specify the research question are:

- What was the context in which the regional innovation agency was created?
- Who were the actors who created the regional innovation agency?
- What are the roles of the regional innovation agency in the regional innovation system?

- How is the regional innovation agency supporting the absorption of extra-regional knowledge into the regional innovation system?
- How is the regional innovation agency supporting structural change in the regional economy?

3.2. The Case Study Research Design.

This thesis uses qualitative research to answer the research questions. Qualitative research has been adopted for three reasons. First, the thesis aims to provide "a complex and detailed understanding of the issue" (Creswell, 2013, p. 48). Second, qualitative research allows for the development of theories when existing theories do not capture the complexity of the problem (Creswell, 2013). Third, the qualitative research allows capturing multiple realities that are layered upon one another, in which knowledge can be obtained through the in-depth understanding of the context and through in-depth interactions with the actors within that context. The qualitative research involves a strong commitment to the research as well as extensive time and resources (Creswell, 2013). Moreover, qualitative research implies an extensive collection of data from multiple sources of information (Creswell, 2013).

This thesis has adopted from the different qualitative approaches, the case study approach. The case study allows the researcher to explore a real-life contemporary bounded system through detailed and in-depth data collection involving multiple sources of information, namely, primary data, secondary data, and direct observations (Creswell, 2013). The case study method has four advantages in that it has the potential to achieve high conceptual validity, to generate new hypotheses, to define causal mechanisms, and to have the capacity to address causal complexity (George & Bennett, 2005, p. 19). Additionally, the case study approach was adopted for three reasons. First, the research question aims to understand contemporary complex social phenomena (Yin, 2013). Second, the research question involves an evolutionary contextual dimension that needs to be traced over time (Yin, 2013). Third, the researcher is posing "how" and "what" questions to a body of materials in which the researcher has little or no control on the organization and context studied (Yin, 2013). Schramm (1971) pointed out that "the essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a decision or a set of decisions: why they were taken, how they were implemented and with what results" (p. 6). As pointed out by Rodrik (2008), case studies are relevant in the context of policy making to complement more quantitative works so that "any cross-country regression giving results that are not validated by case studies needs to be regarded with suspicion. But any policy conclusion that derives from a case study and flies in the face of cross-national evidence needs to be similarly scrutinized. Ultimately, we need both kinds of evidence to guide our views of how the world works" (p. 4).

3.2.1. Case Selection.

The second step in formalizing the methodological approach is to select the case or cases. In this thesis, the case selected is Ruta N Medellín. The case was purposefully selected from the author's own professional and academic experience. Purposeful sampling derives from "the emphasis on in-depth understanding. This leads to selecting information-rich cases for study in depth. Information-rich cases are those from which

one can learn a great deal about issues of central importance to the purpose of the research; thus, the purpose of purposeful sampling" (Patton, 2002, p. 230). From May to August 2013, the author did an internship at Ruta N Medellín working under the supervision of Elkin Echeverrí on Key Performance Indicators related to the implementation of the STI Plan. In reading the literature on new industrial path development and regional innovation systems, the author found that Ruta N could be an interesting case to further investigate since the institutional mechanisms of implementing place-based policies to support new industrial path development, which are recommended in the academic literature, are rarely investigated and are poorly understood. The case was purposefully selected to examine how the regional innovation agency supported new industrial path development in the RIS.

The researcher had first pondered to conduct multiple case-studies in order to generalize his findings to different RISs. Indeed, the researcher considered other regional innovation agencies, such as Agence de Développement et d'Innovation Nouvelle-Aquitaine in Nouvelle-Aquitaine in France, Bretagne Développement Innovation in French Brittany, ARTI Agenzia Regionale per la Tecnologia e l'Innovazione in Apulia Region in Italy, Barcelona Activa in Barcelona, Brainport Development in Eindhoven in the Netherlands, and Innobasque in the Basque Country in Spain. The researcher found, however, that the regional innovation agencies considered had a limited scope compared to Ruta N in Medellín. The regional innovation agencies in France were only offering services to private companies, such as support services for adopting high technologies or for exporting. Moreover, the regional innovation agencies in France are not only providing regional innovation services but also regional investment promotion services. The regional innovation agency in Apulia in Italy, ARTI, is focusing on promoting interactions between private companies-public institutions-universities. The regional innovation agency, Barcelona Activa, has a limited scope providing services to private companies, offering training, and matchmaking between employers and employees. Finally, the Basque Country has two regional innovation agencies, Innobasque and SPRI, showing an example of organizational thickness. While SPRI focuses on the development of private companies, Innobasque focuses on upgrading the socio-institutional structures.

The single case study was selected for five reasons. First, Medellín is being hailed as a best-practice of social and economic transformation around the world. Second, Ruta N is a unique regional innovation governance structure and institutional arrangement in Latin America that has received a strong political support and large public resources (see OECD, 2015a). Third, the author has remained in good contact with former colleagues at Ruta N. The established contact has allowed the researcher to have the status of an insider who already has established trust with former colleagues. The established trust allows the researcher to more rapidly gain access to internal documents, to controversial aspects of the organization, and to the key stakeholders to interview. Fourth, the organization has clear spatial and time boundaries. The organization was formally created on November 11, 2009, and aims to serve Medellín and the Aburrá Valley. The case is thus bounded in time, 2009 to present, and spatially bounded, Medellín and the Aburrá Valley. The regional innovation system refers to the actors located in the Aburrá Valley. Fifth, Ruta N has widely communicated on its actions and on its programs. There are, as a result, extensive contextual materials that can be gathered from multiple sources of information to provide an "in-depth picture of the case" (Creswell, 2013, p. 125).

Ruta N is selected as a single critical, high-impact, and significant case. The case is significant since it provides "rich and deep understanding of the subject and breakthrough insights", the case is high-impact since it provides "a significant contribution" to the literature on economic geography, and is critical since it provides "evidence that permits logical generalization" (Patton, 2015, p. 267). Contrary to a multiple case study sampling, a single case sampling allows the researchers to fully document and extensively describe the context of the case studied. Indeed, Wolcott (2008) points out that any case over one dilutes the level of details that a researcher can provide.

3.2.2. Data Collection and Data Analysis Procedures.

Qualitative research implies an extensive collection of data from multiple sources of information (Creswell, 2013). The case study has the strength to deal with a full variety of evidence in order to present an in-depth understanding of the case (Creswell, 2013; Yin, 2013, p.12). The data collection for a case study evidence may come from six sources: documentation, archival records, interviews, direct observation, participant-observation, and physical artifacts (Yin, 2013, p. 103). The data that has been collected for this thesis comes from four sources: interviews, observations, documents, and audiovisual materials. The data was collected to answer the research questions and research sub-questions.

Interviews. The researcher conducted face-to-face interviews in Medellín in July and August 2017 and 2018. The interviews allowed the researcher to gather extensive data on some aspects of the research question. The interviews were conducted with key stakeholders or "super-informants" (Denzin, 1989), who have participated in the creation of Ruta N, who have an extensive knowledge on Ruta N, who are directly employed by Ruta N, or who have directly collaborated with Ruta N. In 2017, 41 face-to-face interviews with 38 persons were conducted. In 2018, 35 face-to-face interviews with 35 persons were conducted. In total, 76 face-to-face interviews with 61 different persons were conducted. The time of the interviews ranged from 20 to 90 minutes. The interviewees were selected in two different manners. First, some interviewees were directly selected by the researcher based on personal connections and knowledge of the case studied. Second, the other interviewees were selected from the recommendations given by the persons interviewed, following a snowball technique sampling. The interviews have as their main strengths to focus on the research questions, to provide insights, and to offer personal views (Creswell, 2013; Yin, 2013). Interviews also have biases, such as reflexivity-interviewee, which is the tendency to give what the interviewer wants to hear, or the tendency to exaggerate successes and minimize failures.

The interviews were conducted in a semi-structured and in-depth manner. The interviews more so resembled a guided conversation rather than structured queries, and, for those two reasons. First, it allowed the researcher to establish trust and a friendly climate with the interviewees. Second, it allowed the interview to be fluid rather than rigid and to better incorporate the line of research with the interviewee's own personal experience (Rubin & Rubin, 2011; Weiss, 1994). Moreover, the interviews were audiotaped with a Sony ICD-BX140 voice recorder after receiving the interviewee's consent agreement. The audio files were then transcribed on a word file to be coded and analyzed.

The interviews were adapted to the interviewees' experience in such a manner that three different types of interviews were conducted.

- Semi-structured interviews directed towards key informants who have participated in the creation of Ruta N, such as CTA, EPM, City of Medellín, Proantioquia, Ruta N's first employees and directors.
- Semi-structured interviews directed towards key informants who have collaborated with Ruta N on designing programs or implementing programs, such as CREAME, the ANDI, the City of Medellín, the Medellín Chamber of Commerce for Antioquia, IADB, CIDET, Parque E, MIT, Tecnnova, ACI, ECSIM, and EAFIT University.
- Semi-structured interviews directed towards key informants who are working at Ruta N.

The semi-structured interviews directed towards key informants who have participated in the creation of Ruta N aimed to uncover the context, the actors, and the motivation in the creation of the regional innovation agency. The semi-structured interviews directed towards key informants who have collaborated with Ruta N on designing programs or implementing programs aimed to investigate their roles in the implementation of the programs. Finally, the semi-structured interviews directed towards key informants who are working at Ruta N aimed to examine what are the programs, who are the actors implementing the programs, and how they were implemented.

Observations. In 2017, the researcher spent 9 weeks (30 June-3 September), and in 2018, the researcher spent 7 weeks (14 July-1 September), in Medellín to conduct fieldwork. Moreover, the researcher participated in an unpaid internship from May to August 2013 at Ruta N, from which recorded memories have been extracted for this research. Qualitative research implies going into the field to know the participants and to "know what they know" in order to gain an "insider" perspective (Creswell, 2013; Wolcott, 2008). Fieldwork allows one to get as close as possible to the "action" and thus to uncover "both externally observable behaviors and internal states" (Patton, 2015, p. 56). According to Singleton, Straits, and Straits (1993, p. 319), field work is recommended "when a situation is complex, involving interrelated phenomena that must be studied simultaneously and as a whole—for example, the study of an institution."

	Dimension of Field Work	Researcher's Stance
1	Role of observer	Non-Participant
2	Insider versus outsider perspective	Insider and Outsider
3	Number of inquirers	1
4	Degree of collaboration with those being studied	Some Involvement
5	Degree of disclosure of the observer's role to others	Full Disclosure
6	Duration of observations and fieldwork	4 Months
7	Location of observational inquiry	On Site and Virtual
8	Focus of observations	Broad Inquiry
9	Degree of emergence in the field	Fixed and Emergent
10	Degree of topical sensitivity	Some Sensivity

Figure 5. Dimensions of Fieldwork. Adapted by the author from Patton (2015).

The observations have been conducted in three different settings and followed the dimensions described above. The observations refer to situations in which the researcher "gathered field notes by spending more time as an observer than as a participant" and "recording experience for scientific purposes" (Creswell, 2013, p. 160). First, observations have been carried out during events organized by Ruta N or about Ruta N. The researcher participated in the *Concervezatorio*, which is an event that was organized by *Cartel Independiente*, an independent radio station, in *Parque Poblado* on August 9, 2017, in which participants could ask direct questions to some Ruta N's employees present at the event. The researcher participated at the CUEE meeting that was chaired by the CEO of *Bancolombia* and the Dean of the University of Antioquia on August 3, 2018, at the Ruta N building. The researcher also participated to Ruta N Open House, an event organized by Ruta N every month, where Medellín's residents can be acquainted with Ruta N's mission, programs, and opportunities. Second, observations have been carried out during meetings with Ruta N's employees and in the Ruta N building complex to determine the sense of local buzz inside the innovation center. Third, observations have been conducted in the Medellinnovation District in which the researcher spent time walking in the Medellinnovation District to determine the challenges to transform the neighborhoods into an innovation district. Fourth, informal observations have been carried out in different neighborhoods of Medellín, namely in *La Candelaria*, *Laureles*, and *El Poblado,* in order for the researcher to get a sense of the context and to identify what is "in the air," as Marshall (1890) would say. Formal and informal observations have been conducted in an ongoing manner from June 30 to September 3, 2017, and from July 14 to September 1, 2018. Since the thesis investigates a regional innovation agency that is embedded in a regional innovation system, which comprises a multitude of actors operating within a specific socio-institutional structure, informal observations have complemented more formal observations to sense the genius loci of the regional innovation system.

Documents. The documents that have been collected for this research come from seven sources: academic articles; reports and books; articles in magazines, newspaper, and websites; official documents from the City of Medellín, such as statistical data, municipal agreements, official contracts; Ruta N external communication materials, such as Ruta N management reports and articles in Ruta N websites; Ruta N internal documents, such as consultancy reports, internal memos, and internal programs; and documents from other actors in the RIS, such as the Chamber of Commerce, CTA, or Proantioquia.

The academic articles have included, but are not limited to, articles in academic journals, such as *Latin American Research Review*, *California Management Review*, *Latin America Perspectives*, *Local Economy*, and *Environment & Urbanization.* Reports and books have included, but are not limited to, the OECD report on "*Promoting the Development of Local Innovation Systems*", the Developmental Leadership Program on "*The Medellín Miracle*", and books on Colombia's and Medellín's economic and political history. The articles in magazines, newspaper, and websites have included, but are not limited to, *El Colombiano*, *Dinero*, *El Tiempo*, *Semana, El Mundo, El Spectador, pulsosocial.com,* and *MIT Technological Review.* The official municipal documents have included, but are not limited to, statistical data coming from the City of Medellín, municipal agreements related to Ruta N, official contracts related to building Ruta N, and EDU planning documents. Ruta N external communication materials have included, but are not limited to, Ruta N management reports from 2010 to 2018, articles that have been redacted by Ruta N communication teams and published on Ruta N websites, and Ruta N websites. The websites are *distritoMedellín.org, rutanMedellín.org, MiMedellín.org. Citiesfor.life,* and *laboratoriodeinnovacion.co.* Ruta N internal documents have included, but are not limited to, consultancy reports, namely T2 Venture Capital, Technopolis Group, STI Observatory, OECD, internal presentations, internal memos, and internal documents for programs. The other documents have included, but are not limited to, documents from other actors in the RIS and organizations that have participated in Ruta N programs or implemented Ruta N programs, such as Boston College, Purdue University, Penza Group, IC^2, CTA, CREAME, the Medellín Chamber of Commerce for Antioquia, or Tecnnova.

Audiovisual materials. The audiovisual materials have come from, in its large majority, the Ruta N Youtube Channel. The Ruta N Youtube Channel has been created on April 13, 2010, and has more than 800 videos. The videos range from presentations of programs, interviews with participants and actors who have implemented the programs, institutional videos, and internal and external presentations on Ruta N and Medellín.

Data Analysis Procedures. The data analysis consists of examining, categorizing, tabulating, testing, and recombining evidence in order to "produce empirically based findings" (Yin, 2013, p. 132). The data has been analyzed relying on the conceptual framework developed in the literature review. The analysis has involved a three-step process, which has involved analyzing data from multiple data collection methods. First, the analysis involved the full gathering and multiple scanning of the data. Second, the data was analyzed deductively according to the conceptual framework developed from the literature review on the technological catch-up process. Third, the data was analyzed inductively through pattern recognitions to increase the level of details in the conceptual framework on how the regional innovation agency supported new industrial path development and promoted regional structural change in the economy to transform Medellín into a knowledge city. The analysis has relied on the researcher competency to

analyze a large amount of data through pattern recognition. In other words, the researcher's ability "to see patterns in seemingly random information" (Boyatzis, 1998, p. 7). The analysis tried to respect Merriam's (1988) suggestion on the balance between the amount of description (two-thirds) in the case study versus the amount of analysis and interpretation (one-third).

In the first step, the data was collected from multiple sources of data collection. The different sources of information that have been collected—interviews, observations, documents, audiovisual materials—were, if already not, typed down. The data was then scanned multiple times for two reasons. First, the researcher has aimed to be acquainted with the data to retrieved them easily. Second, it facilitated the second and third step of the analysis in finding patterns and emerging patterns that could be categorized to be further analyzed.

In the second step, the data was analyzed in a deductive manner to answer the research question on how the regional innovation agency supported new industrial path development in Medellín. The researcher had to develop codes and categories to build convergence and to find what fitted together. The recurring patterns have to be judged on two criteria: internal homogeneity and external heterogeneity (Patton, 2015). The first criterion concerns "the extent to which the data that belong in a certain category hold together in a meaningful way. The second criterion concerns the extent to which differences among categories are bold and clear" (Patton, 2015, p. 467). The deductive analysis aims first and foremost to deepen and to verify existing theories (Patton, 2015).

In the third step, the researcher identified patterns that Ruta N used through programs and overall strategies to support new industrial path development and technological catch-up. The patterns exist but have remained unperceived by the organization. As a result, "one way of testing analyst-constructed typologies is to present them to people whose world is being analyzed to find out if the constructions make sense to them" (Patton, 2015, p. 459). The emerging patterns served to upgrade the conceptual framework. Frameworks encompass many variables and seek to capture the broad complexity of a phenomenon (Porter, 1991). In the conceptualization of a framework, the researcher will first, identify the relevant variables that affect the research question's outcomes to develop conclusions for the specific case.

The framework was built from a qualitative approach since mathematical models to generate theories have two limitations. First, they are situation-specific models of limited complexity that are only valid under the model's assumptions (Porter, 1991). Second, the numerous models cannot be integrated into a general framework for approaching any situation since they most often rely on a different set of assumptions (Porter, 1991). Mathematical models, however, have dominated economics theories since they provide clear and scientific-like conclusions (Porter, 1991). As a result, frameworks from qualitative research can generate theories that can be useful for both knowledge and practice. Additionally, the framework aims to be dynamic in that new variables can be incorporated to improve the framework predictive outcomes. Consecutively, frameworks should challenge existing models "by highlighting omitted variables, the diversity of competitive situations, the range of actual strategy choices, and the extent to which important parameters are not fixed but continually in flux" (Porter, 1991).

3.2.3. Strategies for Validating Findings.

Scientific knowledge is obtained through reliability and validity. In a qualitative study, reliability refers to "the stability of responses to multiple coders of data sets" (Creswell, 2013, p. 253). Reliability is achieved when the same results are obtained if the researcher follows the same procedures (de Vaus, 2001). Validity is obtained when internal, external, and construct validities are respected. Internal validity refers to the extent to which the case is a real-world demonstration of what it aims to demonstrate. External validity refers to the extent to which generalizations can be made beyond the specific case. Construct validity refers to how well the framework represents a real-world situation that is intended to model.

The internal validity is achieved through prolonged engagement, persistent observation, and triangulation in order to "assure that the right information and interpretations have been obtained" (Stake, 2013, p. 36). Indeed, the triangulation has systematically been conducted between four sources of information—interviews, observations, documents, and audiovisual materials—from actors with different interests and/or frames of thinking about the research question to verify or to contradict responses. Triangulation "is expected to lead either to confirmation that the observation means that we think it means or to ideas about how the observation would be interpreted differently by different people" (Stake, 2013, p. 36). The external validity is achieved through the rich description and contextual elements that allow the readers to make decisions regarding transferability (Patton, 2015). The context-rich descriptions allow the readers to determine whether the findings can be transferred "because of shared characteristics" (Erlandson et al., 1993, p. 32). The construct validity is achieved through the use of multiple sources of evidence in a manner encouraging convergent lines of inquiry (Eisenhardt, 1989; Yin, 2013). Additionally, validity is achieved through the participants' checking. The researcher solicited interviewees to evaluate the validity of the findings and interpretations during his second field trip in July to September 2018 (Lincoln & Guba, 1985; Merriam, 1988). The interviewees were asked to examine the conceptual framework to provide "critical observations or alternative interpretations" (Stake, 1995, p. 115). This technique is for Lincoln and Guba (1985), the "most critical technique for establishing credibility" (p. 314).

3.2.4. Audience.

The audience for this research includes academics, policymakers, practitioners, and the researcher's advisors and thesis committee. The writing style has been adapted to be accessible to a large audience. As pointed out by Schramm (1971), case studies intend primarily to contribute to policy and decision-making rather than to science. This research aims to contribute to policymaking by giving recommendations to design a regional innovation agency and to advance scientific knowledge by showing the importance of the entrepreneurial region in the technological catch-up process. The research will be of interest for academics in evolutionary and institutional economics, regional economic development, and regional innovation studies. The research will primarily be interesting for policymakers in regions on the knowledge periphery around the world, most notably in Southern Europe, Eastern Europe, Central Asia, Southeast Asia, Africa, and Latin America. Moreover, the research will be interesting for Ruta N employees and the actors in the Medellín's regional innovation system.

3.2.5. Limitations, Challenges, and Ethical Issues.

The main limitation of the research is that the answer to the research question is based on a single case study. Multiple case studies are preferred to single case study since it allows the researcher to examine how different regional innovation agencies "perform in different environments" (Stake, 2013, p. 23). The individual case has been selected due to its uniqueness in underlying issues that are internationally important for local and regional economic development in terms of policy and theory-making. The second limitation is that it involves the researcher, who in any social situations, needs to deal with his own impressions as well as those of others. It is thus important to have an assurance to be sure to not oversimplifying the context and the situation.

The main challenges that the researcher faced were related to the cultural dimension in Colombia and Medellín, and the context of doing field-work and of conducting research in a developing country. The Colombian culture is overly optimistic and tends to negate failures. For instance, the Colombian authorities and leaders, especially from Medellín, boasted that Hewlett-Packard and Kimberley-Clark came to Medellín thanks to the city's unique assets but put the entire blame on Hewlett-Packard and Kimberley-Clark for leaving the city. For Ruta N employees, it means not to take responsibility or acknowledge programs, management, and resources that have failed, and to only speak about success stories. The author is from France and has mostly lived in developed countries, which have very different contexts from that of a developing country like Colombia. The researcher has, however, spent more than one year working in Colombia, from May 2013 to August 2013, from April 2014 to November 2014, from June 2017 to September 2017, and from July to September 2018, which has allowed him to understand cultural differences and adapt the interviews to the cultural context. Moreover, although the author is fluent in Spanish, the author's maternal tongue is French. In order to significantly reduce misinterpretations, the interviews were audiotaped and then transcribed.

There is no ethical issue in the research conducted. For each interview, the interviews were conducted after receiving consent from the interviewees. Moreover, the researcher conducted the research independently thanks to his Horizon 2020-Marie Skłodowska-Curie scholarship and own resources. The researcher was never offered or promised to be offered any pecuniary or non-pecuniary benefits by the organizations and/or the actors studied in this thesis.

4. Case Study – Ruta N Medellín.

4.1. The Country Context – Colombia.

Map 1. Map of Latin America and Colombia. Source: own design.

Introduction. Colombia is a country in South America, which is a continent that has experienced periods of economic volatilities and political instabilities. South America's instabilities are the outcome of the region's heavy reliance on extraction and exportation of its raw materials resulting from the institutional legacies put in place by former colonizing countries, namely Spain and Portugal (Acemoglu & Robinson, 2012; Bértola & Ocampo, 2012). For the last two centuries, the continent's GDP per capita has fluctuated around the world average (Bértola & Ocampo, 2012). Colombia's capital city is Bogotá. The country has a total area of 1,141,748 km^2 and shares a border with Brazil, Ecuador, Panama, Peru, and Venezuela. The country has a rich biodiversity with a territory that contains the Amazon rainforest, the Andes mountain range, and the Caribbean and Pacific Coastlines. Colombia is the second most populous country in South America with 49,834,240 inhabitants, after Brazil, 207,652,865 inhabitants, but in front of Argentina, 43,847,340 inhabitants (DANE, 2018a). The three largest cities are, Bogotá with 7,878,783 inhabitants, Medellín with 2,464,322 inhabitants, and Cali with 2,369,821 inhabitants (DANE, 2018a). As of 2016, Colombia has the third largest GDP in South America, current GDP of USD $282 billion or USD $5,805 per capita, after Brazil, current GDP of USD $1,796 billion or USD $8,649 per capita, and Argentina, current GDP of USD $545 billion or USD $12,440 per capita (World Bank, 2018).

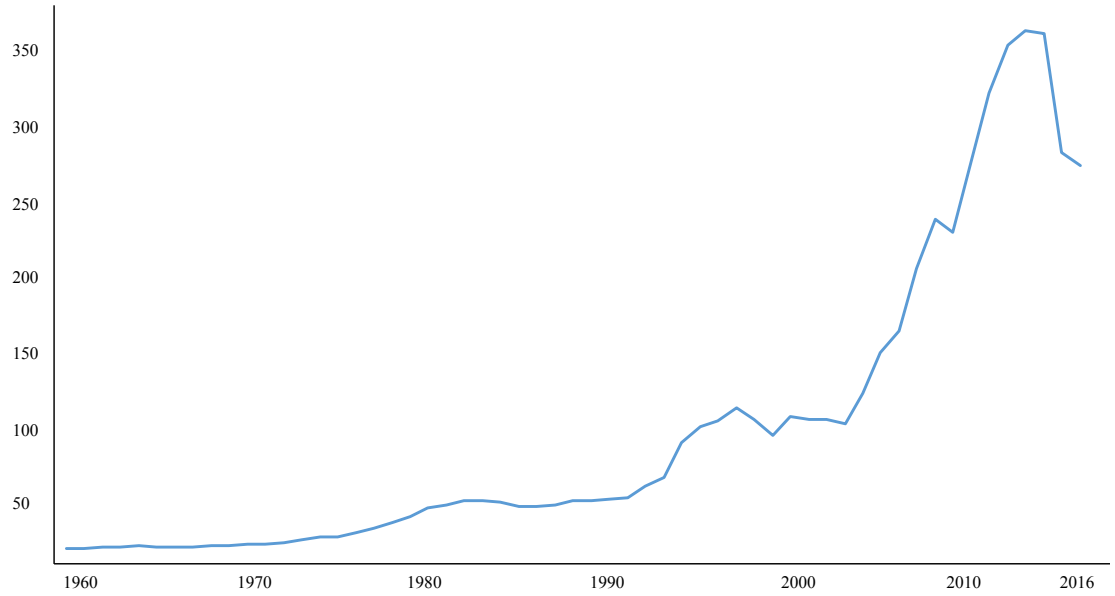


Figure 6. Colombian GDP in Current USD Billion from 1960 to 2016. Source: World Bank (2018).

4.1.1. The Construction of the Nation State (1810-1903).

After Colombia's independence from the Spanish Empire on July 20, 1810, to the end of the 19th century, Colombia went through a period of construction of its nation-state (Caballero Argáez, 2016). The construction of the nation-state was marked by the confrontations between two political parties, the Liberal versus the Conservative, and between two visions for the nascent Colombian nation, centralism versus federalism (Maclean, 2014; Perdomo, 1981; Piedrahita Echeverri, 1988). During the construction period of the nation-state, Colombia's economic development was stagnant. Indeed, from 1800 to 1905, the GDP grew at an average rate of only 1.7% per year, a rate comparable to the population growth (Kalmanovitz & López, 2006). Moreover, the internal market was not integrated since Colombia consisted of small local markets that were geographically separated and isolated due to the country's topographic idiosyncrasy (Caballero Argáez, 2016).

In the mid-19th century, the liberal government initiated bold socio-economic reforms. The most important reforms were the expulsion of the Jesuits, the separation of the Church and the State, the introduction of the civil marriage and divorce, the privatization of education, and the abolition of slavery (Caballero Argáez, 2016). The 1853 Constitution promulgated two fundamental liberal reforms: the universal suffrage granted to all adult males and the introduction of the federal political and administrative system (Caballero Argáez, 2016). The federal Constitution of Rionegro adopted in 1863 renamed Colombia, the United States of Colombia (Caballero Argáez, 2016). The conservative party violently opposed the reforms and Constitutions introduced by the liberal party (Caballero Argáez, 2016). In the 1860s and all the way through the 1880s, social unrests and conflicts between the liberal and conservative parties were numerous (Caballero Argáez, 2016). The state, due to its federal nature, was weak in dealing with the political and social unrest. The 1886 Constitution was adopted to end the period of instability by profoundly reinforcing the centralized nature of the Colombian state

(Caballero Argáez, 2016; Piedrahita Echeverri, 1988). The 1886 Constitution reintroduced the role of the Catholic Church as the main regulator of the social life, the strong role of the president who could directly appoint and dismiss mayors and governors, and revoked liberal reforms (Caballero Argáez, 2016). The Colombian Constitution of 1886 led to a concentration of power that resulted in an inefficient and rigid state with limited political legitimacy (Ramírez Moreno, 2006). The confrontation between the two parties culminated in the Thousand Days War (1899-1902) after the conservative political party had imposed their Constitution in 1886 (Arias Trujillo, 2011). The inability of the central state to negotiate with the United States for the concession of the Panama Canal led to the separation of Panama in 1903 (Caballero Argáez, 2016). At the end of the Thousand Days War, President Reyes (1904-1909) introduced a range of industrial policies, such as an increased in tariffs for final goods and government subsidies to initiate the process of industrialization and to end political unrests (Caballero Argáez, 2016). The industrialization was made possible thanks to coffee exportation that rapidly expanded in the 1880s (Caballero Argáez, 2016). Indeed, the economic surplus from coffee exportation allowed the state to overcome fiscal crises that affected the country for most of the 19th century. The coffee exportation allowed the "diversification of the economy" and to support the "nascent industrial development" (Arias Trujillo, 2011, p. 15).

4.1.2. The State in Conflict (1903-1991).

In the 20th century, the Colombian economy went through three shocks that favored the emergence of three economic periods: the loss of Panama in 1903 after the Thousand Days War; the great depression in 1929-1932; the economic opening in 1989-1991 as a consequence of globalization and the collapse of the USSR (Caballero Argáez, 2016). Colombia's economic development was concurrent with one of the most violent civil wars in the history of the world, *La Violencia*, which mutated into the Colombian's internal conflict (Arias Trujillo, 2011).

The acceleration of Colombia's industrialization was caused by: the expansion of the coffee production and exportation between 1905 and 1929, which resulted in the formation of an internal market for manufactured goods; the creation in the beginning of the 20th century of light manufacturing companies; and the adoption of protectionist macroeconomic policies (Caballero Argáez, 2016). Coffee exports experienced a rapid growth between 1905 and 1930. Indeed, coffee production multiplied by six, from 500,000 to 3,000,000 bags a year; and during the same period, Colombia's GDP multiplied by three (Caballero Argáez, 2016). The industrial dynamics depended much on the foreign currency exchange reserve, and as a result, on coffee exports, which represented up to 80 percent of the total Colombian exports in the 1950s (Caballero Argáez, 2016). From 1930 to 1990, the international coffee prices determined the internal business cycles of the Colombian economy, both in its long-run economic development and in its short-term economic development due to the volatility of the coffee prices (Caballero Argáez, 2016). Coffee was the engine of internal demand and foreign currency exchange reserve (Caballero Argáez, 2016). During the Great Depression (1929-1932), the national government adopted highly protectionist trade barriers and tariffs as well as a series of public work projects to overcome the economic crisis, which created the conditions for the consolidation of the coffee and industrial sectors (Caballero Argáez, 2016; Restrepo Uribe, 1981).

World War I, World War II and the Great Depression demonstrated the limitations of the agro-export model and the importance for Colombia to develop a strong industrial sector. In Latin America, the export sector was limited to raw materials, and in the case of Colombia, to coffee exports. Indeed, between and 1940 and 1970, coffee represented more than 70% of all Colombian exports (Restrepo Santamaria, 2011). In the 1950s, the national government adopted import-substitution and protectionist policies as a national development strategy, which coincided with the peak in power of the industrial elite (Caballero Argáez, 2016, p. 20). Industrial production grew at a very high rate between 1945 and 1955 (Caballero Argáez, 2016). In the 1950s, the share of the industrial sector in the economy was higher in Colombia than in any other Latin American countries (Caballero Argáez, 2016). The import-substitution model, which was pushed by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), ultimately created, however, an uncompetitive industrial export sector.

The industrial and coffee sectors have largely determined the Colombian economic policies implemented between 1930 to 1990 (Caballero Argáez, 2016). The macroeconomic policies were greatly influenced by two associations: the National Federation of Coffee Growers (FedeCafé) founded in Medellín in 1927 and the National Association of Industrialists (ANDI) founded in Medellín in 1944 (Caballero Argáez, 2016). The ANDI was created in response to the suggestion made by President Alfonso Lopez Pumarejo (1942-1946) who proposed to only have one industrial representative from Antioquia to consult with the national government (Caballero Argáez, 2016). The macroeconomic policies promoted by the ANDI and FedeCafé did not only favor the industrial and coffee sectors but also contributed to the delay in the development of other economic sectors (Caballero Argáez, 2016).

In 1930, after 50 years of conservative governments, the Liberal Party managed to return to power, partly due to internal disagreements within the Conservative Party. The Liberal Party remained in power from 1930 to 1946 (Arias Trujillo, 2011). In 1946, the Conservative Party won back the Presidential election and tensions between Liberals and Conservative reemerged. The tensions took a dramatic turn with the assassination of the liberal party presidential candidate Jorge Eliécer Gaitán in 1948, which officially marked the beginning of *La Violencia* (Arias Trujillo, 2011; Caballero Argáez, 2016). The period known as *La Violencia* was extremely complex in that it involved many different actors who had widely diverse motivations (Arias Trujillo, 2011). Indeed, *La Violencia* involved a class conflict, religious persecutions, criminal organizations, State violence, and a conflict between Liberals and Conservatives (Arias Trujillo, 2011). In 1953, General Gustavo Rojas Pinilla staged a military coup to put an end to *La Violencia*, which led the Liberal and Conservative party to enter into an agreement in 1958, known as *El Frente Nacional*, to alternate in the political office (Arias Trujillo, 2011). The political elites from the Liberal or Conservative parties were able through *El Frente Nacional* to retain the political power for themselves, a tactic frequently used between elite groups in Colombia to protect themselves from external threats (Maclean, 2014). *El Frente Nacional,* however, did not end the violence. Indeed, the agreement *La Frente Nacional* was the catalyst for the creation of left-insurrectionary militias, such as the *Ejército de Liberación Nacional* (ELN) and the *Fuerzas Armadas Revolucionarias de Colombia—Ejército del Pueblo* (FARC–EP) in 1964 (Restrepo Santamaria, 2011). The internal conflict reemerged through new actors, first, came the left-insurrectionary guerrillas in the 1960s, then, the narco-traffickers in the late 1970s, and finally, the paramilitaries in the late 1980s. The internal conflict was fueled with drug money that deeply penetrated

all the layers of the Colombian society, from politicians and farmers to guerrilla fighters and bankers (Arias Trujillo, 2011). In order to deal with the extreme level of violence and internal conflict, the State had to formulate a "new social contract" in which the paramilitaries were supported by the most authoritarian actors within the State (Arias Trujillo, 2011, p. 118). Political and economic elites, particularly landowners and agro-industrialists, tacitly supported the creation of self-defense groups to stop left-wing guerrilla groups from extorting local businesses (Amnesty International, 2005). From 1958 to 2012, the Colombian conflict claimed the lives of at least 220,000 people, 81.5 % of whose were civilians (Grupo de Memoria Histórica, 2016). Since 1958, around 5 million people have been internally-displaced (Grupo de Memoria Histórica, 2016). The peak of violence was reached during 1988 and 1989 when Pablo Escobar and other narco-traffickers pressured the State to end the extradition treaty between Colombia and the United States (Arias Trujillo, 2011). During the 1990 presidential campaign, three candidates were assassinated (Caballero Argáez, 2016).

The internal conflict and the Latin American debt crisis in the 1980s forced the political elites to adopt political and economic structural reforms. As for many other Latin American countries, the economic reforms that Colombia introduced in the 1980s were pushed by multilateral development banks, namely the International Monetary Fund (IMF), as a prior condition for applying to international credit loans (Restrepo Santamaria, 2011). The reforms ended protectionism, redefined the role of the State, introduced flexible labor laws, and eliminated State monopolies (Restrepo Santamaria, 2011). In addition to economic reforms, the State started to discuss political and social reforms. The internal conflict challenged the legitimacy of the State. President Belisario Betancur (1982-1986) was the first President to recognize that the left-insurrectionary guerrillas had legitimate combats, such as fighting for social justice and against political exclusion (Arias Trujillo, 2011). Betancur's (1982-1986) peace process initiative included negotiation, social reforms, and opening up the political space (Arias Trujillo, 2011). In 1988, mayors were for the first time elected through the universal suffrage and not appointed through presidential decree (Martin, 2012; Moncada, 2016). The political reforms initiated in the 1980s paved the way to the introduction of a new Constitution.

4.1.3. The Modern State (1991-present).

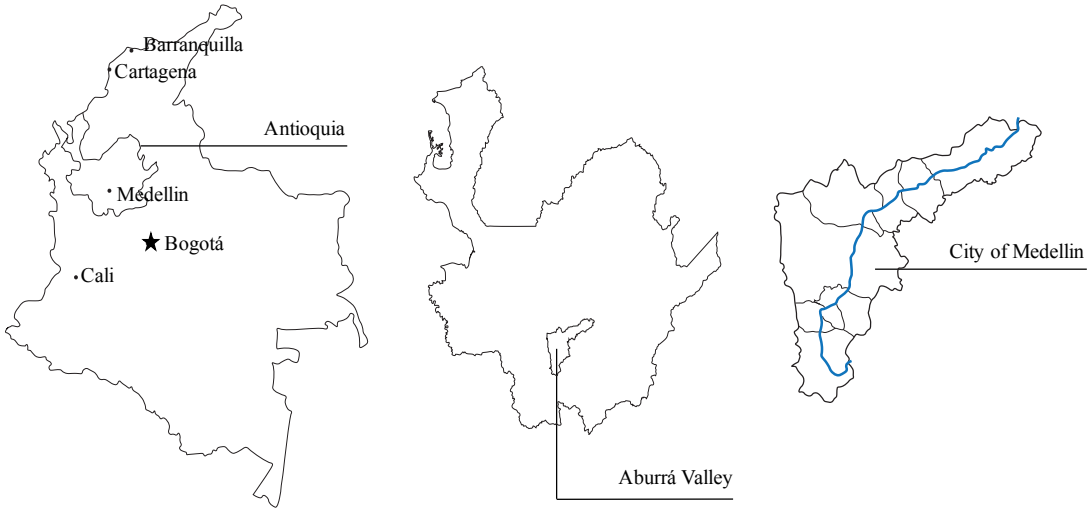
In the 1990s, Colombia engaged itself in a structural institutional and economic transformation. The transformations led to the creation of modern Colombia. In the late 1980s and early 1990s, President Virgilio Barco Vargas (1986-1990) and President César Gaviria Trujillo (1990-1994) initiated the process of "Colombia's economic opening" (Restrepo, 2000). The economic reforms included reforms in international trades, foreign direct investment, taxation, labor, and privatization, that were greatly influenced by "Washington Consensus" economic policies (Restrepo, 2000). In 1991, tariffs were decreased from 50% to 15% and many non-tariff barriers were eliminated (Caballero Argáez, 2016; Restrepo Santamaria, 2011). The economic reforms were opposed by the industrial and agricultural sectors but welcomed in the financial and service sectors (Franco Restrepo, 2006; Restrepo Santamaria, 2011). On July 4, 1991, President César Gaviria Trujillo (1990-1994) signed the new Constitution that replaced the political Constitution of 1886 and became the symbol of "Colombia's economic opening" (Restrepo, 2000). The 1991 Constitution is a democratic milestone since it redistributed power between the executive and the judiciary, guaranteed social rights to minority groups, limited traditional power structures, decentralized some economic and fiscal

authorities to regions and municipalities, and encouraged participatory democracy and social inclusion (Palacios, 2006). The article 1 of the 1991 Constitution states that "Colombia is a social state under the rule of law, organized in the form of a unitary republic, decentralized, with autonomy of its territorial units, democratic, participatory, and pluralistic, based on the respect of human dignity, the work and solidarity of the individuals who belong to it, and the prevalence of the general interest" (Senado de la República, 1991). The 1991 Constitution led the guerrillas to reassess the legitimacy of their armed struggle (Arias Trujillo, 2011). Additionally, the 1991 constitution promoted administrative decentralization with four territorial entities: departments, districts, municipalities, and indigenous territories (Senado de la República, 1991). The territorial entities are responsible for the development of their own territories. The Constitution also introduced two instruments of municipal strategic planning, namely, the Municipal Development Plan in 1994 and the Territorial Organizational Planning in 1997 (Senado de la República, 1991).

The Colombian Constitution of 1991 also deferred to regions some authority to design and to implement Science, Technology, and Innovation (STI) policies (Sánchez Mejía, 2011). The Law 29 of 1990 in Science and Technology promotes the organization of a Science and Technology Strategic National System led by the National Council and the Technical Secretariat Colciencias (Sánchez Mejía, 2011). In the 1990s, Colciencias recognized the importance of regions in participating and in coordinating the National System of Science and Technology (Sánchez Mejía, 2011). In 2011, the General System of Royalties was created through the Legislative Act 05 amending the articles 360 and 361 of the Constitution. The General System of Royalties is a mechanism to redistribute the State revenues from the exploitation of non-renewable resources to finance strategic projects in STI in Colombia. 10% of the General System of Royalties are distributed between the Colombian regions in order to finance projects in Science, Technology, and Innovation (STI) at the regional level through the Science, Technology and Innovation Fund (STIF). The purpose of the fund is to strengthen the region's capacities in STI as well as to contribute to social and economic equity between regions and to regional competitiveness. The General System of Royalties was created, as an instrument that promoted administrative decentralization with the National Science, Technology and Innovation System (Suárez Cepeda, 2016).

In the 1990s, the government of Colombia engaged in controversial methods to end the internal conflict. In 1993, Decree 2535 authorized civilians to use military weapons (Amnesty International, 2005). In 1994, Decree 356 authorized the creation of legal paramilitary structures, the *Servicios Especiales de Vigilancia y Seguriadad Privada*, also known as CONVIVIR, to maintain control over guerrillas' activity zones (Amnesty International, 2005). The controversial government of Alvaro Uribe (2002-2010) had a mandate to restore security in the country and to defeat the guerrilla groups. *Plan Colombia,* a United States foreign aid, military, and diplomatic programs, allowed the Colombian State to have near unlimited resources to fight left-insurrectionary guerrillas (Arias Trujillo, 2011). For Uribe's supporters, who constitute a large majority of Colombians, Uribe has allowed Colombia to enter an era of peace, competitiveness, and confidence (Arias Trujillo, 2011). The government of Juan Manuel Santos (2010-2018) succeeded to sign a peace deal on November 24, 2016, with the *FARC-EP* paving the way to the end of the Colombian internal conflict.

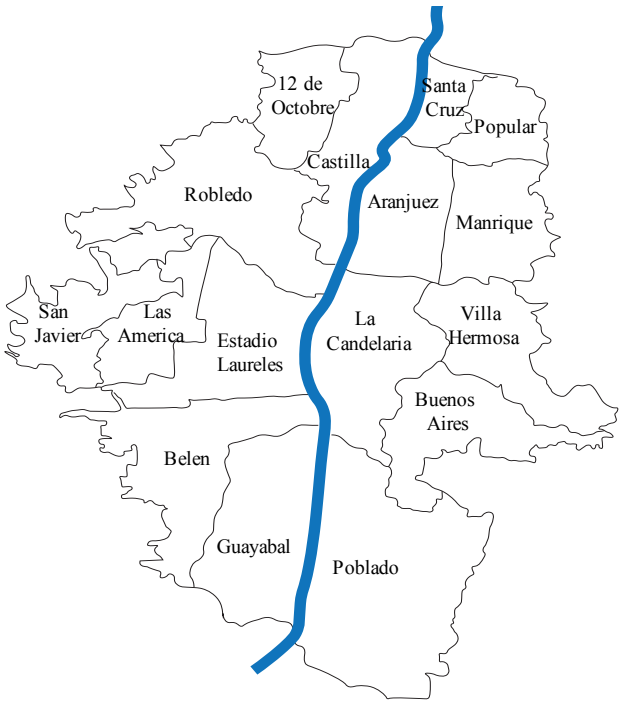
4.2. The City Context – Medellín.



Map 2. Maps of Colombia, Antioquia, and Aburrá Valley. Source: own design.

Medellín – Introduction. The dazzling landscapes of Medellín and its heavenly climate have caused the admiration of foreign travelers, such as Carl August Gosselman (1826) and the geographer Manuel Uribe Angel (1895) (Hermelin, 1996). In 1825, the French geologist and mineralogist Juan Bautista visited Medellín and reported in his writings that "if Paris did not exist, I would decide to live in Medellín" (as cited in Ortiz Mesa, 1996, p. 289). The city of Medellín was founded in 1616 after the Spanish conquerors led by Jorge Robledo discovered the Aburrá Valley on August 23, 1541 (Alvarez, 1996, p 57). The people from the region of Antioquia are commonly known as *Paisa*, who are proud of their distinct culture, especially from the capital city Bogotá.

The city of Medellín is located in the Aburrá Valley in the midst of the Andes mountain range. The valley is approximately 7 kilometers wide and 30 kilometers long with a total area of 1,157 km^2 (Hermelin, 1996). At the center of the valley is the Medellín River, which receives its water from a multitude of streams. The urban center is at an altitude ranging from 1,400 to 1,800 meters above sea level surrounded by mountains that peak above 3,000 meters above sea level (Hermelin, 1996). The altitude at which the urban center lies and its closeness to the Earth's equator create unique climatic conditions. The climate is stable all year long with daily temperatures ranging from 18 to 26 degrees Celsius and average annual precipitation of 1,500 mm (Hermelin, 1996). The city of Medellín is the capital and the largest urban center in the department of Antioquia. In 2015, the population was of 2,464,322 inhabitants in Medellín and 3,777,009 inhabitants in the Aburrá Valley (City of Medellín, 2018). The city of Medellín is part of the Aburrá Valley Metropolitan Area, including the cities of Itagui, La Sabaneta, La Estrella, Caldas, Bello, Copacabana, Girardota, Barbosa, Medellín, and Envigado (Jaramillo, 2015). The city of Medellín is divided into 16 comunas; they are: Popular, Santa Cruz, Manrique, Aranjuez, Castilla, 12 de Octobre, Robledo, Villa Hermosa, Buenos Aires, La Candelaria, Laureles-Estadio, Las Américas, San Javier, El Poblado, Guayabal, and Belén.



Map 3. Map of Medellín and Communes. Source: own design.

4.2.1. The Mining City (1826-1904).

During the Spanish colonial period (1616-1810), Medellín was a small town that had no political or economic importance. In the first census conducted in Medellín on October 19, 1675, there were 221 families, ethnically distributed as followed: 45% mixed race (black and white), 23% mestizo (American Indian and white), 18% white, and 13% American Indians (Alvarez, 1996, p. 57). In the 18th century, immigrants to Antioquia and to Medellín were mostly composed of Andalusian, Basque, and Extramaduran (Restrepo Santamaria, 2011). The discovery and exploration of gold in the region and its designation as the capital of the province of Antioquia in 1826 provoked the city's economic development (Molina Londoño, 1996; Restrepo Uribe, 1981).

The mining sector was the main economic activity in the region until the end of the 19th century. The gold production doubled between 1750 and 1779 and then quadrupled between 1780 and 1880 (González Escobar, 2007, p. 14). The mining boom was accompanied by a thriving agricultural economy, namely sugar cane, coffee, and cocoa, and growing internal demand for manufacturing goods (Molina Londoño, 1996). The expansion of the agricultural and mining sector led the mining and political elites to invest in large infrastructure projects, such as the railroad (1874-1914), the Telegraph (1867), and bridges over the Cauca river in Jerico (1881) and Santa Fe de Antioquia (1895) in order to connect Medellín with international trade routes (Molina Londoño, 1996). Between 1820 and 1880, the mining sector favored the emergence of a business elite and commercial activities, first with Jamaica and then with Europe (González Escobar, 2007). In 1870, Charles Saffray, a French Botanist, reported that in Medellín "there was no export trade since the city only had gold, which was sent abroad to import large quantities of merchandises, such as irons and cotton from England; hardware, toys, and matches from Germany; fabrics from Switzerland; footwear, clothes, hats from

Spain; and medicines from France" (as cited in Caballero Argáez, 2016, p. 59). By 1870, Medellín was the second largest city in the country with 29,795 inhabitants, after Bogotá with 40,883 inhabitants (Alvarez, 1996).

The mining elite realized that an increased in mining productivity, and thus profitability, could be achieved by the introduction of technological innovations from abroad (González Escobar, 2007, p. 32). In the 1820s, engineers like Carlos Segismundo de Greiff or Tyrrel Moore and technicians like Enrique Hauesler and Julian Jones came to Medellín to work in the mining sector. In his book, *Immigrant Engineers and Scientists in Colombia 1760-1950*, Poveda Ramos (2011) shows the importance of foreign engineers, most notably from England, Germany, Sweden, and France, in diffusing knowledge, especially in the mining sector, in Colombia, namely in Medellín. Poveda Ramos (2011, p. 255) points out that almost all important innovations in the mining sectors in Colombia, except for the Antioquia mill, were brought or invented by foreign engineers. In 1898, another French explorer Pierre d'Espagnat stated: "Medellín is the center of the gold region, it is where mining businesses, gold ingots, and mining reports converge" (as cited in Alvarez, 1996, p. 77).

From 1880, coffee exploitation and production became the main economic activity of the Antioquia economy since the region not only has the best climate to produce coffee but also high-quality volcanic soils (Restrepo Santamaria, 2011). Coffee and mining were the two most important determinants of Medellín's industrialization. Indeed, coffee and mining were the connection between agriculture and industry that allowed Medellín to branch into new industrial activities. The expansion of coffee production generated a strong internal demand for agricultural machinery and for intermediary goods (Restrepo Santamaria, 2011, p. 20). Moreover, the mining and agricultural sectors fostered the development of workshops and steel and iron foundries that would later pave the way for the process of industrialization.

The rapid economic development had critical cultural repercussions on the inhabitants of Medellín who were, as pointed out by José Manuel Restrepo, culturally backward and spent their time engaging in "disputes to know whether Medellín was better than Rionegro" (as cited in González Escobar, 2007, p. 16). The economic elite founded on February 9, 1898, the *Sociedad de Mejoras Públicas* (SMP) to merge their pragmatic conception of the State and politics with their concerns for public affairs (Botero Herrera, 1996; García Estrada, 1999). The elite's vision led to strong interconnections between the SMP and the Medellín's City Council (Botero Herrera, 1996). The SMP not only performed public duties but also was an instrument to channel the elite's visions in the realization of public works (Botero Herrera, 1996). The SMP and the municipal administration were interrelated in such a way, that the distinction between the private and public sector was blurred (Botero Herrera, 1996). The SMP participated in providing telephone services; in creating the Botanical Gardens, the Fine Arts school, the Antioquia Museum, the Zoological parks, the Nutibara hotel, the Pablo Tobón Uribe Theater; and in financing the canalization of the Medellín River and the urban planning with the Master Plan for Medellín (García Estrada, 1999). The SMP would later be merged with other utility companies to become in 1955 the *Empresas Públicas de Medellín* (EPM) (see 5.1.3. The *Empresas Públicas de Medellín*). By 1891, George Brisson observed that Medellín had a University, an art school, a museum, a public library, covered marketplaces, a new cathedral, and parks (as cited in Alvarez, 1996, p. 77). The elite ethos was, however, extremely conservative focusing on family, work, and Catholicism.

Wealth and power were maintained through inbreeding and marriages of convenience (Caballero Argáez, 2016, p. 61).

At the end of the 19th century, Januario Henao Álvarez, Antioquia Secretary of the Treasury and the first Secretary of the Chamber of Commerce of Medellín, pointed out the importance develop a local industry to limit the city's reliance on imports (Molina Londoño, 1996, p. 221). Antioquia's economy went through a deep structural crisis that reached bottom in 1904 with the bankruptcy of the public sector (Molina Londoño, 1996, p. 212). The crisis was a determining factor for the political and business elites to initiate the process of Medellín's industrialization (Molina Londoño, 1996).

4.2.2. The Industrial City (1904-1981).

In Medellín, the process of industrialization underwent four stages. In the first stage (1904-1929), the protectionist policies that were put in place in 1904, the rapid growth in coffee exports, the entrepreneurial economic elites with their Calvinist ethos, and the accumulated industrial knowledge related to mining, allowed Medellín to develop a light manufacturing and durable consumer industry, such as textile, soft drinks, beers, cigarettes, and household appliances (Tamayo, 2016; Valencia Restrepo, 1996). In 1904, the soft drinks company Posada Tobon, Postobón, was founded. In 1905, Medellín hosted the first industrial exhibition in Colombia (Poveda Ramos, 1996). In 1907, the textile company Coltejer was founded. The engine of industrialization was the coffee exportation, which created a robust internal demand for industrial machinery and allowed the economic surplus to be reinvested in supporting the infant industries (Caballero Argáez, 2016; Poveda Ramos, 1996). By 1920, Medellín was the most important industrial city in Colombia (Caballero Argáez, 2016).

In the second stage (1929-1945), the industrial diversification was motivated due to the shortages from importing essential goods from Europe and the United States during the first and second World Wars (Valencia Restrepo, 1996, p. 475). Industrial growth was also stimulated by large government projects that were undertaken during the Great Depression (1929-1932). In 1932, the national government undertook the construction of large infrastructure projects, such as the Oyala Herrera Airport in Medellín, the hydroelectric dam in Guadalupe, and other large transportation infrastructures (Poveda Ramos, 1996, p. 320). From 1935, the destination of most industrial machinery importation was Medellín (Poveda Ramos, 1996). Between 1934 and 1945, the annual average industrial growth was between 7 and 8 percent (Poveda Ramos, 1996). In the 1930s, industries in Medellín started to produce intermediary goods, such as chemical products, ceramics, cement, glass, paper, machinery, and electronics (Poveda Ramos, 1996; Valencia Restrepo, 1996). From the industrial development also emerged a strong financial sector (Valencia Restrepo, 1996).

In the third stage (1945-1973), Medellín was an industrial powerhouse. The industrial sector greatly benefited from import-substitution and protectionist policies that were put in place after World War II. The economy grew between 1945 and 1956 at an average annual growth rate of 11% (Valencia Restrepo, 1996, p. 483). In 1967, Daniel Herrero, who investigated Medellín's industrial development between 1925 and 1965 pointed out that "Medellín is the Latin American's Manchester. The city has often been compared to São Paulo. The textile activity has constituted the driving force of the industrial development in the city" (as cited in Valencia Restrepo, 1996, p. 476). In the 1950s,

Medellín was producing up to 90 % of the Colombian textiles and ranked first in Latin America in terms of uses of textile machinery (Valencia Restrepo, 1996, p. 476). Life Magazine (1947) depicted Medellín in an article as a "capitalist paradise," where people are "devoutly Catholic." The industrialist families, such as the Restrepos and the Echeverrías, shaped a paternalistic working class ethos, for instance, the workers at the textile company Coltejer, "like thousands of others in the city, are docile, well-trained well cared for. The company offers bonuses, paid vacations, cheap housing, stock-investment plans, while at the same time paying high dividends and expanding plant facilities" (Life Magazine, 1947, p. 116). The textile factories offered to the working class "a respectable occupation under the patriarchal protection of family firms and the Catholic Church" (Hylton, 2007, p. 74). Medellín was relatively unaffected at the beginning of *La Violencia,* and benefited from it through displaced refugees to work in the growing industrial sector. The ANDI and the industrialist families painted the image of a city being "a peaceful oasis of capitalist productivity" thanks to the benevolence of its industrial elites (Hylton, 2007, p. 76). In 1954, the industrial elites created the *Caja de Compensación Familiar de Antioquia* (COMFAMA), a service delivery agency, to provide social benefits to its workers. Medellín however, attracted a large number of displaced people from the internal conflict and economic migrants in search of work and of a better life in the industries. The fast-growing population in the 1960s and 1970s led to the creation and expansion of informal settlements from which the local authorities responded with repression and evictions (Hylton, 2007; Jaramillo, 2015).

In the fourth stage (1973-1981), the industrial sector went through a deep structural crisis. In the late 1970s and early 1980s, the industrial sector in Medellín was confronted to the worst crisis in its history. The crisis was caused by both external and internal factors. The external factors can be summed up to, the recession in developed countries after the 1973 and the 1979 oil crisis; the decreased coffee prices on international markets; and the increased competition from the Four Asian Tiger Economies in the textile, automobile, and industrial sectors (Valencia Restrepo, 1996). The internal factors can be summed up to, the lower industrial sales; the low investments in industrial capacities; the low investments from the government in infrastructures, namely transportation infrastructures; the national macroeconomic policies, such as the protectionist policies; the smuggling due to protectionist policies; and the trade union's operations to sabotage or slow down production (Valencia Restrepo, 1996). The city was confronted at the same time to waves of internally displaced refugees and economic migrants looking for jobs in the industries. One of the main consequences of the industrial crisis was the inability of the city to absorb additional workers and the subsequent rise in unemployment and expansion of the informal settlements (Villa, 2007). Indeed, the city of Medellín has grown during its industrial stage at an exponential rate from 100,000 inhabitants in 1925 to 1,100,000 inhabitants in 1975 (Restrepo Uribe, 1981).

4.2.3. The Narco City (1981-2003).

For Maclean (2014), Medellín became a narco city due to: the inability of the industries to absorb the workforce fleeing the Colombian's internal conflict in the 1970s; the concentration and spatial distribution of poverty in some neighborhoods; the strategic position of the city in the cocaine's production and distribution routes; and its smuggling knowledge. From the narco city would emerge a complex and violent conflict involving non-State armed actors, such as the narco-traffickers, left-insurrectionary militias, criminal gangs, and paramilitary, and State actors (Maclean, 2014). The informal

settlements on the hillside of the city were the recruitment ground and the battleground of the conflicts between the different non-State armed actors. The narco-economy quickly expanded since it provided unheard off job opportunities and upward social mobility for the youth without prospects of education or waged work (Hylton, 2007). The extreme level of violence in Medellín from the late 1980s to the early 2000s has greatly damaged the city's image internationally. The social and cultural transformation in the 1970s that accompanied the transformation of Medellín into a narco-city were important. Indeed, Medellín was "the most conservative city in the most conservative country" in Latin America (Hylton, 2007, p. 71). The narco-city redefined the social and cultural contexts of Medellín. The new rich elites from narco-trafficking with their "glitzy tastes and violence" were in dramatic contrast with the "piety and conservatism" of the industrialists (Hylton, 2007, p. 78).

In the 1970s, Medellín was an important smuggling center—namely cigarettes and alcohol—from the duty-free zone of Panama to avoid high import tariffs resulting from protectionist policies (Hylton, 2007). Before becoming the Medellín Cartel kingpin, Pablo Escobar was fighting the Marlboro wars with rival criminal gangs to acquire the monopoly of the cigarettes' contraband (Hylton, 2007). In 1981, Pablo Escobar formed the *Muerte a Secuestradores* group, a death squad, to respond to the kidnapping by the M-19 guerrillas of Martha Nieves Ochoa (Amnesty International, 2005; Filippone, 1994). The group would later be known as the Medellín Cartel. Pablo Escobar, who once called himself Robin Hood, funded social programs to build soccer fields, churches, and even an entire neighborhood for the poorest inhabitants of Medellín, receiving, as a result, their sympathies (Lamb, 2010). At its peak in the late 1980s, the Medellín Cartel controlled 60 percent of the Colombian cocaine traffic and employed up to 120,000 people, including 2,000 to 3,000 in the United States (Filippone, 1994). The downfall of Pablo Escobar began when he was elected as deputy and was forced to resign of the Chamber of Representatives in 1982 (Hylton, 2007). The catalyst to stop Escobar, came, however, with the assassination of the presidential candidate Luis Carlos Galán in 1989 (Hylton, 2007). The Colombian government backed the Drug Enforcement Agency (DEA) demand for Escobar's extradition, which he responded with a campaign of bombings and targeted assassinations of pro-extraditionists, such as journalists, university professors, and judges as well as directly confronting the State with the assassination of 500 policemen between 1990 and 1991 (Hylton, 2007, p. 82). The search block, *Bloque de Búsqueda,* and the DEA finally killed Pablo Escobar on December 2, 1993 (Hylton, 2007).

In parallel to the narco-economy, left-insurrectionary militias and paramilitary groups emerged. The left-insurrectionary militias were formed to take control of failed-neighborhoods controlled by criminal gangs (Hylton, 2007). The FARC took control of *Comuna* 13, the M-19 of the Eastern *Comunas,* and the ELN of the Northeastern *Comunas*. The left-insurrectionary militias legitimized the use of violence due to the high rates of poverty and exclusion in Medellín (Maclean, 2014). These actors replaced the State in the failed-communities providing security and social services while at the same time reproducing the authoritarian methods that they fought against in the first place (Hylton, 2007; Maclean, 2014). With the expansion of the left-insurrectionary militias and the Medellín Cartel, right-wing paramilitaries and vigilant groups emerged. Diego Fernando Murillo Bejarano, also known as Don Berna, led the *Bloque Cacique Nutibara* (BCN), an important paramilitary organization in Medellín. Don Berna was a leading figure in the *Perseguidos por Pablo Escobar* (PEPES), a death squad to kill Pablo

Escobar, and *La Oficina de Envigado*, a drug cartel and criminal organization that took over the activities of the Medellín Cartel (Amnesty International, 2005). In the early 1990s, right-wing groups, such as *Amor por Medellín* or *Mano Negra*, were undertaking social cleansing in order to eliminate "undesirables", such as petty criminals, drug addicts, communists, and prostitutes from Medellín's streets (Restrepo, 1992). The left-insurrectionary militias were the highest enemies of the Colombian State, in front of the drug-cartels and the paramilitaries, leading the most authoritarian elements of the Colombian State to tacitly support the paramilitaries (Hylton, 2007). The conflict between and within non-State armed actors and the State in Medellín led to a period of extreme violence. In 1991, at the peak of violence, there were 381 homicides for 100,000 inhabitants in Medellín, that is almost 40 times higher than what the United Nations (UN) consider epidemic violence (Hylton, 2007). The violence would shake the foundations of the State. The industrial and political elites had a responsibility in the emergence of violence in the city due to their inability to create inclusive growth during the industrial period of prosperity (Maclean, 2014). In the late 1990s, 0.3 percent of the Colombian population controlled 60 percent of the productive land, 10 percent of the population held 58 percent of national income; and unemployment reached 20 percent (Avilés, 2006, p. 391). The political and business class also contributed to the violence through their clientelism and complicity with informal non-State actors, namely paramilitary groups (Maclean, 2014). From the 1970s to 2000, Franco Restrepo (2006) argues that there was a rupture between the political and economic elites in Medellín and Antioquia. The rupture caused an absence of political and territorial projects binding the elites together to promote regional development. The causes of this rupture are diverse, among which, the reorganization of regional industrial activities, the context of violence, the emergence of "narco-elite", and the changing political and power structures (Franco Restrepo, 2006).

In 1988, the Mayor of Medellín was, for the first time, elected through universal suffrage. Indeed, from 1948 to 1987, there were 49 different Mayors, averaging an office tenure of 10 months, which greatly hindered any long-term, or even short-term, planning (Alcaldía de Medellín & Banco Interamericano de Desarrollo, 2009). First, Mayors served a 2-year term, then a 3-year term, and since 2004, a 4-year term (Martin, 2012). The local government began to adopt transformative social, economic, and institutional policies. The program PRIMED started in 1993 as a pilot project between the City of Medellín, the governments of Colombia and Germany, and the United Nations Development Program (UNDP) to improve the quality of life of the residents in some of the poorest neighborhoods of the city through urban upgrading (Echeverri & Orsini, 2010). The *Empresa de Desarrollo Urbano* (EDU) was created in 1993 by the city to plan urban development and Territorial Organizational Plans. The Medellín Metro was in inaugurated in 1995 and is the only train-based public transit system in Colombia (Maclean, 2014). The participatory budget was first implemented by Mayor Juan Gómez Martínez in 1998. After a visit at the Guggenheim Museum in Spain, Mayor Luis Pérez (2001-2003) decided to build the first cable car line in Medellín in order to create "something emblematic" for Medellín (Martin, 2012). In 2002, Mayor Luis Pérez (2001-2003) created the *Asociación de Cooperación e Inversión en Medellín y Área Metropolitana* (ACI) with support from private companies, EPM, and the Metropolitan Area. The ACI was Colombia's first decentralized international cooperation agency.

In the years 1998-2002, Medellín went through its worst economic crisis since the great depression (Gómez, Aparicio, & Urbano, 2015; Restrepo Santamaria, 2011). The effects

of the crisis were strongly experienced in Antioquia and Medellín that did not only go through a deep economic recession but also a social crisis as well (Restrepo Santamaria, 2011, p 189). In 2001, the city had an unemployment rate of 22% and a homicide rate of 169 for 100,000 inhabitants (Gómez, Aparicio, & Urbano, 2015). The economic crisis was seen, depending on the elites, as an opportunity or as a threat. The new elites who were involved in finance, real-estate, and service wanted more integration of the city in the world economy, while the old industrial elites wanted to engage in more protectionist measures (Maclean, 2014).

For Maclean (2014), the local policies that have contributed to the decline in violence in Medellín are: the transportation and infrastructure projects that addressed exclusion; the investments in the poorest areas of the city; the creation of public spaces and parks; the investment in education; the attention to solidarity and competitiveness; the increased participation and community involvement in policy. For Maclean (2014), the national policies and global trends that have contributed to the decline in violence in Medellín are the Colombian Constitution of 1991; the popular election of mayors; the globalization; the close ties with the USA; and the end of the cold war. For Maclean (2014), there were also informal institutional changes, such as, the style of leadership; cultural capital; the increased participation; and the reduced corruption. In summary, for Maclean (2014), the global trends, informal institutional changes, national, and local policies all contributed the "Medellín Miracle," which refers to the rapid decline in violence experienced in the city since 1993. Some authors point out, however, that the decline in violence was achieved through the monopoly over illegal activities of one non-State armed actor, namely Don Berna, leading to a tacit agreement between the local authorities and the drug lord (Amnesty International, 2005; Hylton, 2007). Indeed, following Pablo Escobar's death in 1993 and the military operations—operation *Mariscal*, operation *Orión*, and *Estrella VI*—conducted by the State to reclaim the *comunas* controlled by the left-insurrectionary militias in 2002 and 2003, Don Berna established a total control over the city and homicide rates started to fall precipitously (Hylton, 2007). In June 2003, the BCN issued a communiqué in which they stated their responsibility in the rapid fall of homicides in Medellín contributing, as a result, to "the necessary climate so that investment, particularly foreign, which is fundamental if we do not want to be left behind by the engine of globalization, returns, is encouraged, and productive and long-term employment can be generated" (Amnesty International, 2005, p. 32)

4.3. Medellín - Towards the Knowledge City (2004-present).

For many academics, politics, and journalists, Medellín has since the early 2000s transformed itself into an "urban miracle" (Brodzinsky, 2014; Fukuyama & Colby; Maclean, 2014; Romero, 2007). For *The Guardian,* Medellín has transformed "from murder capital to model city" (Brodzinsky, 2014). For the *New York Times,* "Medellín's Nonconformist Mayor Turns Blight to Beauty" (Romero, 2007). From 1991 to 2016, Medellín's homicide rate has been divided by fifteen and, is thus safer than many cities in the United States, like Detroit (Michigan), New Orleans (Louisiana), or Chicago (Illinois). The rapid decline of violence, the social programs led by the emblematic Mayor Sergio Fajardo, and the innovation-led local policies have contributed to the "Medellín's miracle" (Maclean, 2014), the "Medellín's half a miracle" (Fukuyama & Colby, 2011), and the "Medellín's model" (Brand, 2013). The City of Medellín even elaborated a book with a recollection of articles praising the transformation of the city, published in diverse magazines and newspapers from around the world: such as *Monocle*,

Frankfurter All Zeitung, *Cadena Ser*, *Revista Brasileiros*, *Le Figaro*, *The New York Times*, *ABC*, *El País*, *The Guardian*, *Forbes*, *Financial Times*, and *MIT Technological Review* (Alcaldia de Medellín, 2015). The "Medellín's miracle" has, however, some grey areas. In 2006, President Uribe extradited 13 paramilitary commanders, including Don Berna, which resulted in a spike in the homicide rate in Medellín during the years 2007, 2008, and 2009 demonstrating the violation of the tacit agreement between narco-traffickers and the local authorities (Martin, 2012). Criminal gangs have occasionally captured participatory budgeting to consolidate power in their controlled territories (Caracol Radio Medellín, 2017). The city had in 2015, and still has, a very high GINI coefficient of 0.49 and is still a very unequal city with HDI ranging in 2012 from 98.67 in Poblado to 80.88 in Popular (Alcadía de Medellín, 2018). Moreover, "narco-elite," also known as "*clase emergente,*" still poses a threat to the economic and social transformation of the city (Franz, 2018; Stone, 2016).

The group of actors at the center of the transformation of Medellín into a knowledge city is the *Grupo Empresarial Antioqueño* (GEA), which is an informal network of the largest companies and *multilatina*s in Medellín (see 5.1.2. Proantiquia). The reorganization of the GEA strategic priorities, the threat from "narco-elite" to the GEA, and the elections of Mayor Sergio Fajardo (2004-2007), Alonso Salazar (2008-2011), and Aníbal Gaviria (2012-2015), which were backed by the GEA, have led to structural reforms in education, social urbanism, social inclusion, and innovation-led policies, have paved the way to Medellín's economic transformation to more knowledge-based activities. Indeed, the realignment of interests between the business elites and the political class during the mandates of Sergio Fajardo (2004-2007), Alonso Salazar (2008-2011), and Aníbal Gaviria (2012-2015) was unprecedented since the 1970s. Mayor Sergio Fajardo Valderrama (2004-2007), the poster child of the "Medellín's miracle", was invited to participate in the politics of the city at the initiative of Proantioaquia (Fajardo & Andrews, 2014; Franz, 2017). The political party led by Fajardo was the *Compromiso Ciudadano*, a broad coalition that emerged as a civic movement in the 1990s, involving public actors, the "reflexive middle-class", academics, nongovernmental organizations, the media, and the local economic elite (Franz, 2017; Maclean, 2014). The civic movement became a political party that was able to break the Liberal versus Conservative hegemony (Maclean, 2014). Despite his inexperience, Sergio Fajardo (2004-2007) achieved to bridge the private and the public sectors into participating in common regional projects thanks to his contacts with Proantioquia and the GEA (Fajardo & Andrews, 2014; Restrepo Santamaria, 2011). The limited capabilities of the Fajardo's cabinet were compensated by his close links with the private sectors. The symbol of his mandate, the Spanish Library, that is located in one of the poorest comuna has received a large administrative support from COMFAMA (Fajardo & Andrews, 2014). The Fajardo's administration prioritized Education to combat income inequality and violence, under the umbrella programs, "Medellín, the most educated", as the engine for social transformation (Alcaldía de Medellín, 2007). The programs under the Fajardo's administration were the Entrepreneurship Culture (Culture E), the participatory budgeting, the social urbanism, the integrated urban projects, and Inclusive Medellín (Alcaldía de Medellín, 2007). The administration of Sergio Fajardo's (2004-2007) main achievement is to have restored confidence in the local government among all Medellín's residents (Jaramillo, 2015).

The 1991 Colombian Constitution has devolved many responsibilities to Municipal Governments to design strategic plans, which were carefully planned and implemented in Medellín. In 1994, the Municipal Development Plan is introduced as a social pact between the community and the State to plan territorial development in all its dimensions (economic, social, political, etc.). The Municipal Development Plan contains the programs, subprograms, and projects, that mayors will develop during their mandates. In 1995, the City of Medellín drafted its first development plan. In 1997, the Territorial Planning Plan (POT) became the main instrument of urban planning. The Territorial Planning Plan has been used extensively in Medellín to transform the city into a knowledge city through the creation of iconic public spaces, such as the Botanical Garden (2007), the Parque Explora (2008), Parque de los Pies Descalzos (1999), Plaza Botero (2000), and the Parque de los Deseos (2003) (Galindo Muñoz, 2011). Medellín has been one of the cities in Colombia to systematically adopt strategic planning instruments (Alcaldía de Medellín & Banco Interamericano de Desarrollo, 2009, p. 47). The first influential strategic plan was the Monitor Report, *Competitive Advantages for Medellín,* published in 1994. The report, which was commissioned by the Medellín's Chamber of Commerce, provided a SWOT analysis of Medellín. The report pointed out that Medellín had to be more integrated globally and adapt its culture to fully exploit its economic potential (Monitor, 1994). Other influential strategic plans for Medellín and Antioquia include: the plan *Vision Antioquia 21st century*, published in 1997; the *Strategic Plan for Antioquia* (PLANEA) in 2007; the *Regional Plan for Competitiveness for Medellín, the Aburrá Valley, and Antioquia* released in 2011 (Brunner et al., 2012).

Years	Municipal Development Plan	Mayor
1995-1997	*Plan de Desarrollo de Medellin 1995-1997* Medellin Development Plan 1995-1997	Sergio Naranjo
1998-2000	*Plan de Desarrollo de Medellín 1998-2000, Por una Ciudad Más Humana* Medellin Development Plan 1998-2000, For a More Humane City	Juan Gómez Martínez
2001-2003	*Plan de Desarrollo de Medellín 2001–2003 Medellín Competitiva* Medellin Development Plan 2001-2003 Medellin Competitive	Luis Pérez Gutiérrez
2004-2007	*Plan de Desarrollo 2004-2007 Medellin, Compromiso de Toda la Ciudadanía* Development Plan 2004-2007 Medellin, Commitment of All Citizenship	Sergio Fajardo
2008-2011	*Plan de Desarrollo 2008-2011. Medellin ES Solidaria y Competitiva* Development Plan 2008-2011. Medellin IS Inclusive and Competitive	Alonso Salazar
2012-2015	*Plan de Desarrollo 2012-2015 Medellin, un Hogar para la Vida* Development Plan 2012-2015 Medellin, a Home for Life	Aníbal Gaviria
2016-2019	*Plan de Desarrollo Municipal 2016-2019 Medellín Cuenta con Vos* Municipal Development Plan 2016-2019 Medellin Count on You	Federico Gutiérrez

Table 1. Municipal Development Plans since 1995. Source: own design.

The decline in violence is associated with the approach to urban development pioneered in the city known as social urbanism (Maclean, 2014). Social urbanism is an umbrella term for the policies enacted in Medellín in the late 1990s and the early 2000s to address some issues facing the city's poorest neighborhoods (Maclean, 2014). The

comprehensive strategy of Social Urbanism was inspired by urban best-practices, namely in Rio de Janeiro and Barcelona, and national experiments, namely in Bogotá and the *Programa Integral de Mejoramiento de Barrios Subnormales de Medellín* (PRIMED) in Medellín in 1993 (Echeverri & Orsini, 2010). Social urbanism was conceptualized in the Development Plan 2004-2007 "*Medellín, compromiso de toda la ciudadanía*" under chapter 2 Medellín social and inclusive under the Fajardo administration (2004-2007). Social urbanism includes diverse strategic elements to promote spatial inclusion through urban projects, such as action zones, Integral Urban Projects to intervene in informal settlements, the linking of strategic processes, the transparent city, public spaces, mediation spaces, and leadership (Alcaldía de Medellín, 2012). The social policies were supported by the elites who understood their role in the crisis that affected the city and the historical debts owed to the poorest areas of the city (Maclean, 2014). The programs that have been implemented can, however, be seen as an extension of the elite power into social and cultural aspects of the city (Maclean, 2014).

The neoliberal reforms, that have accompanied the internationalization of the Colombian economy resonated in Medellín with local policies and programs to promote entrepreneurship and innovation such as, *Cultura E*, *Medellín Mi Empresa*, *Medellinnovation*, *Medellín Digital*, *Ciudad E*, *Medellín Ciudad Clúster*, *Medellín Ciudad para la Vida*, *CREAME*, *Parque E*, *Ruta N* and the *CEDEZOs*, among which Ruta N is by far the most ambitious program that has been implemented. In Medellín, the first policy programs to promote entrepreneurship were introduced in the early 2000s with the program *Medellín Emprende* and *Red Unificada de Emprendimiento de Antioquia* (RUEDA). In 2004, the program *Cultura E* was launched. Many programs undertaken by the municipality were made possible thanks to the resources that EPM-UNE transfers to the municipality, which allow investments in infrastructures, including the metro, metro cable, libraries, and parks; in entrepreneurship programs, and in education (Maclean, 2014). In Latin America, the low tax rates at the local level translate into under-capacitated and passive local governments (Bateman, Durán, & Maclean, 2011). In Medellín, the low fiscal revenues are largely compensated by the mandatory 30% transfer of EPM net annual profits to the municipal budget (Bateman, Durán, & Maclean, 2011).

Medellín has greatly integrated itself in the global economy. Foreign Direct Investment (FDI) increased by tenfold between 2002 and 2009 and Medellín became one of the top Latin American cities for doing business (Moncoda, 2016). Medellín has hosted a number of significant international events, such as the 2008 General Assembly of the Organization on American States; the 2010 South American Games; the 2014 UN-Habitat World Urban Forum; the 2015 World Tourism Organization General Assembly; and the 2016 Global Entrepreneurship Congress. Medellín has also received a large number of national and international awards recognizing the city's urban and social transformation, most notably, International Prize from Habitat Dubai in 2008; Triple A ratings (2006, 2007, 2008) from Duff and Phelps; Prize Holcim in 2008; Prize at the Iberoamerican Bienal in Architecture and Design in 2008; Prize at the XVI Panamerican Bienal in Quito. In 2013, Medellín was awarded the Innovative City of the Year by the Wall Street Journal and Citi bank (WSJ, 2013). Upon accepting the award, Mayor Aníbal Gaviria (2012-2015) pointed out that Medellín is "constantly reinventing itself" (Moncada, 2016). The reinventions are made possible thanks to the commitment of the economic and political elites to engage in ambitious regional projects. The public organization at the center of the transformation of Medellín into a knowledge city is Ruta

N. As Mayor Aníbal Gaviria (2012-2015) pointed out, "an outstanding case of this model of development and transformation of the city is Ruta N" (Almirall et al., 2016, p. 144).

4.4. Medellín's Regional Innovation System.

Located in the Aburrá Valley, the city of Medellín is the largest city in the Antioquia region. The Aburrá Valley concentrates the majority of the region's population and is referred to in this thesis as the regional innovation system. Indeed, the Aburrá Valley concentrates most of the universities, innovative companies, large companies and *multilatinas*, R&D activities, and the Science, Technology, and Innovation sector of the Antioquia region. In 2016, the Antioquia Region is the second largest region in terms of its contribution to the national GDP (13,9%), in front of the Valle del Cauca Region (9,7%) where the City of Cali is located, but after Bogota D.C. (25,7%) (see Table 2). The RIS has been transforming itself in the past two decades (see Tables 4 and 5). The city of Medellín has performed well on many key indicators. From 2009 and 2015, the GDP per capita has grown by 56.3%, the unemployment rate has decreased by 42.5%, the poverty rate has been reduced by 40.2%, the GINI index has decreased by 7.5%, and the homicide rate has decreased by 78.7% (see Table 4). From 2006 to 2015, the GDP in Medellín has been growing at a fast rate between 7.39% in 2015 to 14.15% in 2008 (see Table 5). The GDP per capita has also grown rapidly, reaching COP $ 24,156,607 or USD $7,569 in 2015.

	1996	2000	2004	2008	2012	2016	Difference in Percentage (1996-2016)
Antioquia	14,9	15,2	14,0	13,4	13,0	13,9	-6,62
Bogotá D. C.	22,9	21,7	26,6	25,7	24,6	25,7	12,45
Valle del Cauca	12,1	11,7	10,5	10,0	9,3	9,7	-20,04

Table 2. The Share of the Contribution to the National GDP per Regions from 1996 to 2016. Source: DANE (2018b).

Population Antioquia Region (2015)	6 456 299
Population Aburrá Valley (2015)	3 777 009
Population Medellin (2015)	2 464 322
GDP (in millions COP 2015)	59 529 657
GDP Per Capita (in COP 2015)	24 156 607
Unemployment Rate (2015)	9,03
GINI Index (2015)	0,49
Poverty Rate (2015)	14,3
HDI (2013)	87,52
Largest sectors in percentage of GDP (2015):	
Manufacturing	18,1
Commercial Services	12,3
Services to Companies	12,1

Table 3. Medellín's Key Indicators. Sources: Antioquia Region (2016), City of Medellín (2018)

	2002	2009	2015	Percentage Change (2002-2015)
Population in Medellin	2 129 874	2 317 336	2 464 322	15,7
Unemployment Rate	16,7	15,7	9,0	-45,9
Poverty Rate	36,1	23,9	14,3	-60,4
GINI Index	0,55	0,53	0,49	-10,9
Homicide Rate per 100 000 inhabitants	177	94	20	-88,7

Table 4. Medellín's Selected Key Indicators from 2002 to 2015. Source: City of Medellín (2018), DANE GEIH (2018).

Year	GDP in Medellin (in million COP)	Percentage Growth	GDP in Medellin per Capita in COP	Percentage Growth
2006	26 223 194	N/A	11 711 996	N/A
2007	29 892 093	13,99	13 195 970	12,67
2008	33 181 621	11,01	14 481 077	9,74
2009	35 814 227	7,93	15 454 913	6,72
2010	39 115 464	9,22	16 694 258	8,02
2011	44 999 709	15,04	19 000 993	13,82
2012	48 254 532	7,23	20 164 776	6,12
2013	51 098 978	5,89	21 138 646	4,83
2014	54 848 555	7,34	22 468 575	6,29
2015	59 529 657	8,53	24 156 607	7,51

Table 5. Medellín's GDP and GDP Per Capita from 2006 to 2015 (Current COP). Source: City of Medellín (2018)

The city is still a specialized RIS in which the industrial sector contributes to a large share of its GDP and employment structure (see Tables 6 and 7). In the past two decades, due to the reorganization of the GEA and of the city's economic structure, the city is increasingly moving towards more knowledge-based and service-based activities. Employment in the manufacturing sector has relatively declined from 2001 to 2017 by 29.42% while employment in service sectors, namely real-estate, construction, transportation, and commercial services has increased in relative terms. Although the share in its contribution to the economy has declined from 20.8% in 2003 to 18.1% in 2015, the manufacturing sector is still the largest sector in Medellín (City of Medellín, 2018). The share in the GDP of the service sector is rapidly growing with commercial services and service activities to the business sector representing respectively, 12.3% and 12.1% of Medellín's GDP (see Table 7).

The RIS concept, which originated in the European academic literature, has been used as a powerful analytical tool in different Latin American countries (Llisterri, Pietrobelli, & Larsson, 2011). The RIS concept is a concept that can be applied to analyze Medellín's economic transformation. However, the RIS literature should consider, when applied to Latin America, the contextual specificities that are missing from the European literature. In Latin America, one key specificity, for instance, is the weaker role of governments

and the stronger role of regional elites in their respective RISs, such as the GEA in Medellín. Acemoglu and Robinson (2012) have illustrated how regional elites in Latin America have affected institutional trajectories. In Medellín, the GEA has been one of the most important actors at the center of Medellín's transformation of its RIS (see Figure 7).

> "In 1996, the CTA led the Regional Council for Science and Technology to define the agenda for the Science and Technology Strategic Plan for Antioquia and Medellín. We were the first one to talk about regional innovation systems and themes related to innovation, such as the development of health, biotechnology and software" (Santiago Echavarría, CTA, personal communication, July 12, 2017).

> "I was at an event in Brazil and I said, 'the national innovation systems are over, they are the past, the new paradigm is local innovation systems and national innovation systems are going to be the sum of local innovation systems'" (Elkin Echeverrí, Ruta N, personal communication, 27 July 2017).

Sectors	2001	2009	2017	Absolute employement difference in percentage (2001-2017)	Relative difference in employment in percentage (2001-2017)
Commercial	318 912	444 444	519 470	62,89	8,71
Service	284 846	311 688	371 774	30,52	-12,89
Manufacturing	326 884	324 268	345 710	5,76	-29,42
Real-Estate	85 284	153 476	212 675	149,37	66,43
Transportation	84 680	116 476	159 099	87,88	25,39
Construction	58 467	81 844	130 139	122,58	48,55
Financial	28 388	25 900	41 992	47,92	-1,28
Agricultural	16 428	13 468	16 109	-1,95	-34,56
Energy	2 899	5 328	9 231	218,40	112,50
Mining	846	2 812	3 077	263,88	142,86
Other Sectors	483	296	724	49,83	0,00
Total Number of Employees	1 208 117	1 480 000	1 810 000	49,83	49,83

Table 6. Employment per Sector in Medellín. Source: DANE GEIH (2018).

Sectors	2003	2009	2015	Difference in percentage (2003-2015)
Other Sectors	17,9	18,1	18,3	2,23
Manufacturing	20,8	19,7	18,1	-12,98
Commercial Services	10,7	11,3	12,3	14,95
Service	10,8	11,6	12,1	12,04
Real-Estate	9,9	9,5	8,7	-12,12
Financial Services	5,6	5,6	7,9	41,07
Public Administration	7,5	6,7	6,5	-13,33
Telecommunication	3,5	4,9	4,4	25,71
Construction	4,5	3,7	3,1	-31,11
Health Services	2,9	2,9	3,0	3,45
Tourism	2,8	2,8	2,9	3,57
Transportation	3,1	3,2	2,7	-12,90

Table 7. Share in the city's GDP of the most Important Sectors in Medellín (Constant). Source: City of Medellín (2018).

Following the framework proposed by Liu and White (2001), the main actors in Medellín's regional innovation system are categorized into five different fundamental activities: education, research, linkage, implementation, and government. R&D activities consists of basic, developmental, engineering research and development centers; implementation refers to large private companies, large public companies, small and medium enterprises, and startups; linkage refers to the actors bringing together complementary knowledge; education consists of universities, colleges, and vocational schools; and government refers the municipal and regional governments. The following tables (Tables 8, 9, 10, 11, and 12) do not aim to categorize all the actors in the RIS but to categorize the most important ones in the Medellín's RIS.

Fundamental Activity	Type of Institution	Name	Role
EDUCATION	Higher Education Institutions	National University in Medellin	Universities provide education, research, and training. Eight universities in Medellin are part of G8, an informal agreement, to collaborate on topics related to research, training, and education.
		Medellin University	
		Pontifical Bolivarian University	
		Lasalle University	
		CES University	
		University of Antioquia	
		EAFIT University	
		Engineering School of Antioquia	
		Jaime Isaza Cadavid Polytechnic	
		Grand College of Antioquia	
		Pascual Bravo Technological Institute	
		Metropolitan Technological Institute (ITM)	
	Science Museum	Parque Explora	The Parque Explora is an interactive science museum that was created in 2008.
	Agency for Higher Education	Sapiencia	Sapiencia was created by the City of Medellin in 2014 to support good practices in the municipally-owned higher education institutions, namely ITM, Pascual Bravo, and Grand College of Antioquia. The organization also offers scholarships in collaboration with EPM to support the STI plan.
	Vocational Training	SENA	The SENA was created by the national government in 1957 to provide vocational training.

Table 8. Main Educational Actors in the RIS. Source: own design.

Fundamental Activity	Type of Institution	Name	Role
LINKAGE	Intermediary Institutions	University-Firm-State Committee (CUEE)	The CUEE was established in 2003 by the University of Antioquia in order to foster collaboration between University-Firm-State actors.
		Tecnnova	Tecnnova was created in 2007 by the CUEE to promote research projects and collaboration between University-Firm-State.
		Ruta N	Ruta N was created in 2009 by EPM-UNE and the City of Medellin in order to lead the city's Science, Technology, and Innovation plan.
	Support Organizations	The Center for Science and Technology of Antioquia (CTA)	The CTA was created in 1989 in order to support the local and regional governments to implement Science and Technology policies.
		CREAME	CREAME was created in 1996 by the City of Medellin to incubate and accelerate the development of high-growth startups.
		PARQUE E	Parque E was created in 2006 by the University of Antioquia in order to support the incubation of high-growth startups and entrepreneurs.
		CEDEZOS	The CEDEZOs are support offices located in different part of the city to accompany entrepreneurs and local businesses that was created by the City of Medellin in 2005.
		Medellin Chamber of Commerce for Antioquia	The Medellin Ciudad Cluster is an joint initiative from the Medellin Chamber of Commerce and the City of Medellin to promote and to foster the development of six clusters, namely ICT, Energy, Health, Construction, Design and Fashion, Fairs and Events.
	Business Development Centers	Biointropic, Endeavor, Social Atom	The business Development Centers aim to accelerate the growth of firms in Digital business, biotechnology, and high-growth sectors.

Table 9. Main Linkage Actors in the RIS. Source: own design.

Fundamental Activity	Type of Institution	Name	Role
RESEARCH	Technological Research and Development Centers	CECIF	The CECIF was created in 1997 and managed by Colciencias to work on pharmaceutical and cosmetics research.
		ICIPC	The Plastic and Rubber Training and Research Institute Foundation was created in 1987 to work on plastic and rubber research.
		CIDET	The Center for Research and Technological Development of the Electric Sector was created in 1995 to research on energy.
		CIB	The Corporation for Biological Research was created in 1970 to carry out basic, clinical and high-level technological development research in the biological sciences.
		CIIEN	The Center for Research and Innovation in Energy was created in 2006 by EPM to conduct research in energy.
		PECET	The PECET was created in 1986 as a research center from the University of Antioquia specialized in tropical diseases.

Table 10. Main Research Actors in the RIS. Source: own design.

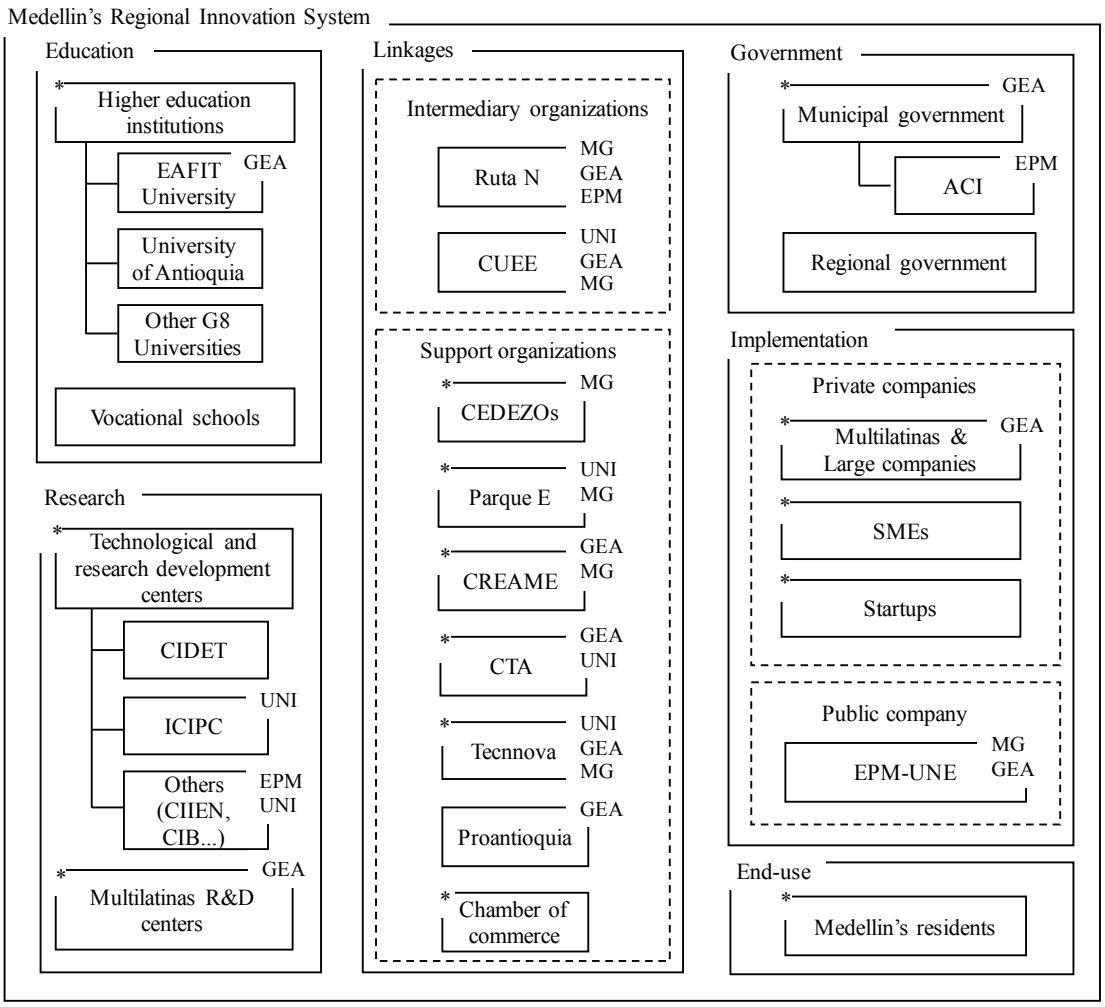
Fundamental Activity	Type of Institution	Name	Role
IMPLEMENTATION	Large Private Companies	ISAGEN (Energy), SURA (Insurance/Financial Services), ARGOS (Cement), NUTRESA (Food), Bancolombia (Banking/Financial Services)	Large Private Companies have established R&D centers. Many large Private Companies are Multilatinas that are part of the GEA or have links with the GEA.
	Public-Utility Company	EPM-UNE	EPM-UNE is a multi-utility company that has established R&D centers in Energy and telecommunications.
	SMEs		Small and Medium Enterprises invoved in innovative activities.
	Startups		Startups involved in innovative activities.

Table 11. Main Implementation Actors in the RIS. Source: own design.

Fundamental Activity	Type of Institution	Name	Role
GOVERNMENT	Municipal Government	City of Medellin	The City of Medellin initiates STI strategies through Municipal Development Plans.
		Secretary of Economic Development	The Secretary of Economic Development was created in 2013 to support economic development through diverse programs.
		EDU	The EDU was created in 1993 to plan urban development in Medellin.
		ACI	The ACI was established in 2002 as the City's Promotion Agency in order to attract Foreign Direct Investment in Medellin.
	Regional Government	Antioquia Region	Antioquia Region develops regional development plans and receives Royalties from the General System of Royalties for Science and Technology.

Table 12. Main Government Actors in the RIS. Source: own design.

Medellín is a specialized old industrial area and organizationally thick RIS. The industrial sector has suffered from cognitive and political lock-ins due to the city's isolation from global knowledge flows, protectionist policies, and remoteness from global trade routes, which prompted the GEA in the 1990s to support the city's transition towards more service-based and knowledge-based activities. The RIS is characterized by the strong influence of the GEA in diverse institutional arrangements with the municipal government and EPM-UNE (see Figure 7) as a mean to support Medellín's transition towards more knowledge-based activities and to counteract the influence of 'clase emergente' also known as 'narco-elite' on the political economy of the city (Franz, 2018; Stone, 2016). Since the 2000s, the RIS is becoming organizationally thick with the creation of diverse linkage organizations to support the technological innovation process. Indeed, the City of Medellín has created support organizations, such as CEDEZOs in 2005 for the promotion of entrepreneurship, Parque E in 2006 for startup incubation, Ruta N in 2009 to support innovation activities, and the ACI in 2002 for investment promotion. *Multilatinas* and G8 universities have been involved in the creation of technological and research development centers, such as CIDET in 1995 to conduct research on energy, ICIPC in 1987 to research on plastic and rubber, and CIIEN in 2006 to research on energy, and many others. The CUEE was created in 2003 to promote collaboration between triple-helix actors. In 2009, Ruta N, Medellín's innovation agency, was created as one of the main actors dedicated to the promotion of science, technology, and innovation in the RIS.



* The actors that have benefited from Ruta N's programs. Actors influenced or owned by the MG: Municipal Government, GEA: Grupo Empresarial Antioqueño, EPM: Empresas Públicas de Medellin, UNI: Universities.

Figure 7. Medellín's Innovation System Adapted by the Author from the Framework Proposed by Liu and White (2001).

5. The Definition of the Ruta N's Model.

5.1. The Actors in the Creation of Ruta N

Ruta N's creation has been a collective process involving private and public actors as well as universities. There are many actors that have participated in the creation and the formulation of Ruta N. Four actors, however, have played a fundamental role in the creation of Ruta N, they are: The City of Medellín, Proantioquia, the Center for Science and Technology of Antioquia (CTA), and the public-owned multi-utility and communications company EPM-UNE. In addition to those four actors, the University-Firm-State Committee (CUEE), EAFIT University, the Medellín Chamber of Commerce for Antioquia, and the first director and employee of Ruta N, namely Andrés Montoya and Juan Pablo Ortega have played an important role in Ruta N's creation.

> "In the creation of Ruta N, three entities had a key role. Proantioquia, the foundation of the GEA in which are the most important companies, that started to think about the project, the future of the department and the city. The CTA, created by Proantioquia, that works on science, innovation, and competitiveness. And the third is EPM that is really important, saying the city needs that, so let's do it! EPM then talks with Proantioquia to validate the project" (Carlos Franco, Ruta N, personal communication, July 28, 2017).

5.1.1. The City of Medellín.

Mayor Sergio Fajardo (2004-2007) was fundamentally concerned with education. Indeed, Fajardo's administration strategy was dubbed, "Medellín, the most educated" (Fajardo Valderrama, 2007). In 2007, 40% of the city's annual budget went to education and ten schools were built under Fajardo's administration (Fajardo Valderrama, 2007). Mayor Alonso Salazar (2008-2011), building on Mayor Sergio Fajardo's legacy, prioritized during his mandate, innovation and inclusiveness. Mayor Alonso Salazar (2008-2011) presented in his Development Plan 2008-2011, *Medellín is Inclusive and Competitive,* in Chapter 3, Economic Development and Innovation, Section 3.1. Component: Creation and Support of Companies, Subsection 3.1.1. Program: Support for Entrepreneurship, 3.1.1.4. Project: The "Entrepreneurship Block" (*Manzana del Emprendimiento*). The Development Plan 2008-2011 defines the "Entrepreneurship Block" as "a physical space to consolidate science, technology, and innovation in the city" that should be led by EPM and the city's planning department (Alcadía de Medellín, 2008, p. 87). The project, the "Entrepreneurship Block," which would later become known as Ruta N, was instigated by the Municipality but was, however, ill-defined. Neither the Mayor nor his administration knew what the "Entrepreneurship Block" should be. Mayor Alonso Salazar wanted an organization that could support the development of regional high value-added and highly competitive technologies, such as in healthcare where Medellín has a strong competitive advantage (Alonso Salazar, Mayor of Medellín 2008-2011, personal communication, 17 August 2018).

> "When I was running for Mayor of Medellín in 2007, I was thinking that we needed a project to give a regional dimension to innovation, something with a wider reach. We looked at Chile that was successful in creating high value-added products. We wanted to do something similar with Ruta N" (Alonso

> Salazar, Mayor of Medellín 2008-2011, personal communication, 17 August 2018).
>
> "In the plan of the Mayor, there was something called the 'Entrepreneurship Block', but no one knew what an entrepreneurship block was. It was supposed to be a physical space [...] but with our interdisciplinary group, we started to investigate what was happening in the world and what needed the city, from there, we concluded that the city, more than an entrepreneurship block, needed to focus its efforts on issues related to science, technology, and innovation" (Andrés Montoya, Ruta N, personal communication, 17 July 2017).

In contrast with other major Colombian cities, the City of Medellín has for specificity to have a large part of its budget coming from EPM's transfer, which has allowed the City of Medellín to have greater flexibility in implementing a diverse range of social and economic programs. In 2015, the total budget of the City of Medellín amounted to COP $4,842,374,000,000, that is USD $ 1,517,272,129 (see Table 13). The City of Medellín receives incomes from local taxes, EPM's transfer, the Central Government transfer, and other incomes. The local taxes mainly come from the Industry and Commerce tax, which is a local tax that is imposed on revenue generated from industrial, commercial or service activities. As a result, the increased local economy allows the City of Medellín to gain more income from the Industry and Commerce tax.

Income - Municipality of Medellin	2015	In Percentage of Total Budget
Municipality Income	2 449 423	50,6
EPM's Transfer	991 139	20, 5
Central Government's Transfer	889 120	18,4
Other Income	542 692	11,2
Total Income	4 842 374	100

Table 13. The Sources of Revenues for the City of Medellín (in million COP). Source: City of Medellín (2018).

5.1.2. Proantioquia.

Proantioquia is a not-for-profit organization that was created on July 1975 as an initiative of the private sector. The entity's constitution was signed by 12 industrialists from Antioquia who were united to seek the progress and development of Antioquia through transformative projects. *Proantioquia* aims to mobilize the business sector to influence public policies to create favorable conditions for the development of the region, such as better human capital, business-friendly environment, and more inclusive development. In influencing public policies, *Proantioquia* carries out three roles: first, the role of a think-tank; second, the role of an incubator for strategic projects or institutions; and third, the role of an opinion leader.

Proantioquia is the unofficial not-for-profit organization of the *Grupo Empresarial Antioqueño* (GEA), which is an informal group of large regional companies that make up for around 80% of Medellín's GDP and contributes up to about 8% of Colombia's GDP (Franz, 2018). In the late 1970s, notorious industrial companies in Medellín, such as *Coltejer*, *Postobón*, and *Cervunión*, were hostilely being taken over by industrialists

from outside Antioquia, such as Ardila Lülle, Santo Domingo, and Sarmiento Angulo (Calle, 2015). In March 1978, a group of industrialists from Antioquia formed the *Sindicato Antioqueño,* later known as *Grupo Empresarial Antioqueño* (GEA), as an informal association that had for mission to defend each other interests, to not speculate, and to not accept foreign investors (Calle, 2015). Once described in *Business Week* as "The Other Medellín Cartel", the GEA is a Keiretsu-like conglomerate where companies have cross-ownership, which has allowed them to reinvest their profits in long-term projects, to not hostilely being taken over, and to be immune from the influence of narco-money (Calle, 2015; Lane, 1996; Restrepo Santamaria, 2011). The GEA was able for instance, to prevent the hostile take over of *Cementos Paz del Rio*, a GEA member, by *Cemex*, the Mexican cement company, by recapitalizing with the government the company (Lane, 1996). The industrial crisis in the late 1970s led the GEA to envision for the region an economy geared towards service-based and knowledge-based activities, such as financial services, real estate, tourism, and service (Calle, 2015). The GEA has a significant impact in the development of the city and the region to the extent that there is the idea that if Medellín is doing well, then the GEA will be doing well (Schipani, 2014). The GEA's three dominant companies are the investment banking and insurance company, *Grupo Sura*, the food processing company, *Grupo Nutresa*, and the cement company, *Grupo Argos* (Lane, 1996).

The emergence of a new elite structure since the 1980s that has developed close links with narco-traffickers and paramilitary groups has been challenging the established industrial elite, namely the GEA (Franz, 2018; Martin, 2014; Salazar, 1990). The industrial crisis combined with the increased rivalry from "narco-elite", also known as "*clase emergente*", pushed the GEA to reorganized itself into becoming more globalized and integrated (Franz, 2018; The Economist, 2001). Indeed, the transition from the industrial to the service and innovation economy, the process of globalization, and the internationalization of capital implied a restructuration of the strategic industries towards the financial and service sectors (Franco Restrepo, 2006). Thanks to the GEA's high reinvestment rate due to its cross-ownership structure, the GEA began a process of expansion and internationalization of their activities with the creation of *Multilatinas*, mostly in Latin America, which affected their visions for the Medellín and Antioquia (Franco Restrepo, 2006; Gutiérrez, 2008; Restrepo Santamaria, 2011). In the late 1990s and 2000s, the GEA has established strategic alliances with international companies, among which Noel-Danone (France), Noel-Bimbo (Mexico), Éxito-Casino (France), Corfinsura-International Finance Corporation (Washington, the United States), Argos-Holcim (Switzerland), Suramericana-Munich Re (Germany), to access latest technologies, know-how, capital, business knowledge, while most importantly retaining the control of the companies (Londoño, 2004). In the past decades, the GEA has increasingly been involved in the political economy of Medellín to secure their vested interests and to counteract the influence of "narco-elite" on the political class. The GEA has participated in the creation of many public-private partnerships with the municipal government and of many cultural and social projects in the city, such as Ruta N, the CUEE, the CTA, the ACI, Plaza Mayor, Museums, Tecnnova, which allow the GEA to put pressure on the municipal and regional governments to have transparent public management (Franz, 2018). Newly-elected Mayors or Governors, such as Luis Pérez Gutiérrez, Mayor of Medellín from 2001-2003 and Governor of Antioquia from 2016-2019, who represent "*clase emergente*" elite and are against GEA vested interests, will have, as a result, a more limited influence to conduct reforms (Franz, 2018). Indeed, Mayor Luis Pérez Gutiérrez (2001-2003) is considered for the GEA as the Mayor and

Governor who has been the most opposed to their interests (Restrepo Santamaria, 2011).

Proantioquia and its president Rafael Aubad were the most important protagonists in modeling Ruta N. *Proantioquia* played the role of an institutional incubator, shaping Ruta N's governance model, vision, structure, and strategy, while providing conceptual, operational, and management supports. *Proantioquia* helped to organize meetings between the business sector and Ruta N and the Ruta N team to validate the model to the Mayor's office. Moreover, before being officially incorporated, Ruta N's first office was located inside *Proantioquia*'s office. The primary motivation for *Proantioquia* to support Ruta N was the necessity for the region to upgrade its entrepreneurial capacity, to upgrade its innovation capabilities, and to generate new entrepreneurs and high-growth startups. For *Proantioquia*, Medellín has to become more integrated into the global economy and to move away from its industrial past to transform itself into a knowledge city.

> "For Ruta N, which was an initiative brought by the Municipality, we [Proantioquia] wanted to incubate the initiative to support it, to support in defining the governance model, to support in defining the strategic lines, and to support in structuring the project as an organization" (Rafael Aubad, Proantioquia, personal communication, 8 August 2017).

5.1.3. The Empresas Públicas de Medellín (EPM-UNE).

The *Empresas Públicas de Medellín* (EPM) is the largest multi-utility company—water, energy, waste, and UNE telecommunications—in Colombia. EPM was created on August 6, 1955, under the Municipal Agreement 058 during the exceptional regime of Gustavo Rojas Pinella, as an autonomous, independent, decentralized entity from the municipality of Medellín resulting from the merger of different utility companies, including the *Sociedad de Mejoras Públicas* (SMP) (Montoya Mejía, 2015; Toro, 1996). The multi-utility company is 100% owned by the municipality of Medellín and is the object of collective pride for the inhabitants of Medellín no matter his or her socio-economic background (Franco Restrepo, 2006). EPM, which is one of the largest companies in Latin America, reinforces the sentiment of an inherent efficiency and distinctive public administration in Medellín (Franco Restrepo, 2006; Montoya Mejía, 2015). In the 2000s, EPM began a process of expansion and internationalization of its activities by investing in other Colombian cities, such Bogotá, Cali or Bucaramanga, and in other Latin American countries, such as Chile, Panama, Ecuador, Guatemala, El Salvador, and in the Panama Canal (Dinero, 2009). In 2006, EPM created UNE telecommunications as a separate entity in partnership with the telecommunication company Millicom International Cellular (Luxembourg).

The public multi-utility company is closely intertwined with Medellín's political economy. Indeed, EPM is the consolidation of the *Sociedad de Mejoras Públicas* (SMP), which was created by the industrial elite to influence the political economy of the city (Botero Herrera, 1996; García Estrada, 1999). EPM is largely influenced by two elite groups, the City of Medellín and the GEA (Botero Herrera, 1996; García Estrada, 1999). Mayors, highly-ranked public officials, and even the former President of Colombia, Alvaro Uribe Vélez, have previously worked for EPM. Mayor Sergio Naranjo Pérez (1995-1997) initiated the debate to transform EPM into a public-private company, which was met with resistance in Medellín, most notably in El Poblado, the most affluent

neighborhood in the city (Franco Restrepo, 2006; Maclean, 2014). The public multi-utility company is mandated to contribute 30% of its net annual profit to the city's budget (see Table 14), which has valued EPM to be portrayed as the "surprising company behind the transformation of Medellín" (Ashoka, 2014). Indeed, the company has collaborated with the municipality in constructing libraries, parks, schools, transportation infrastructures, Ruta N, and the *Agencia de Cooperación e Inversión en Medellín y Área Metropolitana* (ACI). In contrast with other cities in Colombia and Latin America, Medellín's poorest neighborhoods are well-endowed in public utility infrastructures, such as access to water and electricity, thanks to the work of EPM (Uran, 2010). Additionally, EPM is an important actor in Medellín's RIS. Indeed, EPM has under the leadership of Dr. Juan Felipe Gaviria and Mayor Sergio Fajardo initiated the reinvestment of 0.6% of its annual turnover to R&D activities (Montoya Mejía, 2015). Moreover, EPM has created the entrepreneur funds with USD 10 million to be annually invested in scientific and technological innovations (El Tiempo, 2009). EPM has also created technological and research development centers, such as CIIEN in 2006 to conduct energy research.

Year	EPM Transfers to the City of Medellin (in million COP)	EPM Transfers as a Percentage of the City of Medellin's Total Budget
2004	326 268	33
2005	352 182	28
2006	320 532	20
2007	389 312	24
2008	670 827	37
2009	587 019	28
2010	846 844	36
2011	797 500	32
2012	839 841	32
2013	964 557	33
2014	908 695	28
2015	991 139	29

Table 14. EPM Transfers to the City of Medellín 2004-2015. Source: City of Medellín (2018).

EPM together with its telecommunications subsidiary UNE were fundamental in the creation of Ruta N since they are the ones financing the project, to the extent that the Ruta N's project had to be first validated by Proantioquia and EPM-UNE before being approved by the Medellín's Municipal Council. Moreover, UNE along with the city of Medellín, the ACI, EAFIT University, and the National Government were successful in attracting Hewlett Packard (HP) into the Ruta N building complex thanks to tax-breaks and heavy diplomatic backing from the local, regional, and national governments (Semana, 2011). The arrival of HP made the creation of the third building in the Ruta N building complex financially viable. HP was supposed to operate the Global Support Center for Latin America in Medellín, to occupy a building of 15,000-square-meter, to employ up to 400 persons, and to invest around USD $100 million in the city (Nearshore America, 2015; Samper, 2012).

5.1.4. The Centro de Ciencia y Tecnología de Antioquia (CTA).

The Center for Science and Technology of Antioquia (CTA), a not-for-profit organization, was created by Proantioquia with the support from Colciencias and the Antioquia Region in 1989. The industrial and business elites at the time drafted a strategic plan, titled *Antioquia Siglo XXI*, in which science and technology were to become the basis of the economic transformation of the region during a period of the city and the region characterized by an extreme level of violence. The CTA was to coordinate the city's economic transformation through the articulation, generation, and transfer of scientific and technological knowledge. The CTA has 18 different partners, namely 7 universities, 3 public institutions, and 8 private companies and has been a leading actor drafting strategic development plans for Medellín and Antioquia and creating the *Parque Explora,* a science museum.

In the 2008-2011 Medellín Development Plan, the City of Medellín planted the idea of building a physical space for entrepreneurship. There was a risk, however, that the building would become a "white elephant" or "cathedral in the desert". As a consequence, the CTA promoted the idea that the hardware (infrastructures and urban amenities) had to be complemented with the software (skills and knowledge) and orgware (learning and capacity-building). The CTA was contracted to draft the conceptual and architectonic components. For the architectonic part, the CTA did a referencing of best practices around the world of physical spaces for entrepreneurs and startups, such as MaRS Innovation in Toronto, Monterrey in Mexico, Googleplex in Silicon Valley, and 22@ in Barcelona. The CTA contracted the architects who designed the building Ruta N, namely Alejandro Echeverri and Emerson Marín, who have been involved in well-known architectural projects in Medellín. For the conceptual part, the CTA provided a financial model, an organizational model, wrote the institutional bylaws, and drafted the programs and work areas.

The CTA designed Ruta N's financial and institutional model to limit the influence of the municipality on the organization. Indeed, the board of directors includes private companies, public institutions, and universities. The financial model aimed to make Ruta N financially independent through collecting the rents from the offices located in the Ruta N buildings. The independence of the organization, relative to the local and regional governments, is necessary in order for Ruta N not to fall victim of political rivalries between the political elites and the business elites. The CTA pointed out that Ruta N should become a center for innovation and business (*centro de innovación y negocios*). Moreover, the CTA envisioned the role of Ruta N as a "city manager" supporting the municipality to adopt best-practices related to science, technology, and innovation.

5.1.5. The Comité Universidad-Empresa-Estado (CUEE).

The University-Firm-State Committee (CUEE) in Antioquia was established in 2003 to bring together and to foster connections across universities, public institutions, and private companies (Brunner et al., 2012). The CUEE in Antioquia is composed of 11 tertiary education institutions with regional influence, 21 private companies, 7 Technological Development Centers, the National Association of Colombia's entrepreneurs (ANDI), the National Association of Micro, Small and Medium-Sized Companies (ACOPI), the Secretariat for Productivity (Antioquia) and Secretariat for Municipal Planning (Brunner et al., 2012). The committee has supported numerous

research projects related to its impact on the industrial activities in Antioquia, such as "Research and Documentation of the experience University-Firm-State Committee of Antioquia" (Brunner et al., 2012). The CUEE conducted numerous meetings for triple-helix actors to discuss the role of Ruta N in the RIS. Additionally, the CUEE facilitated to rally the public sector and universities in supporting Ruta N's project and make it a collective regional project.

5.1.6. EAFIT University.

EAFIT university was created in 1960 by a group of 18 prominent industrialists and entrepreneurs as a business-focused university. The objective of the university was to train and educate the future managers of the thriving industrial sector. In 2017, EAFIT university had an enrollment of 11,090 undergraduate students and 3,018 graduate students (EAFIT, 2017). Moreover, EAFIT university is one of the best-ranked universities in Colombia and Latin America (QS World Universities Ranking, 2018). EAFIT university participated in the formulation of the Ruta N's model through the professor in innovation and entrepreneurship, Jorge Mesa, who was at the disposal of the early Ruta N's team, including the CTA, Andrés Montoya, and Proantioquia. EAFIT university has close links with the business sectors, the large Antioquia companies and the GEA. Moreover, the EAFIT university has been leading in themes related to social innovation, innovation management, and entrepreneurship (Mesa Cano, 2005). EAFIT university has also been decisive in attracting Hewlett Packard (HP) to Medellín since it provided the building facilities for HP until the completion of the construction of the Ruta N building complex (Gutiérrez, 2010).

5.1.7. Cámara de Comercio de Medellín para Antioquia (CCMA).

The Medellín Chamber of Commerce for Antioquia was created in 1904 by President Rafael Reyes through Presidential decree. In addition to registering and supporting the development of private companies, the Medellín Chamber of Commerce for Antioquia is a private not-for-profit organization that has been the protagonist of many initiatives related to innovation in the region. Indeed, the Medellín Chamber of Commerce for Antioquia sponsored the Monitor Report, *Competitive Advantages for Medellín,* published in 1994. The Medellín Chamber of Commerce for Antioquia was leading the project, *Alliance for Innovation in Antioquia*, which involved different actors in thinking about the development of technological innovation in the region.

Medellín *Ciudad Clúster* is an initiative of the Municipal Government and the Medellín Chamber of Commerce for Antioquia, where six strategic clusters have been defined: energy; textile and fashion design; construction; business tourism, fairs and conventions; health and health tourism; and information and communication technologies (ICT). In 2009, the Municipal Council of Medellín approved the Municipal Agreement 087, which made the program Medellín *Ciudad Clúster,* a public policy. The program revolves around three structuring axes and two transversal axes that are coordinated by different actors in the RIS. The structuring axes involve the support of clusters in their development and internationalization, the promotion of national and foreign direct investments in the clusters, and promoting technological innovations. The transversal axes involve the development of human capital and physical and virtual infrastructures. The Medellín Chamber of Commerce for Antioquia has launched the Productive

Specialization Strategy based on the EU Smart Specialization Strategy (S3) to strengthen the productivity and competitiveness of the clusters.

From 2012 to 2015, the teams from the Medellín Chamber of Commerce for Antioquia of the three clusters: ICT, Health, and Energy were located in the Ruta N building within the Ruta N office and were treated as part of the Ruta N team. The teams of the three clusters were involved in advising Ruta N on diverse topics, such as evaluating companies for the soft landing platforms, and in co-creating programs with Ruta N to upgrade the local capacities in ICT, health, and energy. In 2015, the teams of the three clusters left the Ruta N building complex to relocate in the main office of the Medellín Chamber of Commerce for Antioquia due to a degradation of the collaboration and lack of involvement between the teams of the three clusters and Ruta N.

5.1.8. Andrés Montoya and Juan Pablo Ortega.

Andrés Montoya and Juan Pablo Ortega have been involved in leading the creation of Ruta N. In late 2008, Andrés Montoya, Ruta N's first director, was selected to lead the creation of Ruta N due to his past experience in 2006-2007 as manager of Medellín Digital, a municipal and UNE program to democratize Internet access in the city. At the time, up to the official creation of Ruta N, Andrés Montoya was officially working for the telecommunications company UNE. A few months after Andrés Montoya, Juan Pablo Ortega was selected to participate in the creation of Ruta N. At the time, up to the official creation of Ruta N, Juan Pablo Ortega was officially working for EPM. Juan Pablo Ortega was selected since he had followed a graduate program in innovation management at the Massachusetts Institute of Technology (MIT).

5.2. The Definition of the Model.

The definition of Ruta N's model involved many actors in addition to the actors previously mentioned. The definition of the model was the outcomes of interviews and meetings with the private sector, public sector, universities, and the civil society; the participation of venture capital managers, such as Esteban Velasco, and entrepreneurs, such as Diego Ángel; of benchmarking international best-practices, such as 22@ Barcelona, Barcelona Activa, the Galicia region and Basque Country in Spain, Israel, Singapore, Silicon Valley, Toronto, MIT, and Startup Chile; and of the assessment of initiatives at the local level as well as the roles of Medellín's innovative actors in the regional innovation system.

> "At the beginning of Ruta N, we benchmarked some projects, we looked at MIT, we looked at Toronto, we looked a lot at Barcelona and its innovation district. What we did was referencing best-practices from around the world" (Catalina Gutiérrez, Ruta N, personal communication, 28 July 2017).

The definition of Ruta N's model was the outcome of the participatory process led by Proantioquia and the CTA involving the most important regional leaders coming from the private sector, public sector, universities, and the civil society. The benchmarking of best-practices and participation of experts led to the creation of specific Ruta N's programs. More importantly, Ruta N's model tried to respond to specific regional needs that the existing linkage organizations in the regional innovation system were not addressing. In 2008-2009, Medellín had several linkage organizations promoting

science, technology, innovation, and entrepreneurship. Ruta N, for that matter, had to be different from the existing linkage organizations in the regional innovation system, such as the *Parque Explora*, *Tecnnova*, *Parque E*, *CREAME*, or the technology park of Antioquia. From the assessment, Ruta N was first conceived as an intermediary organization (*entidad de segundo piso*) focusing on strengthening the capacity in science, technology, and innovation of the existing STI actors in the regional innovation system.

> "In the beginning, Ruta N was conceived as an intermediary institution working with actors of the system, the City of Medellín, CTA, Chamber of Commerce, CREAME, Parque E to strengthen them in order for them to operate the programs" (Andrés Montoya, Ruta N, personal communication, 17 July 2017).

Mission, Vision, and Strategic Priorities. Ruta N's mission is to support Medellín's transformation from an industrial into a knowledge city. As pointed out by Federico Gutiérrez, Mayor of Medellín 2016-2019, "we were the industrial capital of Colombia in the 20th century, but due to new global dynamics, we reinvented our economic calling. Today, thanks to Ruta N, we are stimulating our innovation ecosystem, to move towards a knowledge economy" (Ruta N, 2018a, p. 4).

Ruta N's overarching vision is to position Medellín in 2021 as the most innovative city in Latin America. This vision has, however, been redefined to become, "innovation will be the main driver of the economy and the city's quality of life" with the mega that "1,21% of economic growth will be the result of innovation activities" (Ruta N, 2018a).

In 2018, Ruta N had three strategic priorities, they are: to attract and retain talents, capital, and international companies, to develop and strengthen innovative companies and entrepreneurship, and to generate STI solutions for Medellín's challenges (Ruta N, 2018a).

The Official Creation. The Corporation Ruta N Medellín (*Corporación Ruta N Medellín*) was officially incorporated on November 11, 2009. The Ruta N's bylaws state that: "the corporation is a not-for-profit organization, which has for corporate purpose the guidance, participation, coordination, consolidation, organization, promotion, development, diffusion, and operation of the policy and activities related to science, technology, innovation, and technology-based entrepreneurship, in all the areas that are deemed relevant for its Associates, within the City of Medellín's economic development policy, including public-utility, such as energy, water, information and communication technologies, as well as its complementary and related activities, specific to one and everyone of them" (Ruta N, 2010a).

On August 21, 2010, the Medellín's Council approved the municipal agreement 49 of 2010, which officially binds the municipality of Medellín to the Corporation Ruta N Medellín (Gaceta Oficial N°3730, 2010). The article 2 of the municipal agreement 49 of 2010 confers COP $9,167,000,000 to Ruta N operations for the year 2010 (Gaceta Oficial N°3730, 2010, p. 8). The article 4 of the municipal agreement 49 of 2010 points out that the Corporation Ruta N Medellín will be the entity leading matters related to Science, Technology, and Innovation in the Municipality of Medellín (Gaceta Oficial N°3730, 2010, p. 8).

The Building Complex and its Location. Since the Fajardo's administration, social and/or economic transformation has to be embedded in urban transformations. Indeed, the Fajardo administration's prioritization of education led to the creation of hard infrastructures, such as libraries and schools. Medellín's knowledge turn, as a result, had to start with the creation of a building dedicated to Science, Technology, and Innovation.

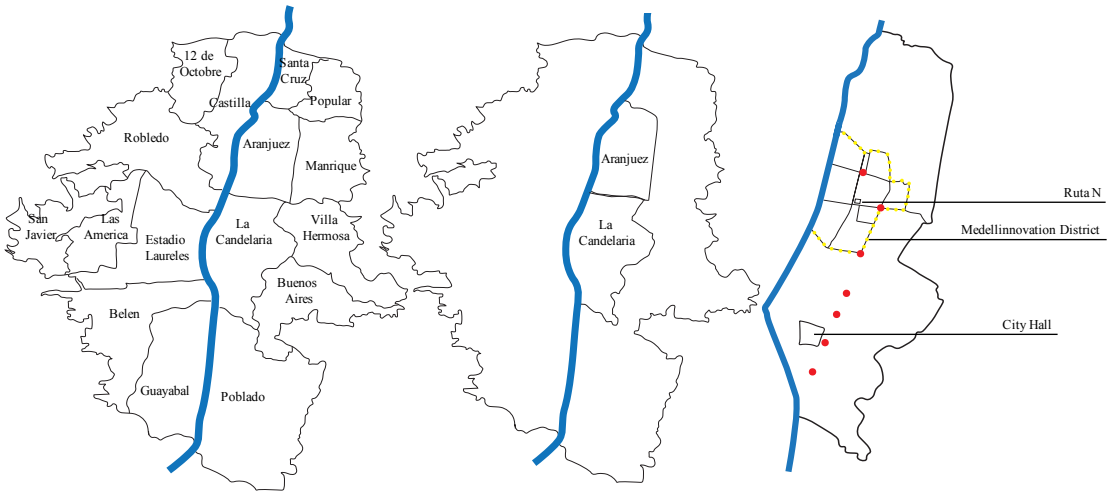
The Ruta N building complex is located between the streets Carabobo and Cundinamarca with the street Barranquilla in the northern part of the city for three reasons. First, the *Parque Explora*, which is located in the northern part of the city, had a reserved empty lot that could be used for construction. Second, the northern part of the city was selected due to its existing infrastructures, such as the University of Antioquia, the National University in Medellín, the *Hospital San Vicente de Paul*, the *Parque Explora*, the *Parque E*, the *Parque de los Deseos*, the Botanical Garden of Medellín, two metro stations—Hospital and Universidad—and its proximity to downtown Medellín. Third, the northern part of the city of Medellín has historically been an impoverished area, concentrating most of the city's poverty and violence. Indeed, the area was known to be the city's garbage dump. Ruta N participates in the City's new north strategy (*Nuevo Norte de la Ciudad*), an urban regeneration strategy to transform the area into a business and innovation district.

The architects, Alejandro Echeverri and Emerson Marín, were selected to build the Ruta N building complex. Ruta N building complex is a 33,140-square-meter three-building complex, comprising three towers, towers A, B, and C. Tower A is a 9,300-square-meter building that is dedicated to the City, it includes: Ruta N office, UNE office, EPM office, soft-landing spaces, an auditorium, 4 conference rooms, a Fab Lab, and the ViveLab. Tower A has a rooftop with a large sitting area, Ping-Pong table, and mini-soccer field. Tower B is an 8,840-square-meter building that is dedicated to EPM-UNE research laboratories. It includes: UNE research center; UNE TV studio; CIIEN laboratories for development and prototyping, measurement and Equipment Certification, and product upgrading; the EATIC laboratories, and Nutresa VIDARIUM Research Centre for Nutrition Health and Wellness. The CIIEN, for instance, is an R&D program that involves researchers from EPM and the University of Antioquia, the Pontifical Bolivarian University, the National University, and the Metropolitan Institute of Technology. Tower C is a 15,000-square-meter building that was dedicated to Hewlett Packard Global Services Centre for Latin America. Since the departure of Hewlett Packard Global Services Centre for Latin America in 2015, the tower C is rented to international and national companies, among which Huawei, Holcim, IBM, the R&D Center of the Metro of Medellín, Algar Tech, and Hewlett Packard. The ground floor of the Ruta N building complex is open to the public; it includes: a food court with 7 restaurants and 2 cafés, a pharmacy, a bank, a tropical garden curated by the Botanical Garden of Medellín. In 2014, the building complex was certified LEED Gold (Leadership in Energy and Environmental Design) by the United States Green Building Council (Ruta N Informe de Gestion, 2014). The building was designed with sustainable construction practices, such as water and energy conservations, a rainwater harvesting system, a green façade, and solar control façade.

The construction of the Ruta N building complex officially began on June 22, 2010, and was completed on March 30, 2012 (Álvarez, 2012; González Toro, 2010; Ortega, 2010). On May 14, 2012, the first residents started to move in towers A and B (Álvarez, 2012). Before moving in the Ruta N building complex, the offices of Ruta N were first located

in the offices of Proantioquia until late 2010, and then in the EPM building. On September 19, 2012, the company Hewlett Packard inaugurated in tower C its Global Support Center for Latin America (Ruta N, 2012). Under the inter-administrative agreements, 4600022452 of the City of Medellín, 29991038156 of EPM, and 10010838167 of UNE, of November 13, 2009, the different stakeholders agree to "join efforts in constructing" the Ruta N Building Complex within 24 months (Escobar Alvarez, 2011). The City of Medellín invested a total of COP $35,000 million, EPM invested a total of COP $28,000 million, and UNE invested a total of COP $7,000 million, for the construction of the Ruta N building complex (Escobar Alvarez, 2011). The cost for the Ruta N building complex amounted to COP $70,000 million divided equally between the City of Medellín and EPM-UNE.

Figure 8. Renders of the Ruta N Building Complex. Source: alejandroecheverri-valencia.co.



Map 4. Maps of Medellín, Aranjuez and La Candelaria, and the Medellinnovation District. Source: own design.

5.2.1. Ruta N's Role in the Regional Innovation System.

Ruta N's role is to support Medellín's transformation from an industrial city into a knowledge city with the objective to support new regional industrial path development and to promote regional structural change in the economy. The creation of a public institution dedicated to Science, Technology, and Innovation implies that the benefits should be greater than the costs it generates. In other words, the potential government failure generated from intervening in the market should be compensated by limiting a wide range of failures produced by the market, namely market and system failures. The rationale for government intervention was motivated by Medellín's relative isolation from global knowledge flows. From the 1970s to 2000s, Medellín was isolated from international knowledge flows due to a period of extreme violence, as well as due to idiosyncratic cultural, social, and geographical factors. The isolation contributed to the cognitive and political lock-ins of the industrial sector, which hindered the region's paths creation and paths branching into more knowledge-based activities. Regions on the knowledge periphery have limited access to extra-regional knowledge and absorptive capacity, which contribute to system failures and require, as in the case of Medellín, some sort of policy intervention. Ruta N was created out of a specific context. Indeed, Medellín has been relatively isolated from the global knowledge flows, which has been accentuated by specific geographical, social, and institutional barriers that limited the acquisition, absorption, and the diffusion of extra-regional knowledge into its RIS.

The city of Medellín is located in a mainland valley surrounded by majestic mountains. This specific geographic dimension has led the city to not only be relatively isolated from the rest of the world but also from the rest of Colombia leading to nurture the idiosyncratic "Paisa culture". In 2018, according to Google Maps, the city of Medellín is located by car at 7 hours and 44 minutes from Bogotá, 7 hours and 39 minutes from Cali, and 7 hours and 9 minutes from Turbo, the nearest seaport (maps.google.com). The transportation infrastructures have, however, considerably improved over the years. Indeed, the transportation time needed to reach Bogota, Cali, or the nearest seaport and port hubs, such as Cartagena, used to take double, triple, or even quadruple the time. Air transportation was seen as the mean to connect Medellín to the outside world due to the

city's challenging topographic and geographic dimensions. The *Olaya Herrera* airport opened in 1932 and is located within the city of Medellín. The *Olaya Herrera* airport has, however, limited capacity and is not adapted to large commercial airplanes. In 1985, the *José María Córdova* international airport was inaugurated to allow the landing of larger commercial airplanes and to increase the passenger and cargo capacity and movement. As of 2018, the *José María Córdova* international airport has only 11 international destinations, which means that international travelers often have to take a connecting flight to reach Medellín. The geographic and topographic isolation contributed to nurture the "Paisa culture", which is characterized by the proudness and inward-looking culture of its inhabitants, the elite's sense of paternalism, family, hardworking, and entrepreneurial values, and the kindness and friendly spontaneity of its inhabitant towards the foreigners who express their affections for Medellín and the Paisas. As put it Juan Pablo Ortega, former Ruta N director, "for the MIT faculty and students, the world is a village. For the Paisas, this village is the world" (Juan Pablo Ortega, Ruta N, personal communication, July 7, 2017).

The city of Medellín has experienced from the late 1970s to the early 2000s, a period of extreme violence. In 1991, at the peak of violence, there were 381 homicides for 100,000 inhabitants making the city of Medellín, the most dangerous city in the world (Hylton, 2007). The violence was the outcome of multi-dimensional conflicts between narco-traffickers, right-wing paramilitaries, left-wing insurrectionary militias, criminal gangs, and the State. In the late 1980s and 1990s, the city was a no-go-zone for international visitors, businessmen, and investors excepting for DEA agents, shady businessmen, and thrill-seekers. The extreme level of violence in Medellín occurred in a period of increasing globalization for most developed and developing countries around the world. The sheer level of violence contributed to further isolate Medellín, at a time in which integration in the world economy was imperative to reap the early benefits of the process of globalization. The violence has thus hindered the diffusion of extra-regional knowledge into the city.

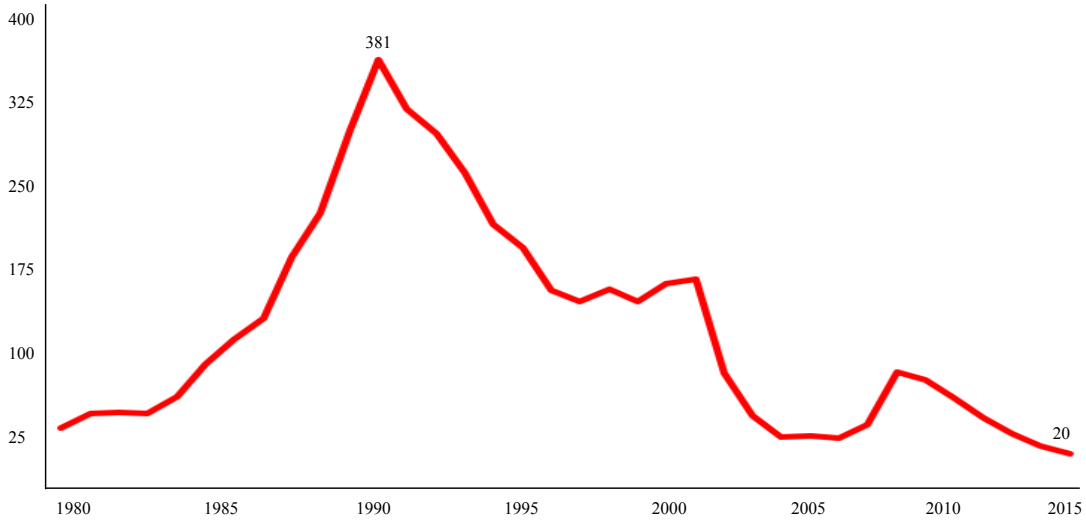


Figure 9. Homicide Rate per 100,000 inhabitants in Medellín from 1980 to 2015. Source: City of Medellín (2018).

The industrial, business, and political elites have traditionally been protective of their regional interests by limiting the number of foreign investments in the region. The *Grupo Empresarial Antioqueño* (GEA), a Keiretsu-like conglomerate where Antioquia

companies have cross-ownership dubbed *The Other Medellín Cartel*, has since the late 1970s consciously limited the amount of extra-regional investments into the region (Lane, 1996). The GEA includes the largest companies in the Antioquia region and represented around 5.5% of the Colombian GDP in 2008 (Gutiérrez, 2008). Helmsing (1990) argues that the low level of foreign direct investment (FDI) in Antioquia greatly contributed to the stagnation of the Antioquia industry. Indeed, foreign companies have favored investing in Cali or Bogotá due to the regionalist attitude of the industrial elite and the region's relatively high labor costs (Helmsing, 1990). The limited role of foreign capital in Medellín's industrial success also contributed to a shared sense of pride among the industrial elites and the population (Helmsing, 1990). In addition, the protectionist nature of the industrial elite allowed to limit the inflow of undesirable competitors, while continuing to expand their operations internationally (Helmsing, 1990). The protectionist nature of the industrial elites was enabled by a shared social and cultural capital. Indeed, the industrial elites come from families that have preserved their wealth for generations, that have developed a close proximity with the public sector to protect their vested interests, that have graduated from the same universities, such as the University of Antioquia, University of the Andes, or EAFIT University; that have country houses (*fincas*) in Rionegro, Retiro, or La Ceja, and that are members of the *Club Unión* and *Club Campestre* (Hylton, 2007; Maclean, 2014; Restrepo Santamaria, 2011). As a result, to be part of the Antioquia elites, one's must not only possess the economic but also the social and cultural capital. For instance, Pablo Escobar could not enter the *Club Campestre*, a traditional elite club, despite being far wealthier than any other member.

In summary, the four most important factors that have contributed to isolate Medellín from extra-regional scientific and technological knowledge are, the geographic and topographic dimensions that have nurtured an inward-looking culture, the period of extreme violence in the late 1970s to the 2000s, and the elite's protectionist nature that has reduced foreign direct investments into the region. This relative isolation has not only contributed to reducing the amount of extra-regional knowledge into the region but also the regional absorptive capacity. The primary rationale for government intervention was to connect Medellín to extra-regional scientific and technological sources of knowledge in order to accelerate Medellín's transformation into a knowledge city.

Proantioquia, the GEA's unofficial philanthropic foundation, was the most important actor in the definition of Ruta N's role in the RIS. Indeed, the most important actors in Ruta N's creation have strong links with Proantioquia, and thus indirectly with the GEA. Mayor Alonso Salazar (2008-2011) was backed by Proantioquia, the CTA was created by Proantioquia, and EPM-UNE has historical links with the industrial elite. Additionally, Ruta N's funding and budget largely come from the mandatory transfers of EPM-UNE to the City of Medellín. The spending of EPM-UNE transfers to the City of Medellín is scrutinized to the extent, that large projects using EPM-UNE funds have to tacitly be approved by the business elite.

Proantioquia (and the GEA) was motivated to create Ruta N for three reasons. The first reason is to promote the region's acquisition of extra-regional scientific and technological knowledge, to connect Medellín with leading innovation hubs, and to make the city visible to leading innovation hubs around the world. In the 1990s, the GEA began to internationalize its activities and to transition towards more service-based and knowledge-based activities. Ruta N is thus the institutional instrument to accelerate this transition. Moreover, Ruta N is serving as an instrument to acquire, diffuse, and

assimilate extra-regional scientific and technological knowledge into the region, thus strengthening the regional firms' capacity to compete abroad, while, at the same time, reducing the threat of the arrival of hostile competitors into the region.

The second reason comes from the genuine commitment of the business elite for regional economic development and the promotion of social inclusion. From 1978 to 2015, the GEA, under the leadership of Nicanor Restrepo Santamaría, assumed a paternalist vision aligned with the regional tradition to promote social and economic progress (Calle, 2015; Restrepo Santamaria, 2011). Ruta N's role was also to promote social transformation and inclusion. Since the 1990s, the economic and political elites understood the importance of social inclusion for regional economic development. More importantly, the economic and political elites also understood their roles in the socio-economic crises of the 1980s-1990s that were driven by economic inequality, the lack of public services, informal housing, and the lack of public spaces and, as a result, felt that they have a historical debt owed to Medellín's poorest neighborhoods and inhabitants (Maclean, 2014).

The third reason comes from the threat posed by "narco-elite", also known as "*clase emergente*", to the GEA's vested interests. As argued by Franz (2018), the creation of Ruta N as a public-private partnership can serve as a leverage to put pressure on the local government in the case where the local government is not aligned with the interests of the GEA but of competing elite groups, such as "narco-elite". Indeed, "narco-elite" have the resources to corrupt the political class, which can hinder regional economic development and Medellín's transformation into a knowledge city (Franz, 2018; Stone, 2016). The leaks from confidential cables from the US Embassy in Bogotá shows that "narco-groups" have indeed been successful at corrupting politicians, public officials, and police forces. Mayor Alonso Salazar actively fought against Luis Pérez who is suspected of having links with the *Oficina de Envigado* (US Embassy, 2008).

> "There wasn't an institution promoting innovation and entrepreneurship that we [Proantioquia] think has to be a permanent objective for a city like ours if we want to become more connected in the new competitive realities of Latin America and the world. We shared with the municipal government the importance of structuring a vehicle to support new entrepreneurs, especially entrepreneurs in new businesses, new technologies, new types of products and services, and for globalization" (Rafael Aubad, Proantioquia, personal communication, 8 August 2017).

5.2.2. Sources of Funding.

Ruta N's funding structure comes from five sources, namely from the city of Medellín, from EPM-UNE, from rents received from the Ruta N building complex, from agreements with partners, and from Ruta N's programs. In 2013, funds also came from the General System of Royalties, which was created in 2011 through the Legislative Act 05 amending the articles 360 and 361 of the Colombian Constitution of 1991. Ruta N was selected by the regional government to manage the General System of Royalties for Antioquia which transferred some funds from the central government to be invested in projects related to Science, Technology, and Innovation (STI) in the region. The General System of Royalties is administered and allocated from Bogotá by the Collegiate Bodies of Administration and Decision (OCAD), which comprises representatives from the local, regional, and central governments. The General System of Royalties works in a

three-step manner. First, the Antioquia region is allocated a specific amount of fund through Science, Technology and Innovation Fund. Second, Ruta N selects some projects to be funded. Third, the OCAD evaluates and approves Ruta N's projects in terms of their scientific and technological values.

Ruta N's primary source of funding comes from the City of Medellín and EPM-UNE. The City of Medellín is responsible for allocating to Ruta N the resources for Ruta N transferred by EPM-UNE to the City of Medellín. On August 10, 2012, the Medellín's Council adopted the 2011-2021 Science, Technology and Innovation (STI) Plan through the Municipal Agreement 024 of 2012, which seeks to "support, promote, and coordinate STI policies for scientific research, technological development, and innovation in Medellín with the objectives to identify and to create new knowledge-based companies" (Concejo de Medellín, 2012). The second article of the Municipal Agreement 024 of 2012 empowers the Mayor to fund the 2011-2021 Science, Technology and Innovation Plan with at least 7% of the ordinary resources coming from EPM-UNE that are transferred annually to the City of Medellín (Concejo de Medellín, 2012). Moreover, the second article of the Municipal Agreement 024 of 2012 designates Ruta N as the entity in charge of the implementation of the 2011-2021 STI plan (Concejo de Medellín, 2012). The City of Medellín has, however, never followed with the Municipal Agreement 024 in allocating 7% of the EPM ordinary profits to Ruta N and has systematically allocated less since the City of Medellín started with the Secretary of Economic Development to directly implement programs related to STI (see Table 15). After the election of Mayor Federico Gutiérrez (2016-2019), Ruta N's funding from the municipal government decreased by 60% due to the Gutiérrez administration's intention to directly implement STI projects at the Secretary of Economic Development and to prioritize other areas, such as security.

Year	Funding from Partners	Change in Percentage from Previous Year
2010	21 403 575	N/A
2011	21 601 238	0,92%
2012	27 116 700	20,34%
2013	22 389 000	-17,43%
2014	22 077 977	-1,39%
2015	30 928 113	40,08%
2016	12 310 000	-60,20%
2017	16 570 190	13,46%

Table 15. Funding from the City of Medellín and EPM-UNE Transferred to Ruta N by Year (Amount in Thousand Colombian Pesos). Sources: Ruta N Management Reports.

The Ruta N's model aimed to make the organization as financially independent as possible from the City of Medellín to limit the influence of political changes on Ruta N's strategy. In addition to the funding from its partners, namely the City of Medellín and

EPM-UNE, Ruta N is receiving income from multiple sources. Since the opening of the Ruta N building complex, Ruta N receives rents from the companies and startups located in the soft landing platform as well as rents from commercial and retail spaces located in the building (see Table 16). Moreover, Ruta N receives financial compensation from bilateral agreements, such as from the University at Wisconsin-Madison, Bancoldex, Bio Nano Center Limited, the Historic and Touristic District of Santa Marta, and the Health Institute of the Nariño Department (Ruta N, 2016, p. 92). Ruta N also receives financial compensations from the organized workshops, short courses, and training, such as at the ViveLab, Laboratorio de Creación, or the Great Pact for the Innovation. Finally, Ruta N receives financial compensations from consulting services to clients, and from selling digital animations and web services (Ruta N, 2016, p. 92). Despite the financial model to make the organization financially independent from the City of Medellín, political interference is still a source of concerns.

> "I really worry on the political dimension of Ruta N. Until now we have had excellent directors, but it is a politician who selects the director and I am worried that the next Mayor be a Luis Pérez or someone like him. The political interference in Ruta N can be quite strong which means that the entity can serve the Mayor at the political and economic levels" (Jorge Mesa, EAFIT University, personal communication, 24 July 2017).

> "I thought that Ruta N was more shielded from political changes since it always was tacitly agreed that there should be continuity from the Municipality of Medellín to back Ruta N" (Juan Camilo Quintero, Ruta N, personal communication, 23 August 2018).

	2015	2016	2017
Rents from the Ruta N Building Complex	5 504 751	7 637 378	9 557 410
Agreements (Universities, Research Centers...)	751 652	1 442 723	3 336 491
Agreement with EPM	181 319	168 051	N/A
Tuition Fees to Classes and Programs	82 580	5 862	9 174
Consulting and Other Revenues	11 235	153 145	341 780
Total	6 531 537	9 407 159	13 244 855

Table 16. Ruta N's Revenues from Rents, Agreements, Consulting, and Tuition Fees and other Revenues in 2015, 2016, and 2017 (Amount in Thousand Colombian Pesos). Sources: Ruta N Management Reports.

Ruta N has also received funding from the General System of Royalties for Antioquia to be invested in strategic STI projects in the region. On March 18, 2013, Ruta N was designated through the Agreement 004 to allocate COP $25,178 million for the execution of the Macro-Health Project, which involved 17 projects such as Articá, Tele-Health, Biobanco... On August 23, 2013, through Agreement 008, Ruta N allocated COP $4,036 million for the Solar Panel Cell Project. On October 18, 2013 through Agreement 011, Ruta N allocated COP $46,366 million in four macro-health projects. Ruta N has managed a total amount of COP $75,581 million from the Science, Technology and

Innovation Fund of the General Royalty System that was allocated by the Collegiate Body of Administration and Decision. The election of Luis Pérez Gutiérrez as Governor of Antioquia (2016-2019), who has traditionally opposed the GEA interests, decided to transfer back the management of the General System of Royalties from Ruta N to the Antioquia Region.

5.2.3. Employees and Working Areas.

In 2017, there were 64 full-time employees and 52 independent contractors working at Ruta N. The number of employees has grown from 9 full-time employees in 2010 to 64 full-time employees in 2017. The number of full-time employees peaked in 2015 with 70 employees (see Table 17). At the time, the total number of employees including the independent contractors reached 122. The number of employees has declined between 2015 and 2018 due to the decline in funding from Ruta N's partners, namely the City of Medellín. The employees have diverse backgrounds, some have experience in the private or public sectors, almost all hold a bachelor and/or a master and/or PhD degrees, mostly from the EAFIT University, University of Antioquia, or The Pontifical Bolivarian University, some have experience abroad, and some hold master from universities abroad, namely, Germany, France, Portugal, Italy, Spain, and the United States, and/or certifications from universities in the United States. From November 2009 to 2018, there has been 4 directors, Andrés Montoya (2009-2011), Juan Pablo Ortega (2011-2013), Juan Camilo Quintero, (2013-2016), and Alejandro Franco (2016-). Juan Camilo Quintero and Alejandro Franco were the former directors of Tecnnova, an organization created by the CUEE, that aims to foster collaborations between the private sector, the public sector, and universities.

Year	Director Ruta N	Full-Time Employees
2010	Andrés Montoya	9
2011	Juan Pablo Ortega	14
2012	Juan Pablo Ortega	16
2013	Juan Pablo Ortega	45
2014	Juan Camilo Quintero	63
2015	Juan Camilo Quintero	70
2016	Alejandro Franco	65
2017	Alejandro Franco	64

Table 17. Ruta N Number of Full-Time Employees per Year (not including independent contractors). Source: Ruta N Management Reports.

The organization has considerably evolved since its creation in November 2009. Ruta N was first structured around two strategic working areas: Innovation Platforms and Knowledge Business. In 2013, Ruta N added three working areas, Innovation Culture, the Medellinnovation District, and the Science, Technology, and Innovation (STI) Plan. In 2015, the working areas, Innovation Platforms and Innovation Culture were, to some extent, merged into the working area, Organizational Innovation, and the working area

STI Plan was, to some extent, merged into the working areas, Research and Development and Planning and Prospective. The working area, Planning and Prospective was created in 2014. The support functions to the working areas, namely Executive Direction, Marketing and Communication, and Administration and Finance were created in 2010. Operations was added in 2015 to supervise in a more systematic manner the strategic working areas.

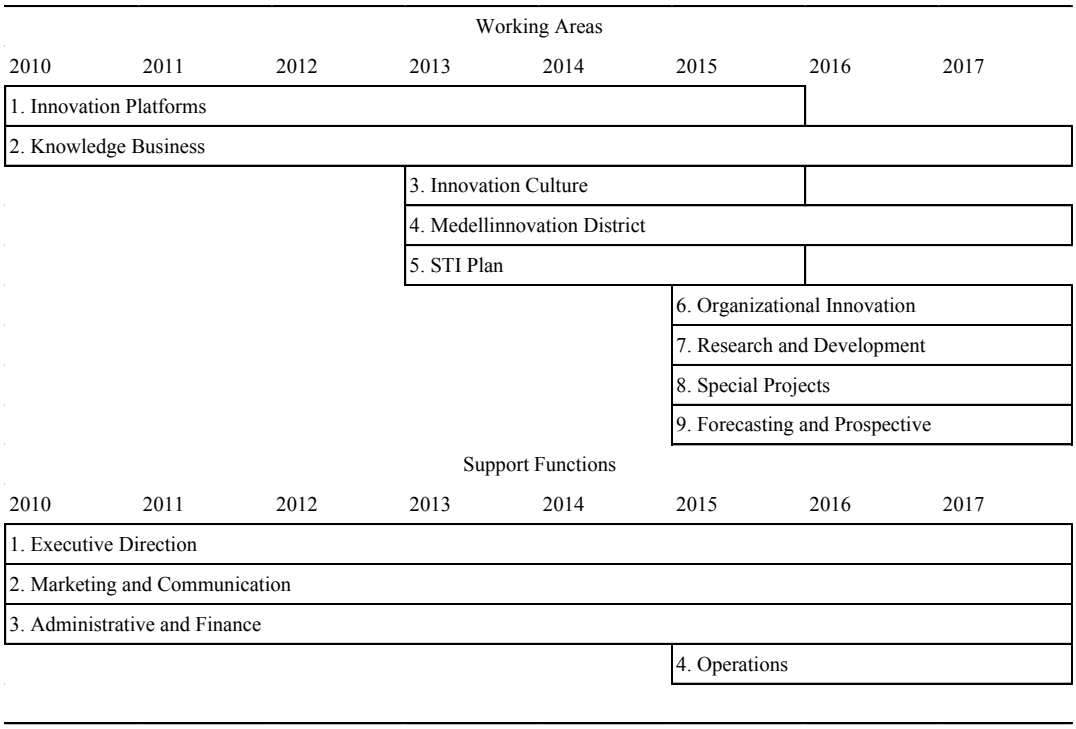


Figure 10. Ruta N Working Areas and Support Functions. Source: own design.

Ruta N's organizational chart has significantly evolved since its creation. As of 2018, the organizational chart is as followed (see Figure 11). Ruta N's director meets once a month with the board of directors to discuss strategic priorities and projects impacts. The board of directors includes the Mayor of Medellín; the director of EPM; the director of Tigo-UNE; the President of Proantioquia; Deans of universities, past board members have included, EAFIT University, University of Antioquia, and the EIA University; CEO of private companies, past board members have included, Bancolombia, Argos Group, Colinversiones, Celsia, Corbeta, Conconcreto, and Distrihogar; and nor-for-profit organizations, past board members have included, the Competitiveness Private Council and the Medellín Chamber of Commerce for Antioquia. Most of the board members are either members of the GEA (Argos Group, Bancolombia, Conconcreto, Celsia, Proantioquia...) or closely connected to the GEA (EAFIT University, EIA University, EPM-UNE, Distrihogar…). The six working areas have each an area manager who reports to the Chief Operation Director who is in charge of the daily operations and the successful completion of targets. The Director directly oversees the Chief Operation Director, and other support functions such as Marketing and Communications, and Administration and Finance.

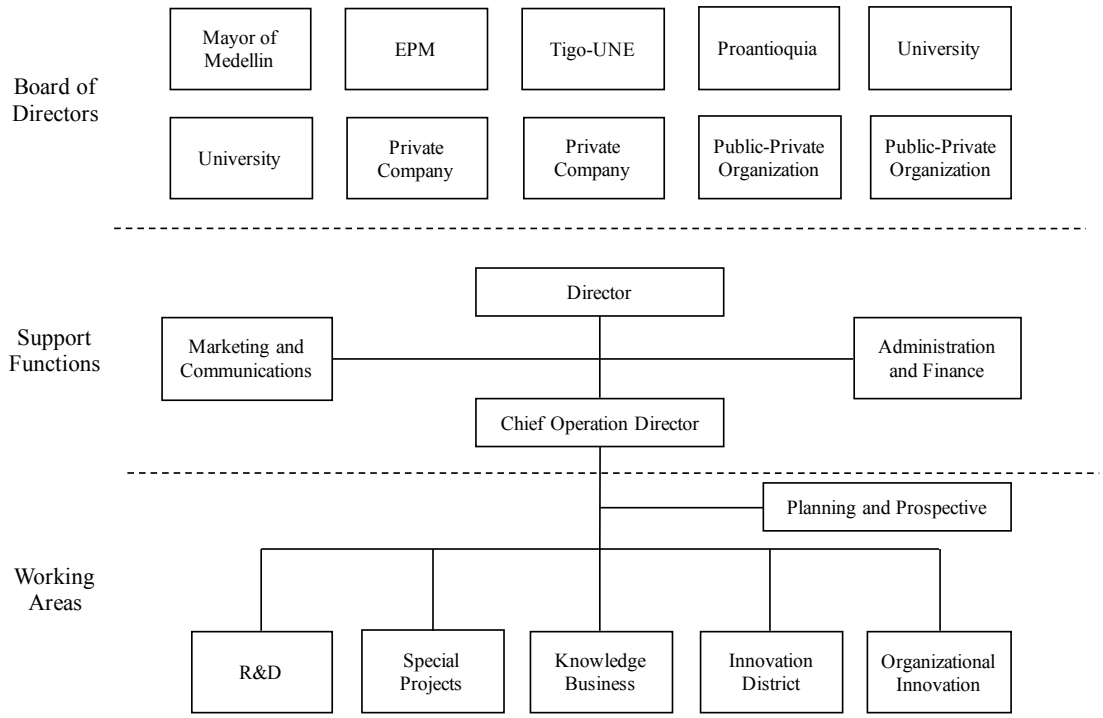


Figure 11. Ruta N Organizational Chart as of August 2018. Source: own design.

6. Evolution of the Model.

Ruta N's model has considerably evolved since its creation. The public organization was first conceived as an intermediary organization that should focus in implementing the science, technology, and innovation (STI) plan of 2011-2021 and in strengthening the capacity in science, technology, and innovation of the existing actors of the RIS. From 2012 to 2016, Ruta N has extended its mandate and developed numerous programs to accelerate the evolution of the socio-institutional structure. Moreover, Ruta N has deviated from its initial role of being an intermediary organization to directly implement programs, becoming as a result, a hybrid support and intermediary organization.

> "We [CTA] thought that Ruta N should be composed of a small team who doesn't execute projects but who thinks, a team who is more like of 'minders', who dynamizes the system and who thinks on structural topics and not on narrow programs. The primary inspiration for this model came from our own experience and what needed Medellín was not an organization to execute programs" (Santiago Echavarría, CTA, personal communication, July 12, 2017).

In 2016, with the election of Mayor Federico Gutiérrez (2016-2019), the budget of Ruta N was substantially reduced, leading the public organization to reorganize itself and to redefine its mission. Mayor Federico Gutiérrez (2016-2019) cut the budget of Ruta N for three reasons. First, Mayor Federico Gutiérrez was not directly backed by the GEA. Although he has good relations with the GEA, he was the GEA's second-best candidate after Alonso Salazar. Second, Mayor Federico Gutiérrez took notice that other actors in the RIS, among which the Secretary for Economic Development, the Chamber of Commerce, CTA, CREAME, Parque E and other actors in the RIS, complained about Ruta N directly competing in its offerings with them. Third, Ruta N has been over-promoting itself and its impact on the RIS while undermining the impact of other actors in the RIS. As a result, Ruta N's strategy since 2016 has been to pursue financial self-sustainability. Indeed, Ruta N created new programs to generate new revenues while cutting programs that didn't generate revenues, such as the working area Innovation Culture.

As of August 2018, there are discussions within Ruta N to undergo a large organizational and strategic re-structuration. At the organizational level, Ruta N is planning to have a "holacratic fluid organizational structure", which means that the organization won't be structured around working areas (see Figure 12). Project managers will be in a pool of talents who will be able to propose their own programs, which will be supervised by mentors and a project management office (PMO). The new organizational structure aims to facilitate collaboration within the organization. At the strategic level, Ruta N will consist of two strategic operational areas, Ruta N Ventures and Ruta N Experience. The two strategic operational areas will receive strategic information from the programs "marketplace" and "intelligence" that will provide dynamic strategic information on the activities to prioritize for Ruta N to respond to specific challenges facing the city. Ruta N Ventures will aim to provide capital through loans (Ruta N Capital) and to support the creation of disruptive business models to leverage on existing opportunities in the regional innovation system while aiming to respond to specific challenges that the city is facing. The disruptive business models under Ruta N Ventures have the following

characteristics. First, Ruta N and ECSIM are drafting a scoring methodology to select potential disruptive projects that would be identified in the planning and forecasting working area. Second, Ruta N drafts the business model for the disruptive project that should be relevant for the city and scalable in other Latin American markets. Third, Ruta N looks for a partner to implement the disruptive project while providing funding and taking a participation in the company. As of August 2018, Ruta N is structuring many different disruptive business models, such as Digital American Pipeline Initiative (DAPI), which is the first project to have successfully been created. DAPI is a company created as a joint-venture between Ruta N and IRPA to support the development of human capital related to artificial intelligence to transform Medellín into a hub for outsourcing artificial intelligence projects. The other disruptive business models that are being structured are, for instance, the Advance Manufacturing CDI to identify opportunities in the industrial sector, the Talent Broker to find solutions for companies to find talents, Home Telehealth to provide virtual health service to residents, PITS to be a web platform to integrate information on patients' health, Mobility as a service to offer an integrated system for smart mobility with electric vehicles in Medellín. Ruta N Experience aims to provide consulting services to private companies, namely large private companies, to develop specific innovative capabilities. Ruta N Experience aims to scale-up existing programs, such as the creation laboratory or innovation is for everyone, to favor their adoptions in large private companies

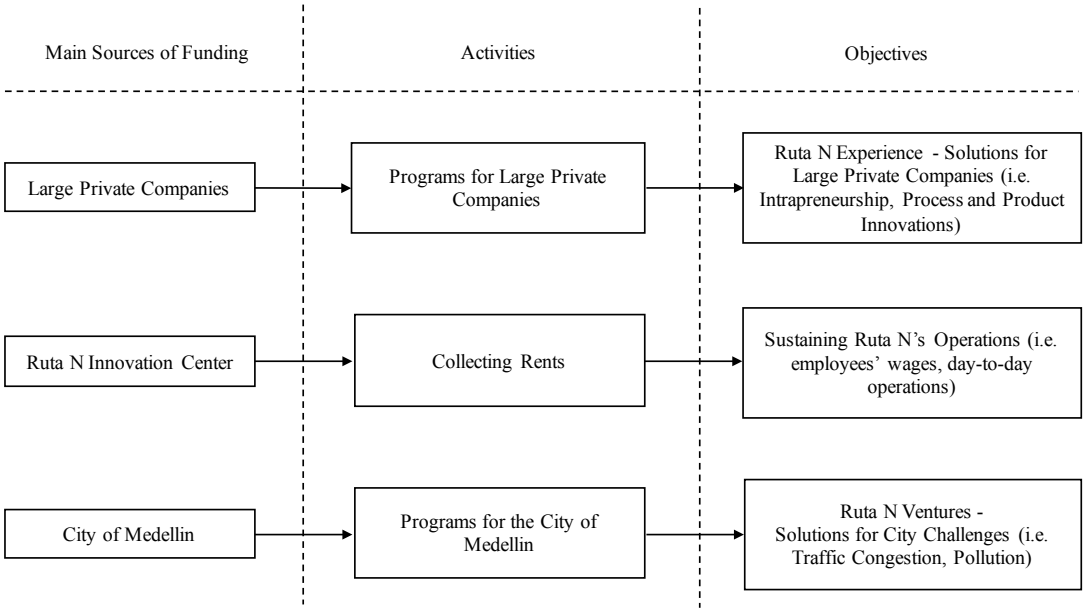


Figure 12. Ruta N's Potential Future Model in Discussion. Source: own design.

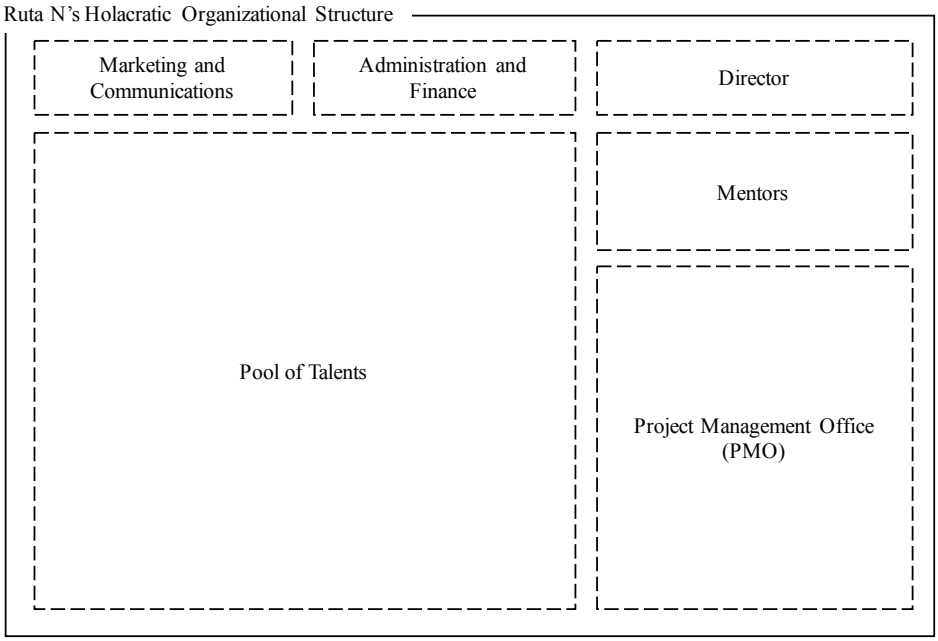


Figure 13. Ruta N's Potential Future Organizational Structure in Discussion. Source: own design.

6.1. The Ruta N Working Areas. (See appendix 6 for the List of Ruta N Programs per Working Area from November 2009 to August 2018).

Innovation Platforms (*Plataformas de Innovación*). Innovation Platforms was one of the first two working areas at Ruta N. Innovation Platforms had the objectives to strengthen the organizations implementing and/or devising formal institutions in the RIS and to the support the development of product innovations. Innovation Platforms primary targeted universities, research groups, technology development centers, technology-based incubators, and other interface entities, such as Tecnnova and the CTA, in the RIS. Innovation Platforms has implemented a wide range of programs. Innovation Platforms first involved three dimensions: knowledge management and capacity-building, network-building, and innovation culture. Knowledge management and capacity building involved the creation of an ecosystem conducive to the exchange of knowledge. Network-building aimed to establish links between local entities and the rest of the world. Innovation culture related to making the concept of innovation understandable to as many Medellín's residents as possible.

Knowledge Business (*Negocios del Conocimiento*). Knowledge Business was one of the first two working areas at Ruta N. The working area Knowledge Business aims to promote and to consolidate knowledge-based companies, namely startups and innovative SMEs, in Medellín. Knowledge Business works on three strategic axes: access to markets, access to capital, and capacity-building for knowledge-based companies. The strategic dimension access to market aims to connect local knowledge-based companies with local, national, and international markets. The strategic dimension access to capital aims to support local knowledge-based companies to access funding opportunities and sources of capital. The strategic dimension capacity-building for knowledge-based companies seeks to create a culture of continuous innovation within local knowledge-based companies.

Innovation District (*Distrito de Innovación*). The working area Innovation District was officially created in 2013. Paulina Villa, however, the current working area manager, worked at Ruta N since 2010, and some programs, such as the soft landing platform and the vision to create an innovation district can be traced back to 2010. The innovation district was first conceived as the District for Science, Technology, and Innovation that was to be located in the Sevilla District directly around the Ruta N Building Complex. In the Municipal Development Plan 2012-2015, Chapter 3 Competitiveness for Economic Development with Equity, the program the District for Science, Technology, and Innovation is officially announced (Alcadía de Medellín, 2012). The District for Science, Technology, and Innovation aims to generate the conditions for the development of knowledge-based and high-value-added companies in ICT, health, and energy in the city's "New North" (Alcadía de Medellín, 2012). The District for Science, Technology, and Innovation aims to consolidate a high-quality urban space to be attractive to investments and scientific research and thus, to nationally and internationally position the city as a knowledge city.

The northern part of the city was selected due to its existing infrastructures, such as the University of Antioquia, the National University, the *Hospital San Vicente de Paul*, the *Parque Explora*, the *Parque de Los Deseos*, and the Botanical Garden of Medellín, two metro stations: Hospital and Universidad, the Ruta N building complex, and the close proximity to the city center. Most importantly, the northern part of the city of Medellín has historically been an impoverished area, concentrating most of the city's poverty. Indeed, the Moravia district was designated in 1977 as the city's landfill, which offered subsistence jobs to many internal conflict refugees and became one of the densest and poorest neighborhood in Medellín (Ruta N, 2015a).

In 2014, the Municipal Agreement 048 was adopted, which revised and included in the Territorial Planning Plan of Medellín, the Medellinnovation District as the Sub-area 2 of the Rio Macroproject under the Strategic Intervention Area Corredor del Río (MEDRío) in the Río Centro Zone. As of 2018, the innovation district, dubbed as the Medellinnovation District, aims to regenerate an area of 172 hectares with a population in 2015 of 12,244 inhabitants, comprising the districts of Chagualo, Jesús Nazareno, Sevilla, and San Pedro (Ruta N, 2015a). The innovation district is planned around Ruta N innovation center, a 33,140-square-meter three-building complex that houses Ruta N offices, EPM-UNE research laboratories, the ViveLab animation learning center, international companies, and international startups. The Innovation District working area works on three dimensions: social, business attraction, and urban. The social dimension aims to harmonize the current districts' residents with the arrival of new creative and knowledge-based companies and workers by promoting social inclusion and community participation. The business attraction dimension aims to attract knowledge-based startups and companies, namely in ICT, health, and energy, into the innovation district. The urban dimension is to articulate the district's development and regeneration with the public institutions and private organizations located in the district.

Innovation Culture (*Cultura de Innovación*). The Innovation Culture working area was in charge of promoting the inclusive appropriation of science, technology, and innovation to the entire civil society. Indeed, the working area aimed to create and to change attitudes on science, technology, and innovation to the whole civil society, focusing mainly on students from public schools and residents from disadvantaged neighborhoods. The Innovation Culture working area wanted to include the civil society

into the Triple-Helix leading in order to form a Quadruple Helix where the civil society is an essential engine for supporting the city's transformation into a knowledge city. The Innovation Culture working area aimed through programs to influence students from public schools and residents to appropriate science, technology, and innovation on two dimensions: to inspire and to connect. Events and programs were shaped to inspire and to connect persons who were not necessarily associated with the innovation process. The two main programs of the Innovation Culture working area were: Horizons and the Medellinnovation Festival. The program Horizons was connecting and inspiring public schoolchildren and high-school students to appropriate the innovation process through gamification and competition. The Medellinnovation Festival aimed to connect the whole civil society to innovation concepts.

> "When I arrived at Ruta N, it was not clear whether 'Innovation Culture' should work on the culture at the level of citizens or companies. Because of my social work background, I focused on citizens since I wanted to bring innovations from the triple helix to the quadruple helix" (Angélica Jaramillo, personal communication, 24 August 2017).

STI Plan (*Plan CTi*). In 2013, the Science, Technology, and Innovation (STI) Plan working area was created to implement the STI plan 2011-2021. The STI plan, which was collectively drafted by leading city's leaders, has the objective "to promote and coordinate policies to support research and scientific, technological and innovative development in Medellín, with a view towards the identification and exploitation of new knowledge-based businesses" (Pineda & Scheel, 2011). The STI Plan was adopted as a public policy by the Medellín Council through the Municipal Agreement 024 of 2012, which grants, for the period 2011-2021, 7% of EPM ordinary profits to Ruta N to conduct investments and to support research and knowledge-based businesses using science, technology, and innovation. The STI Plan aims to transform Medellín into the "most innovative city in Latin America," to promote world-class universities, to foster knowledge-based companies, and to substantially increase R&D and STI spending (Pineda & Scheel, 2011). The STI Plan targets three sectors: ICT, energy, and health, which were selected on the basis of potential growth and prior capabilities. The STI Plan working area has designed programs on the following three dimensions: regional and international networks, General System of Royalties, and programs to reduce technological and scientific gaps between Medellín and innovation hubs around the world.

Special Projects (*Proyectos Especiales*). In 2015, the working area Special Projects was created to support Ruta N in generating new sources of income. The working area Special Projects is Ruta N's platform to publicize and to promote to national and international partners Ruta N's programs. The working area Special Projects comprises three dimensions: the Great Pact for innovation, consulting services, and co-creation programs. In the Great Pact for Innovation, the working area has created programs and strategies to inspire and motivate companies and organizations to pursue R&D activities while promoting the offering of Ruta N's programs. For consulting services, Special Project has packaged existing Ruta N's programs to be replicated in other Colombian cities and around the world. Special Projects offers a service portfolio to national and international clients that wish to pursue regional economic development. Finally, the co-creation programs have the objective to generate participative democracy in connecting

residents with the city of Medellín with the program MiMedellín or to connect Medellín with cities around the world with the program Citiesfor.life.

Forecasting and Planning (*Prospectiva y Planeación*). In 2015, the Forecasting and Planning working area was created as a spinoff of the STI Plan working area. The Forecasting and Planning working area is in charge of incubating and planning future Ruta N programs. The working area also monitors science, technology, and innovation for Medellín and emerging technological trends. The Forecasting and Planning working area works on three dimensions: strengthening public policies for innovation, incubating disruptive startups and programs, and monitoring the RIS. The working area supports the city of Medellín in developing public policies conducive for science, technology, and innovation activities. The working area incubates potential programs for Ruta N by developing pilot programs. Moreover, the Forecasting and Planning working area incubates disruptive business models to be converted into disruptive spinoffs for the city of Medellín. Finally, the Forecasting and Planning working area monitors best-practices in successful RISs to potentially be adapted into Ruta N's programs.

Organizational Innovation (*Innovación Organizacional*). In 2015, the Organizational Innovation working area was created to incorporate two former Ruta N's working areas, namely Innovation Platforms and Innovation Culture. The Organizational Innovation working area has the primary objective to build science, technology, and innovation capacities for private companies (SMEs and large companies), educational institutions (high schools and universities), and the government (municipality and decentralized organizations). The Organizational Innovation working area prioritized the development of science, technology, and innovation capacities for private companies over other organizations since the programs' outcomes are easier to monitor and to evaluate. Moreover, the Organizational Innovation working area has created programs to promote the development of specific high-demand skills and human capital, to support organizational innovation, and to generate capacities in intellectual property.

Research and Development (*Investigación y Desarrollo*). In 2015, the Research and Development working area was created as a spinoff of the STI Plan working area. The Research and Development working area aims to strengthen the city's science, technology, and innovation capacities in the initial phases of the innovation process. More specifically, the working area seeks to generate R&D capabilities in universities, private companies, and public institutions in the three identified sectors—ICT, health, and energy—of the STI Plan. The Research and Development working area focuses on three dimensions: co-financing STI projects, promoting regional networks, and encouraging international travels and agreements. The co-financing of STI projects involves direct funding mechanisms for specific STI projects. The regional networks engage in the creation of networks between universities, private companies, and public institutions in Key Enabling Technologies (KET). The international travels and agreements aim to facilitate international collaboration and international agreements between local research institutions and international research institutions in innovation hubs at the technological frontiers.

The agreement of cooperation for the development of the Franco-Colombian bilateral program, COOPOL, between the French Embassy in Colombia and Ruta N aims to create research networks between spin-offs, SMEs, and large companies and between both countries. The COOPOL program lasted two years and received funding from the French

Embassy in Colombia (COP $80 million) and Ruta N (COP $80 million). Ruta N also funded travels to French competitiveness poles. In 2015, 12 institutions from Medellín went to France to visit the French Alternative Energies and Atomic Energy Commission, the FEMTO-ST Institute, the University of Lorraine, the Langevin Institute, and Poma Group during 10 days to get familiar with the latest research in electric transportation and energy storage. The companies selected were Hybrytec, Creatti Labs, Celsia, Haceb, Tronex, and Asei. The international mobility program ultimately aims to favor knowledge transfer between actors in the RIS and leading technology actors and to facilitate synergies and future R&D joint-research projects.

Support Functions and Marketing and Communications (*Mercadeo y Communicaciones*). In 2010, Ruta N's support functions to the working areas, such as the Executive Direction, Marketing and Communications, and Administration and Finance were created. In 2015, Operations was created to supervise and to evaluate more systematically the working areas. The support functions are performing the required activities to support Ruta N's efficient delivery of its programs and overall management. The executive director is responsible for overseeing Marketing and Communication, and Administration and Finance, Operations, and the working areas. The executive director manages the strategic plan for Ruta N and reports directly every month to the Board of Directors. The executive director also participates at the CUEE every month and at the Municipal Meetings with other decentralized municipal entities at the Mayor's office every week. The support function Administration and Finance is in charge of human resources and overseeing Ruta N's financial budgeting. The support function Operations supervises the operational efficiency of the working areas and coordinates the different programs working to some extent as a project management office. The Chief Operations Officer continuously reports to the City of Medellín on the programs' progress and participates in the Board of Directors and at the CUEE. Among the support function, Marketing and Communication is implementing specific programs.

7. Ruta N and New Industrial Regional Path Development.

The regional innovation agency (RIA), Ruta N, has the mission to support new industrial regional path development and to promote structural change in the regional economy. Indeed, Ruta N's primary objective is to support Medellín's economic transformation from industrial into a knowledge city. The RIA was thus mandated to promote the upgrading of traditional industrial activities into more knowledge-based and service-based activities. This mandate comes from the lessons learned from Medellín's economic history. In the 1970s and 1980s, Medellín experienced a situation of cognitive and political lock-ins of its industrial sector, which ultimately led to the city's worst economic and social period in its history. In the 1990s, the city's economic structure was reorganized towards more service-based and knowledge-based activities from the GEA understanding that lasting economic growth and social well-being would only come from developing strong and growing knowledge-based and service-based activities. As pointed out by a Google Manager in a talk at Ruta N, "the Paisa is famous for its entrepreneurial spirit, and it is the view that we have had for the last 50 years. No large company, however, has emerged in Medellín in the past couple of decades. That is what Ruta N is trying to make it happen through bringing together young entrepreneurs who want to solve global and regional problems" (as cited in Ruta N, 2013). The RIA has pursued new industrial path development in six different sectors, including path branching and path creation. The sectors that have been selected for path branching, which are sectors that already existed in the region but that needed to be upgraded, are, ICT, health, and energy. The sectors that have been selected for path creation, which are sectors that did not exist in the region are, nanotechnology, digital animation and video games, and to a lesser extent biotechnology.

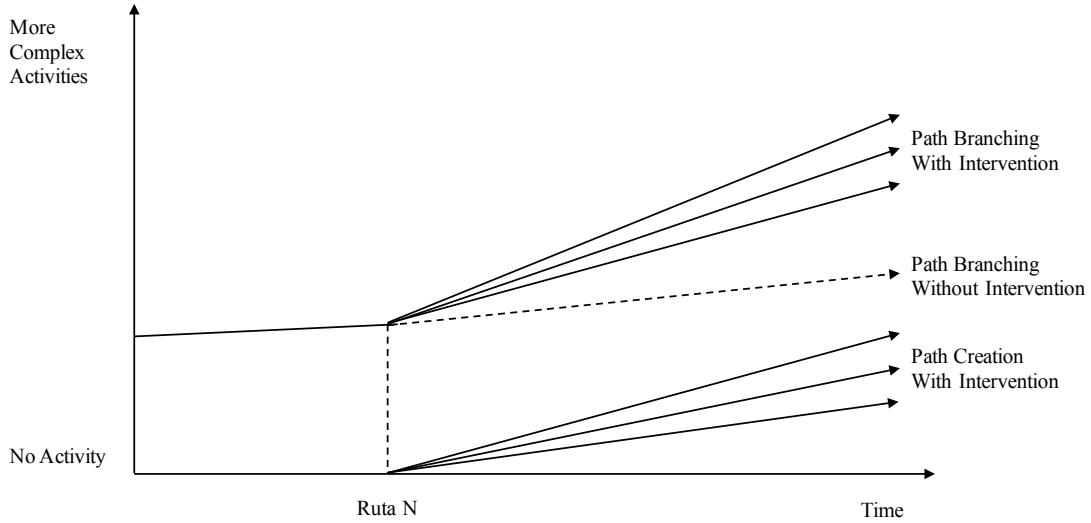


Figure 14. The Policy Objectives of Promoting New Industrial Path Development. Source: own design.

7.1. Path Branching.

The regional innovation agency is in charge of implementing the Science, Technology, and Innovation (STI) plan 2011-2021, which was drafted in 2010 from a collective effort involving more than 250 regional leaders, namely entrepreneurs, business leaders,

policymakers, and academics to identify new industrial path development. The STI plan has the objective "to promote and coordinate policies to support research and scientific, technological and innovative development in Medellín, with a view towards the identification and exploitation of new knowledge-based businesses" as well as to transform Medellín into the "most innovative city in Latin America" (Pineda & Scheel, 2011). The STI plan was adopted as a public policy by the Medellín Council through the Municipal Agreement 024 of 2012, which granted, for the period 2011-2021, 7% of EPM ordinary profits to Ruta N to conduct investments and to support companies and research organizations in science, technology, and innovation. The STI plan targets three sectors, ICT, energy, and health, which were selected on the basis of potential growth and prior capabilities.

Ruta N's mission is to support three existing sectors—ICT, energy, and health—to branch into more complex activities. Ruta N has thus developed many programs to support path branching in ICT, energy, and health. Ruta N's working area STI Plan and now R&D and Forecasting and Planning are in charge of promoting new industrial path development in ICT, energy, and health. Ruta N has supported path branching in ICT, energy, and health through facilitating the emergence of intra-regional and extra-regional networks, through facilitating access to capital and co-financing specific innovative projects, and through facilitating the identification of technological and scientific opportunities. In many cases, Ruta N has been supporting the identification, acquisition, diffusion, and exploitation of extra-regional technological and scientific knowledge.

Ruta N has supported path branching in the ICT, energy, and health sectors through devising programs to respond to weaknesses in the Technology Readiness Levels (TRLs), which are "indicators of the maturity level of particular technologies", of the actors in the three sectors (European Commission, 2016). For the identification of opportunities, Ruta N has launched the Science, Technology, and Innovation Observatory as an information system for companies, universities, and research groups to identify and screen potential opportunities, markets, and partners in ICT, energy, and health. The opportunities are identified through the Technological Watch and Competitive Intelligence network, Tecnnova, and Ruta N, and are relative to the technological conditions of the local and global markets. In research and development, Ruta N operates Cooperation N to provide travel grants to companies and research groups to conduct research abroad and thus to build networks with technological leaders. Ruta N has created programs targeting actors in the RIS, such as SMEs, startups, and research groups, to upgrade their capacities, for instance, in developing prototypes, in the commercialization process, in the protection of intellectual properties, or in their internationalization. In many cases, the programs were implemented by various international actors from knowledge hubs to transfer knowledge to the local actors. Ruta N also provides co-financing opportunities to actors in the ICT, energy, and health sector. To illustrate the role of Ruta N in the RIS, one project, for instance, was the Telemedicine project in the health sector initiated by the University of Antioquia. Ruta N supported the project through providing funding, screening for potential international partners that are leaders in telemedicine, facilitating the collaboration of local actors with the Open University of Catalonia (Spain), and supporting the effective absorption of extra-regional knowledge to the local actors by continuously monitoring the project.

7.2. Path Creation.

Ruta N is also supporting path creation in the nanotechnology, in the digital animation and video games, and the biotechnology sectors. The nanotechnology, digital animation and video games, and biotechnology have been selected from their perceived potential growth and strategic importance in the RIS since the region didn't have significant prior capabilities in any of the three sectors. The new industrial path development were selected from diverse opportunities that have emerged from various actors in the RIS. In paths creation, Ruta N has relied on external partners to share the risk of the potential path development failure. Ruta N has actively pursued the creation of nanotechnology and digital animation and video games as new industrial path development in the RIS with a wide range of programs and important resources to activate their development and growth. The pursuit of biotechnology as new industrial path development in the RIS has received fewer resources from Ruta N.

7.2.1. Nanotechnology.

The pursuit of nanotechnology as a new industrial path development came from the leadership of EPM. In 2011, EPM pursued the initiative of launching the National Center for Nanotechnology in collaboration with Professor Arvind Raman from the Birck Nanotechnology Center at Purdue University, United States (Montoya Mejía, 2015). In 2011, EPM-UNE and Purdue University announced a partnership to build the National Center for Nanotechnology in Medellín modeled after the Birck Nanotechnology Center at Purdue University (Dinero, 2011). In 2013, EPM even pledged to invest COP $50 million in the National Center for Nanotechnology. EPM decided, however, to transfer the leadership of creating the National Center for Nanotechnology to Ruta N (Montoya Mejía, 2015). In 2013, EPM, Colciencias, Ruta N, and various Colombian universities organized a workshop on Nanotechnology in the Ruta N building complex with representatives from General Electric, Purdue University, Cornell University, and the University of Texas at Austin. The speakers presented the latest technological innovations in Nanotechnology and defined a strategic roadmap to foster the nanotechnology sector and to build a National Center for Nanotechnology in Medellín.

Since 2013, Ruta N has created various programs to develop the infant nanotechnology sector. The programs have involved, creating of the National Center for Nanotechnology (CN2), establishing courses for high-school students, organizing events, and promoting networks between regional triple-helix actors. In 2014, the working area Innovation Culture launched the program Interchange targeting public high-school students to develop skills in nanotechnology through bringing voluntary international faculty from the Birck Nanotechnology Center at Purdue University to Medellín to teach at the Spanish Library in one of Medellín's poorest neighborhoods. The winning high-school student team traveled to Purdue University to participate in the Scientific Camp Pulsar II in Summer 2014. Ruta N also communicated widely on the importance of nanotechnology for the city and organized specific events during the Medellinnovation festival on nanotechnology. In 2013, Ruta N launched the program Regional Innovation Initiatives (RII) to promote interactions between public institutions, private companies, and universities in diverse Key Enabling Technologies (KETs). The Nano N was the first RII to be created and involved the participation of 15 companies and 13 universities in 2013.

In 2015, Tecnalia (Spain) was contracted to draft a viable business model for the National Nanotechnology Centre to be implemented by a local actor. The business model was, however, too European-centered, especially in its financing structure. The Forecasting and Planning working area decided to create the disruptive business model program to restructure the business model to adapt the CN2 business model to the Colombian context. In March 2018, the CN2 was opened to support the mass adoption of nanotechnology in the city and works as a one-stop shop for companies in the field of Nanotechnology. It involves a network of experts in the field of Nanotechnology to provide services to companies. In 2017 and 2018, the CN2 surveyed companies to map and understand the local capacities and demand for Nanotechnology. Additionally, the CN2 is partnering with MIT ILP to exchange best-practices and have access to MIT ILP network. As pointed out by Elkin Echeverrí, director of the Forecasting and Planning working area, "the National Center for Nanotechnology is a one-stop shop in which we can give you all the services that you require with easy understanding and leaving the mysteries and complex jargons aside. You can contract here the services that give you the capacity to move forwards with Nanotechnology. It is very important because it is through appropriation that Medellín will transform itself into a leader in Nanotechnology" (Ruta N, 2018b).

7.2.2. Digital Animation and Video Games.

The pursuit of the digital animation and video game industry as a new industrial path development was the result of chance rather than a joint strategy among the innovative actors of the RIS. The idea to pursue the digital animation and video game sector came from the recommendations made by Diego Ángel, an entrepreneur originally from Medellín, who created his startup in the United States. Diego Ángel created the digital animation and video game publisher startup Angel Studio that was later sold in 2004 to Rockstar Games for USD $38 million (Dinero, 2013). In 2009, Horacio Vélez de Bedout, the CEO of UNE, invited Ángel to collaborate as an external consultant with Ruta N (Dinero, 2013). For Ángel, Medellín and Colombia as a whole had the potential to develop a strong digital animation and video game industry. Indeed, Guatemala, which was used as a case study for designing the digital animation and game video strategy, has a thriving industry and is working on projects for Pixar Animation Studios and Walt Disney Studios among others. From Ángel's recommendations, the national strategy, led by the Ministry of ICT and Colciencias—Vive Digital—was established. The ViveLab, which is one of the programs under the Vive Digital strategy from the Ministry of ICT, were established across the country to generate capacity building in digital animation and video games. The ViveLab Medellín has received more than COP $100 million to give courses in digital animation and video games. The ViveLab was opened in October 2013 in the Ruta N building complex with delegates from the City of Medellín, Colciencias, the Ministry of ICT, and Ruta N.

> "For digital animation and video game sector, we looked at the Guatemalan case where there were startups producing movies for Hollywood, such as Narnia. An entrepreneur from Guatemala came to Medellín, but we quickly understood that the companies in Medellín had to be consolidated since they lacked in resources, capacities, and organizational skills. That is why we came with the idea to bring Pipeline Studios that then located in Pascual Bravo" (Jorge Mesa, EAFIT University, personal communication, 24 July 2017).

Ruta N has supported path creation in the digital animation and video game sector by attracting international companies, providing specialized courses, and organizing events. Ruta N with the City of Medellín and PROCOLOMBIA persuaded the Canadian digital animation and video game company, Pipeline Studios, to outsource some of its activities to Medellín by granting various monetary and non-monetary benefits. In 2010, Pipeline Studios arrived in Medellín and was first located on the campus of the Pascual Bravo Technological Institute, before being relocated to the Ruta N building complex. Ruta N has also provided courses and training in digital animation and video game in the ViveLab, a training center located in Ruta N building complex with 27 workstations. International experts from Naska Digital (Bogotá), the University of Southern California (Los Angeles, USA), Unity 3D (San Francisco, USA), Pipeline Studios (Canada), Paramotion (Spain), BWStudios (Argentina), and many others, came to Medellín to teach classes at the ViveLab. Ruta N has also supported in collaboration with Colciencias and the Ministry of ICT, programs such as Apps.co and With Vive Digital Medellín, Talents are in IT to train professionals in design thinking and software development. Ruta N also promoted events around digital animation and video games during the innovation week as well as communicating on the digital animation and video games sector in Medellín and Colombia.

7.2.3. Biotechnology.

The pursuit of the biotechnology sector as a new industrial path development was the result of the leadership from the University of Antioquia. Indeed, the University of Antioquia has a strong research capacity and leading research groups in biotechnology. In 2008, the CUEE decided, as a result, to strengthen the emergence of spinoffs in biotechnology with the creation of Business Center in Biotechnology (CDNBio). Ruta N has supported the biotechnology sector with much fewer resources than the other new industrial path development to the extent that the biotechnology has been for Ruta N a lesser strategic sector than the other five sectors. Ruta N has supported the creation of the Business Development Center (CDN) in biotechnology, Biointropic, through a public call to strengthen the entity in building capacities for startups and spinoffs in the biotechnology sector. Biointropic, previously known as the Business Center in Biotechnology (CDNBio), was created from various organizations and universities specialized in biotechnology, such as the University of Antioquia, EAFIT University, the National University of Colombia in Medellín, the University of Medellín, the EIA University, CES University, Ecoflora, and Superbac. Biointropic offers specialized service, such as competitive intelligence, seed capital, acceleration, networking opportunities, and events for companies in the biotechnology sector. Since 2014, Biointropic has supported with financial resources more than 70 companies. Ruta N and Biointropic have promoted the elaboration of the technical report “Medellín BIOTEC2032” to explore strategic opportunities for the city in the field of biotechnology. Moreover, Ruta N through the STI Observatory has provided competitive intelligence and technology watch documents in biotechnology. Ruta N has also through the program Talent N provided a scholarship to Vanessa Restrepo Schild to conduct research in biotechnology at Oxford University. Vanessa Restrepo Schild is frequently hailed in various events and Ruta N communications as an aspirational leader for students in Medellín.

7.3. The Evolution of the New Industrial Path Development.

Ruta N's strategy to support new industrial path development has heavily relied on acquiring, exploiting, and diffusing extra-regional technological and scientific knowledge. The degree to which extra-regional knowledge was acquired depended on whether the new industrial path development already existed in the region. For path branching, extra-regional knowledge has been acquired to respond to specific weaknesses in ICT, health, and energy to strengthen local capacities. The extra-regional knowledge has been acquired to permit the process of recombination with local capacities and thus to facilitate the generation of technological innovations. The acquisition of extra-regional knowledge reduces technological lock-ins and strengthen the capacity of the new industrial path development to move towards new technological opportunities. For path creation, the digital animation and video games and the nanotechnology sector have heavily relied on the extra-regional knowledge to build capacities and extra-regional actors to implement programs.

In path branching, from 2007 to 2017, the number of companies in the ICT, health, and energy sectors have rapidly increased (see Table 18). Concerning path creation, although the nanotechnology sector has had some moderate success, the digital animation and video game sector has thus far failed to generate notable results. In the nanotechnology sector, Ruta N has opened the National Center for Nanotechnology in March 2018 to support the mass adoption of nanotechnology. The number of actors that have participated in the regional innovation initiative in nanotechnology has grown from 28 in 2013 to 60 in 2017. In the digital animation and video game sector, the company Pipeline Studios, which was the poster child of the digital animation and video game sector in Medellín, left the city in 2016. In 2017, there were only 35 companies with more than 10 employees in Medellín that used skills related to the digital animation and video game sector, such as graphic design, software development, video postproduction, and audiovisual creation (see Table 19).

New Industrial Path Development	2007	2009	2011	2013	2015	2017	Percentage Change (2007-2017)
Path Branching							
ICT	2251	2090	2392	2811	3704	4257	89,12
Energy	884	818	1014	632	847	915	3,51
Health	1173	1254	1502	3082	3910	4215	259,34
Path Creation							
Digital Animation and Video Game*	_	_	_	338	522	616	
Nanotechnology+	_	_	_	28	44	60	

* The digital animation and video game sector includes: software development, video postproduction, graphic design, and audiovisual creation corresponding to ISIC 5820, 5912, 7410, and 9004.
+ Nanotechnology includes the actors participating in the regional innovation initiative in nanotechnology.

Table 18. Number of Companies in the New Industrial Path Development. Source: Economic Research Unit, Chamber of Commerce of Medellín for Antioquia.

	Micro	Small	Medium	Large	Total
Software Development	57	11			68
Video Postproduction	11	3			14
Graphic Design	434	20		1	455
Video Creation	79				79

Micro ≤ 10 employees, Small ≥11 employees and ≤ 50 employees, Medium ≥ 51 employees and ≤ 200 employees, Large ≥ 201 employees.

Table 19. Number of Companies in the Digital Animation and Video Game and Related Sectors in 2017. Source: Economic Research Unit, Chamber of Commerce of Medellín for Antioquia.

7.4. Ruta N's Intermediary Role.

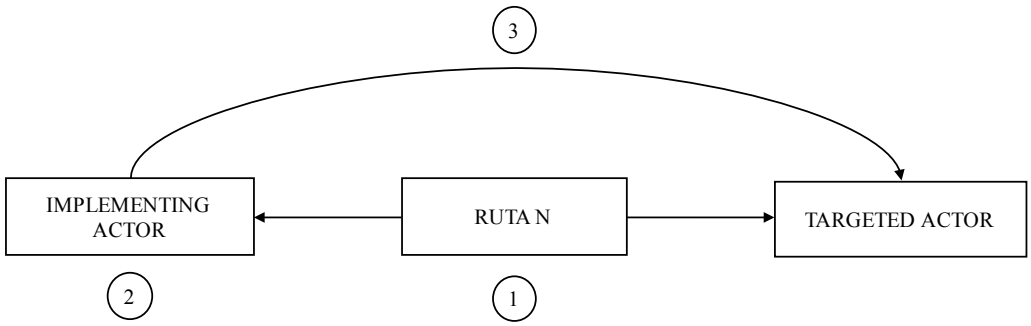


Figure 15. Ruta N's Intermediary Role. Source: own design.

A Knowledge Broker. Ruta N has supported new industrial path development by working as a knowledge broker in the RIS. Indeed, the RIA has played the role of an intermediary organization between extra-regional actors and actors within the RIS with the objective to strengthen the capacities in science, technology, and innovation of the actors in the RIS. In supporting new industrial path development, Ruta N has been performing three primary functions. First, Ruta N screens the weaknesses in the RIS and identifies the actors in the RIS to strengthen, such as private companies, public institutions, universities, technological development centers, civil society, and so on. Second, Ruta N identifies the potential regional or extra-regional actor with the capacity to strengthen the targeted actor. Third, the regional or extra-regional actor with the capacity implements a program to transfer that capacity to the targeted actor. In the words of Elkin Echeverrí, director of the Forecasting and Planning working area, "what Ruta N tries to do is: to observe the world, to determine what the regional innovation system is missing, to find the organizations with the solution, to bring them into the system, and to inject that capacity. The organizations do not come to Medellín to give a conference but have contracts to stay 6 months, 8 months, or a year" (Ruta N, 2015b). As a result, Ruta N's primary role is to act as a knowledge broker between the actors that possess the knowledge and the actors that require the knowledge. For the RIA, the brokerage of extra-regional knowledge has three objectives: first, to improve the capacity of the RIS to acquire, absorb, and diffuse extra-regional knowledge; second, to connect Medellín and Ruta N to relevant innovation hubs around the world, such as Boston, Austin, Silicon Valley, Israel, or Cambridge, to generate formal and informal networks between regional and international actors; and third, to improve the visibility of Medellín and Ruta N as a relevant innovation system in the world.

> "The strategy was to connect us to innovation hubs around the world. It was to not only make us relevant and visible but also to learn from best practices and knowledge in which they had real expertise in" (Juan Pablo Ortega, Ruta N, personal communication, July 7, 2017).

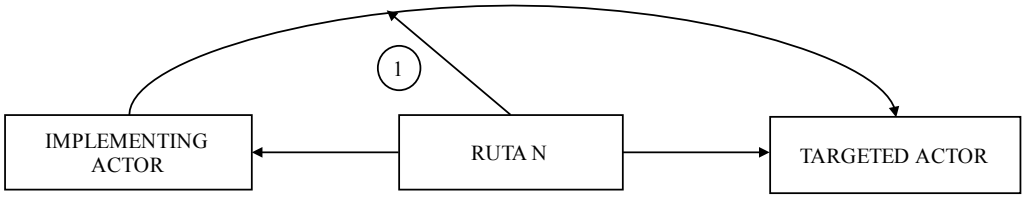


Figure 16. Ruta N's Knowledge Gatekeeper Role. Source: own design.

A Knowledge Gatekeeper. In addition to brokering knowledge, Ruta N monitors the progress of each of its program, especially when it involves an extra-regional implementing actor, thus playing the role of a knowledge gatekeeper. During the course of a program, Ruta N will make sure that knowledge is properly transferred from the implementing actor to the targeted actor. Ruta N's role is, as a result, to help the implementing actor to translate the knowledge to the Colombian's and Medellín's context in order for that extra-regional knowledge to be properly transferred and absorbed. Ruta N is thus supporting new industrial path development by working as a knowledge gatekeeper. Knowledge gatekeepers work as intermediaries between the creator of information and its users (Allen, 1977) and are thus able to operate between two coding schemes (Allen & Cohen, 1969). Knowledge gatekeepers have a dual role: the acquisition of external knowledge and its translation (Allen, 1977). Graf (2011), Morrison (2008), and Giuliani (2005), among others, have used the concept of gatekeepers within innovation systems as agents acquiring external knowledge to diffuse it within the RIS. At the regional level, knowledge gatekeepers have the capacity to establish linkages with innovative actors from other regions (Breschi & Lenzi, 2015; Graf & Krüger, 2011). Knowledge gatekeepers are seen as brokers of knowledge, allowing knowledge to flow between separate regions (Gould & Fernandez, 1989). In RIS, knowledge gatekeepers are over-exposed to sources of scientific and technological knowledge from outside their RIS. Knowledge gatekeepers are thus at the core of the information network in their RIS.

As a public knowledge gatekeeper in the RIS, Ruta N is performing three primary functions. First, the RIA is continuously monitoring best-practices in RIS around the world. Second, the RIA acts as a node in the RIS that is exposed to weaknesses in the RIS and best practices around the world. Third, the RIA has the capacity to assist extra-regional actors in translating the extra-regional knowledge to actors in the RIS. In contrast to knowledge brokers that only act as an intermediary in the acquisition of knowledge between two actors, knowledge gatekeepers support the translation of the knowledge, and thus facilitates its absorption into the RIS. Indeed, Ruta N monitors the programs implemented by extra-regional actors to ensure that the knowledge is effectively transferred and is relevant to the local context. In the case of Ruta N, its role as knowledge gatekeeper is conducted through supporting the "tropicalization" of the extra-regional knowledge, that is, through the hybridization of the tacit extra-regional knowledge with the local knowledge. Ruta N is thus the institutional arrangement and regional innovation governance structure that aims to respond to the two most significant challenges in establishing successful global pipelines. The first one relates to the

identification of the pipelines to tap into (Bathelt, Malmberg, & Maskell, 2004). The second one relates to the translation and assimilation of the information arriving through the pipelines (Bathelt, Malmberg, & Maskell, 2004).

7.4.1. Tropicalizing Extra-Regional Knowledge

The act of "tropicalizing knowledge," coined due to the city's geographic location between the tropics, refers to the adaptation of the extra-regional knowledge to Medellín's context, culture, and existing capacities to better facilitate its absorption by the actors of the RIS. Indeed, Ruta N provides continuous support for extra-regional actors, mainly from developed countries, that are implementing programs "to tropicalize" their programs to the context of the city. Ruta N's knowledge gatekeeper role is conducted by supporting the "tropicalization" of the extra-regional knowledge, that is, through the hybridization of the tacit extra-regional knowledge with the local knowledge. The public knowledge gatekeeper, Ruta N, has three roles: the acquisition of extra-regional knowledge, the "tropicalization" of that knowledge, and the diffusion of that knowledge into the RIS.

Every month Ruta N organizes the Ruta N Open House event to connect entrepreneurs and students to some of the main actors in the RIS, such as *CREAME*, *ANDI*, *Parque E*, *Social Atom*, and *Ruta N*. During the Ruta N Open House held on August 31, 2017, the speaker from Ruta N told the diverse audience, including students, local residents, knowledge workers, and entrepreneurs on how Ruta N defines innovation, "we took the definition of innovation from the Oslo Manual that is used by the most developed and the most competitive cities in the world and adapted it to our context in Medellín in order for it to make sense to us." For Ruta N, innovation is defined as "a new idea and billing", in other words, the generation of economic value-added to the exploitation of a new idea (Ruta N, 2014). Ruta N in defining innovation was, as a result, "tropicalizing" extra-regional knowledge, that is, adapting extra-regional knowledge to make it relevant and understandable to the audience. This event illustrates Ruta N's role and mission as a knowledge gatekeeper to improve the region's absorptive capacity to extra-regional knowledge.

Ruta N's knowledge gatekeeper role of "tropicalizing knowledge" was highlighted in many interviews.

> "our [Ruta N] greatest effort was to ensure that the knowledge was relevant to the context of the city. That is, not doing the program in the same way it is done in Austin, Texas. That what we did with IC^2, we were super demanding with them and they were quite surprised, telling us, they always were transferring the methodology in the same way. We told them, let's check if it has meaning for the conditions of Medellín, Colombia, and Latin America. We were like partners, building together the program" (Juan Pablo Ortega, Ruta N, personal communication, July 7, 2017).

> "Ruta N has a particularity in that we have connections with many different entities around the world. What we do is, we capture experience, we capture knowledge, and we bring it to Medellín while obviously transforming it to the Colombian context [...] so we always seek to culturize or tropicalize, to

> say in that way, all this knowledge to our realities" (Andrés Calle, Ruta N, personal communication, July 26, 2017).
>
> "A business development center is a public or private entity that is in charge of supporting projects to bring them to the market in a way that is financially viable with a global reach. It is more or less the same thing as an acceleration process but with implications much more rooted in the Colombian culture" (Susana Ortiz, Ruta N, personal communication, 4 August 2017).
>
> "In 2015, we [Ruta N] contracted the Spanish firm Tecnalia to design a business model for the National Centre for Nanotechnology. The business model was very well done but had one important flaw in that it was very European centered, especially in its financing structure. What we did is, take part of the model and adapt it to our context" (Melisa Arango, Ruta N, personal communication, July 17, 2018).

Ruta N has, however, faced some difficulties in "tropicalizing knowledge" due to a lack of internal capabilities in contextualizing extra-regional knowledge and a misunderstanding of its core knowledge gatekeeping role. In its infancy, Ruta N has also misjudged the innovative capacities of many actors in the RIS and thus their capacities to effectively absorb extra-regional knowledge, which, as a result, limited the policy effectiveness of brokering extra-regional knowledge.

> "They [Ruta N] brought very skilled experts in different fields of innovation. I remember well the Israelis who came to Medellín to give a course that was so complex for us that the entrepreneurs were saying, 'I don't understand and don't have the capacity to assimilate what they are offering'" (Rubén Cadavid, Medellín Chamber of Commerce for Antioquia, personal communication, August 3, 2018).
>
> "The program led by the Founder Institute brought really successful entrepreneurs from the Silicon Valley. The local entrepreneurs, however, were unprepared to really take advantage of the program and the mentors from the Founder Institute didn't have knowledge of the local innovation system. I used to tell my boss that the program was like having a Renault car with Ferrari tires. The Founder Institute didn't want to adapt their program to the local needs, saying that they were conducting the same program all over the world in the same way and didn't have to adapt their program. We thus decided to hire the Argentine company NXTP Labs for the next version of the program since they had more experience in Latin America" (Catalina Gutierrez, Ruta N, July 28, 2017).

7.4.2. Diffusing Knowledge into the Regional Innovation System.

In addition to tropicalizing knowledge, Ruta N has devised programs to diffuse the acquired knowledge into the RIS. As shown by Morrison, Rabelloti, and Zirulia (2013), global pipelines are most beneficial to RIS with high-quality local buzz and weakly endowed in terms of knowledge. Ruta N is supporting interactions to diffuse the extra-regional knowledge between different actors of the RIS (see Table 20). The programs aim to foster face-to-face interactions and virtual face-to-face interactions to create a

sense of "local buzz" to diffuse knowledge between different actors in the RIS. Ruta N promotes "local buzz" through programs that specifically encourage repeated face-to-face and virtual interactions and through the creation of specific urban amenities, namely the innovation center and the innovation district. The programs aim to contribute to a sense of "local buzz" conducive to the exchange of tacit knowledge between actors within the RIS.

The programs that Ruta N has implemented to foster interactions at the regional level between quadruple helix actors, namely private companies, public institutions, universities and the civil society, are: the web platforms SUNN and Brainbook, events, such as the Innovation Week and the Medellinnovation Festival, and the Great Pact for Innovation. Interactions between triple helix actors, namely private companies, public institutions, and universities, were promoted through the Regional Innovation Initiatives (RII) that aim to activate discussions around Key Enabling Technologies (KET). Interactions between private companies-universities were promoted through the N-Lab program, the Market Access Network, or the Innovation Challenge. Interactions between public institutions-civil society were promoted through the web platform MiMedellín and MEDATA. Interactions between universities-civil society were promoted through the program Comuna Innova. Interactions between public institutions-private companies were promoted through the programs, the Innovation Laboratories for Government and Education. Interactions between private companies were promoted through the web platform SUNN. Interactions between public institutions were promoted through the web platform Cities for Life. Interactions between universities were promoted through the program Cooperation N. Finally, interactions between Ruta N and the civil society were promoted through the Open House.

Interactions between	Programs
Public Institutions-Private Companies-Universities-Civil Society	SUNN, Brainbook, Innovation Week, Medellinnovation Festival, Great Pact for the Innovation
Public Institutions-Private Companies-Universities	Regional Innovation Initiatives (RII)
Public Institutions-Private Companies	Innovation Laboratories for Government and Education
Private Companies-Universities	N-Lab, Innovation Challenges, Market Access Network
Public Institutions-Civil Society	Web Platform-MiMedellin
Universities-Civil Society	Comuna Innova
Private Companies-Private Companies	Web Platform-SUNN
Universities-Universities	Cooperation N
Public Institutions-Public Institutions	Web Platform-Citiesforlife
Ruta N-Civil Society	Open House

Table 20. Ruta N's Programs to Promote Interactions. Source: own design.

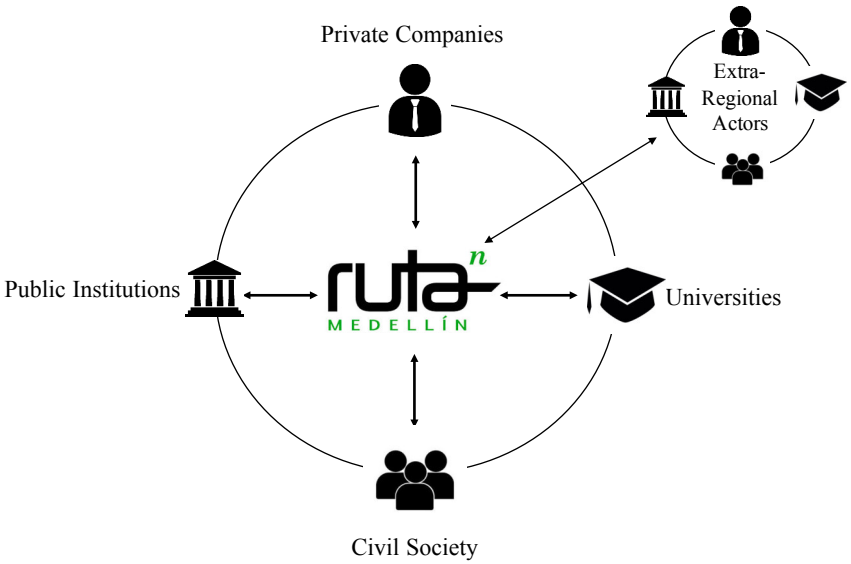
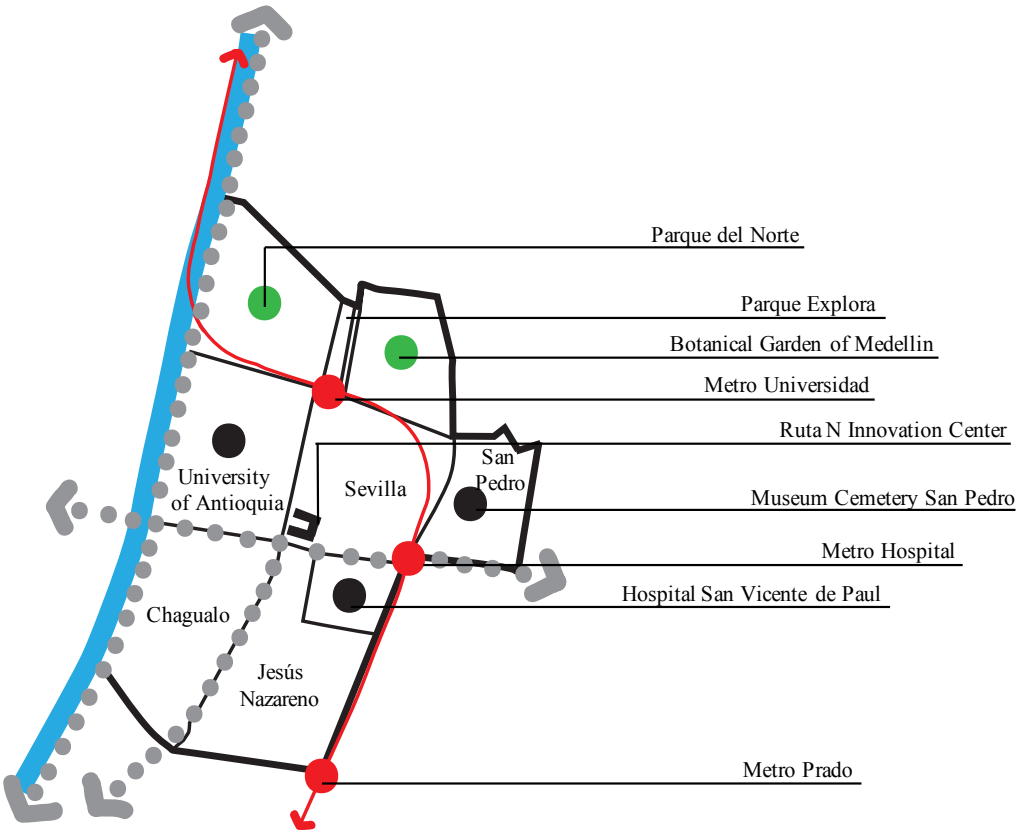


Figure 17. Ruta N's Role in Fostering Interactions in the Quadruple Helix. Source: own design.

Ruta N is also implementing urban transformations that promote face-to-face interactions between different actors in the RIS. Indeed, one of the objectives of the Ruta N innovation center and the Medellinnovation District is to encourage repeated face-to-face interactions and the spread of tacit knowledge by clustering different innovative actors of the RIS in a high-quality and high amenities urban district. The Medellinnovation District aims to regenerate a 172-hectare area around the Ruta N building complex, which serves as an anchor space for the innovation district. Indeed, the Ruta N building complex is an innovation center in which are located national and international startups, Ruta N, research centers, universities, and private companies (see Morisson, 2018). The urban component aims to facilitate repeated face-to-face interactions, serendipitous encounters, the spread of tacit knowledge, local buzz, and ultimately the collaboration between widely diverse innovative actors located in the innovation center and the innovation district.



Map 5. The Medellinnovation District. Source: own design.

7.4.3. International Partners.

The international actors that have directly been contracted by Ruta N to implement programs or to support Ruta N programs are listed in Table 21. As of August 2018, there have been 39 different international entities from 15 different countries that came to Medellín to deliver or to provide support to programs at Ruta N. The international actors mainly come from the United States and Western Europe, namely Spain and the United Kingdom. The period 2011-2014 was when Ruta N contracted many international actors. Some international actors have conducted multiple programs on different occasions, such as Kleer, Penza Perception Lab, or Idealaboratoriet, while others participated on a single program, such as T2 Venture Capital, 2Thinknow, or Desai Group. The list of international entities does not include international partners that are participating in the Market Access Network or the Smart Capital Access Network as well as other international entities that have voluntarily contributed to Ruta N programs without remuneration. Moreover, over the years, Ruta N has formally and informally contacted many international actors to discuss potential collaborations or consultancy projects. Ruta N is also on an ongoing basis conducting benchmarking of best-practices and monitoring international best-practices when designing a new program.

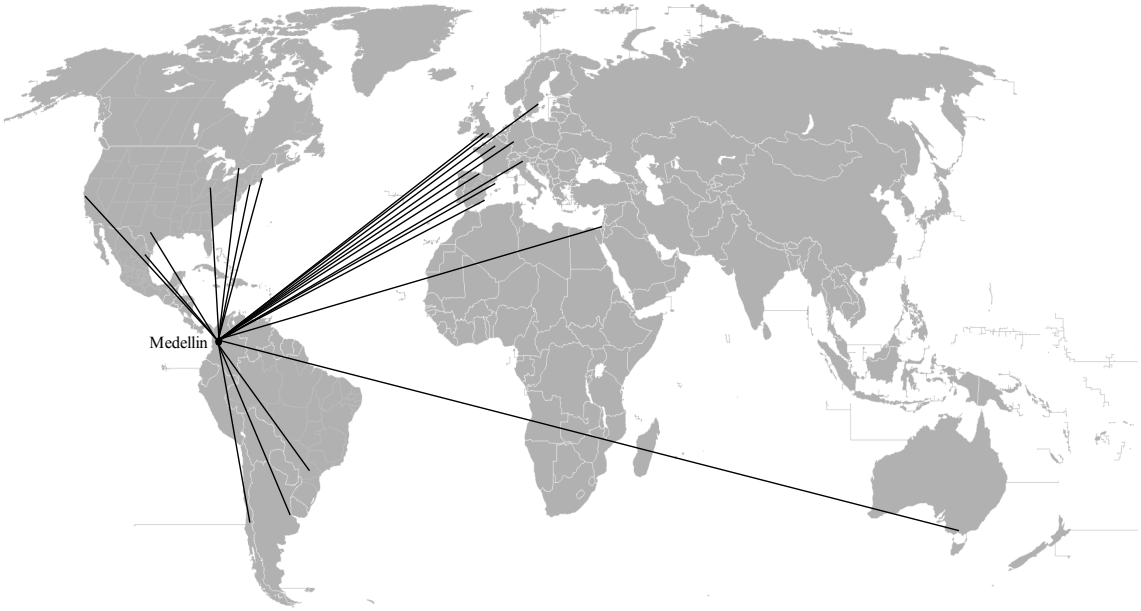
ORGANIZATION	CITY	COUNTRY	CONTINENT
KLEER	Buenos Aires	Argentina	SOUTH AMERICA
NXTP Labs	Buenos Aires	Argentina	SOUTH AMERICA
2ThinkNow	Melbourne	Australia	OCEANIA
National Institute for Industrial Property	Rio de Janeiro	Brazil	SOUTH AMERICA
Pipeline Studios	Hamilton	Canada	NORTH AMERICA
Socialab	Santiago	Chile	SOUTH AMERICA
Territories of Tomorrow	Paris	France	EUROPE
OECD	Paris/Trento	France/Italy	EUROPE
Unistaff Associates	Frankfurt	Germany	EUROPE
Penza Perception Lab	Tel Aviv	Israel	ASIA
Carlo Ratti Associates	Turin	Italy	EUROPE
EGADE-Monterrey Institute of Technology	Monterrey	Mexico	NORTH AMERICA
Polytechnic University of Valencia	Valencia	Spain	EUROPE
Instituto Tecnologico de Informatica (ITI)	Valencia	Spain	EUROPE
22@ Barcelona	Barcelona	Spain	EUROPE
Barcelona Activa	Barcelona	Spain	EUROPE
Inteligencia Creativa	Barcelona	Spain	EUROPE
4i Latam	Madrid	Spain	EUROPE
Tecnalia	Bilbao	Spain	EUROPE
IDOM	Bilbao	Spain	EUROPE
World Tech Makers	Barcelona	Spain	EUROPE
Idelaboratoriet	Malmo	Sweden	EUROPE
World Intellectual Property Organization (WIPO)	Geneva	Switzerland	EUROPE
Oxford University	Oxford	United Kingdom	EUROPE
Pearson V. T.	London	United Kingdom	EUROPE
CENTRIM	Brighton	United Kingdom	EUROPE
Cambridge Enterprise Limited	Cambridge	United Kingdom	EUROPE
Technopolis	Brighton	United Kingdom	EUROPE
IC2-University of Texas at Austin	Austin, Texas	United States	NORTH AMERICA
T2 Venture Capital	Silicon Valley	United States	NORTH AMERICA
Desai Group	Hartford, Connecticut	United States	NORTH AMERICA
Boston College	Boston, Massachusetts	United States	NORTH AMERICA
Santa Clara University	San Francisco, California	United States	NORTH AMERICA
Founder Institute	Silicon Valley	United States	NORTH AMERICA
MIT ILP	Cambridge, Massachusetts	United States	NORTH AMERICA
MIT	Cambridge, Massachusetts	United States	NORTH AMERICA
Purdue University	West Lafayette, Indiana	United States	NORTH AMERICA
Fast-Track Institute	Silicon Valley	United States	NORTH AMERICA
Babson University	Boston, Massachusetts	United States	NORTH AMERICA

Table 21. List of the International Actors that have Implemented Ruta N Programs. Source: own design.

The collaboration with international actors has, for Ruta N, three objectives. The first objective is to transfer knowledge to the regional actors in the regional innovation

system. Horacio Vélez, CEO of UNE, pointed out, "we are seeking alliances, not partnerships, which is not the same thing, we are looking to bring to the city knowledge from all over the world from world class actors such as HP, Huawei" (Ruta N, 2010b). The second objective is to connect Ruta N and Medellín to innovation hubs around the world, such as Boston, Austin, Silicon Valley, Israel, or Cambridge, and thus to generate networks between regional and international actors. The third objective is to position Ruta N and Medellín as a significant innovation system in the world.

The international actors were selected through networking, referencing best-practices, and the actor's reputation. Ruta N's employees frequently travel to international fairs and congress or participate in short professional courses abroad, namely the United States, United Kingdom, and Israel. The frequent travels to relevant international innovation systems allow Ruta N employees not only to identify and to establish contact with international actors that could participate in conducting Ruta N programs but also to examine best-practice programs that could potentially be implemented in Medellín.

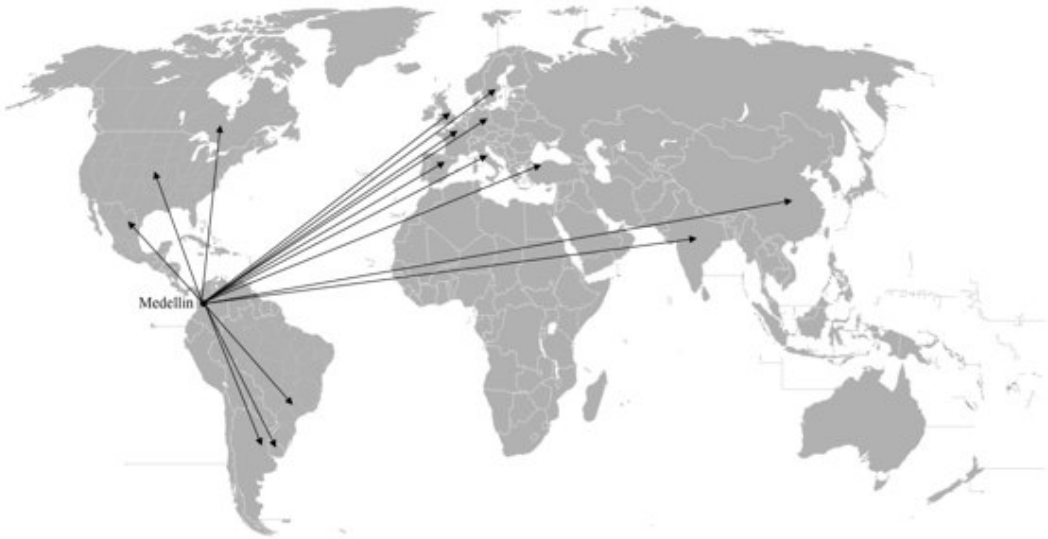


Map 6. World Map Showing where the International Actors that have Implemented Ruta N Programs come from. Source: own design.

Cooperation N. The program Cooperation N aims to upgrade regional scientific capabilities by acquiring extra-regional scientific knowledge. The program Cooperation N has two components, namely travel grants and international agreements, which both have different objectives. The travel grants facilitate local research groups to conduct international research travels at leading research groups. The travel grants are delivered at the condition of reciprocal research travels and prioritize research groups in ICT, health, and energy. Research travels have been conducted in 15 countries, namely in Argentina, Brazil, Canada, China, India, Italy, France, Germany, Mexico, Spain, Turkey, the United States, the United Kingdom, Uruguay, and Sweden. The main objectives of the travel grants are to foster knowledge transfer, international networking, and potential formal international cooperation agreements. The international agreements are agreements between Ruta N and an international partner to conduct joint research projects through joint-funding. International agreements have been signed with different countries, namely with Israel, France, Germany, Spain, and the United Kingdom.

ORGANIZATION	CITY	COUNTRY	CONTINENT
DNDi Latin America	Rio de Janeiro	Brazil	SOUTH AMERICA
French Embassy in Bogotá (COOPOL)	N/A	France	EUROPE
Max Planck	N/A	Germany	EUROPE
Fraunhofer Society	N/A	Germany	EUROPE
Israel Innovation Authority	N/A	Israel	ASIA
Innobasque	Bilbao	Spain	EUROPE
ERICA (Spain and its Regions Exchange Knowledge with Antioquia	N/A	Spain	EUROPE
Polytechnic University of Catalunia	Barcelona	Spain	EUROPE
University Hospital of Val d'Hebron	Barcelona	Spain	EUROPE
Royal Academy of Engineering	N/A	United Kingdom	EUROPE
Embassy of Great Britain	N/A	United Kingdom	EUROPE
Purdue University	West Lafayette, Indiana	United States	NORTH AMERICA
University of Wisconsin	Madison, Wisconsin	United States	NORTH AMERICA
World Bank	Washington	United States	NORTH AMERICA
Inter-American Development Bank	Washington	United States	NORTH AMERICA

Table 22. List of Ruta N International Agreements. Source: own design.



Map 7. World Map Showing the Countries that Have Participated in Ruta N Travel Grants. Source: own design.

7.5. Ruta N's Strategy for Supporting the Innovation Process.

Ruta N creates programs to support new industrial path development by addressing weaknesses in the Technology Readiness Levels (TRLs) of the specific targeted sector or subsector. TRLs are "indicators of the maturity level of particular technologies" (European Commission, 2016). In the literature, there are nine TRLs ranging from TRL 1 being the lowest to TRL 9 being the highest. Ruta N has used the TRLs in many different programs as heuristics to devise programs, and as metrics to evaluate projects and to provide funding. The TRL is used as a measurement system that provides a

systematic understanding of a technology status in the entire innovation process. In Ruta N's strategy, TRL 0, the idea, and TRL 10, the internationalization, can be added to the traditional Technology Readiness Levels (see Figure 18).

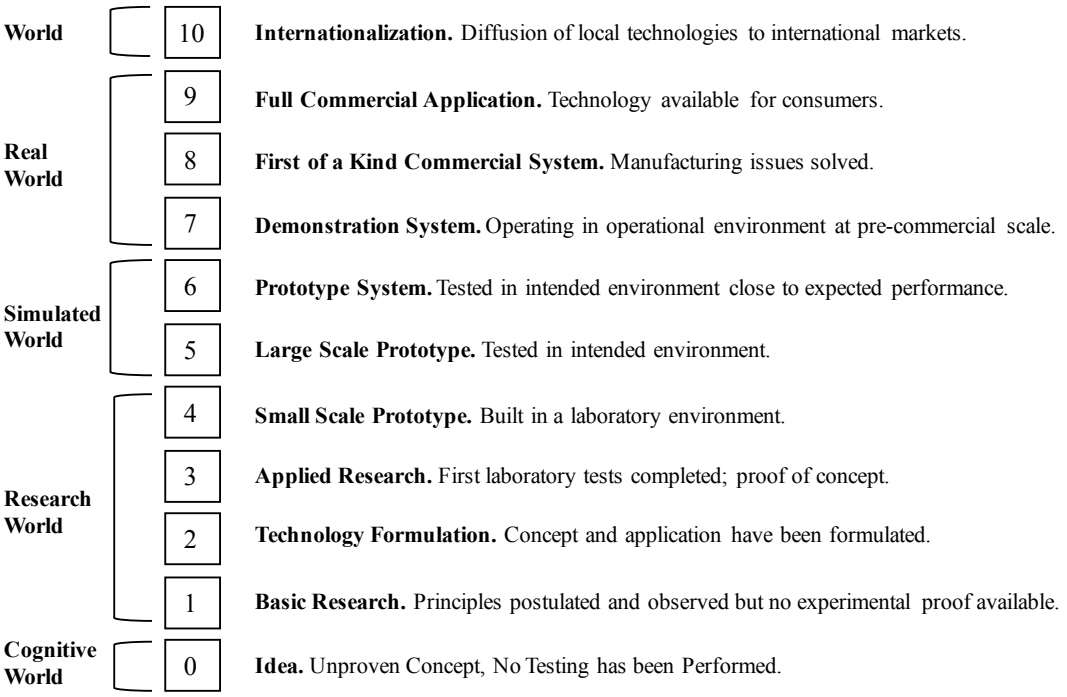


Figure 18. Technology Readiness Levels (TRLs) adapted by the author from the European Commission (2016).

Ruta N has devised and implemented numerous programs to address weaknesses in the RIS's TRL either at the level of the RIS, at the level of a sector, or at the level of a subsector with the end goal to support the technological innovation process (see Figure 19). In the language of Ruta N, this activity refers to "*cerrar brechas*", or literally to close gaps. The activity of "*cerrar brechas*" can be done at the level of the RIS, at the level of a sector, or at the level of a subsector. Ruta N has devised and implemented programs to upgrade the RIS capacities at specific TRLs that either target one element of the TRL, such as Passport N and the Market Access Network, to support local actors in their internationalization process (TRL 10). Ruta N has also created programs to support local actors to move up along the TRL, such as the Pre-Acceleration for Startups (TRL 4 to TRL 8) or the program InLab2Market (TRL 2 to TRL 8). In devising new programs, Ruta N monitors the current significant weaknesses, or "*brechas"*, in the RIS and will design a specific program to intervene in the RIS to bring the needed capacities into the RIS. The innovation process is, however, not linear. Interactions between widely diverse actors in the RIS allow to diffuse knowledge and best-practices, which would enable for recombination and thus reaching higher TRL (see 7.3.3. Diffusing Knowledge in the Regional Innovation System).

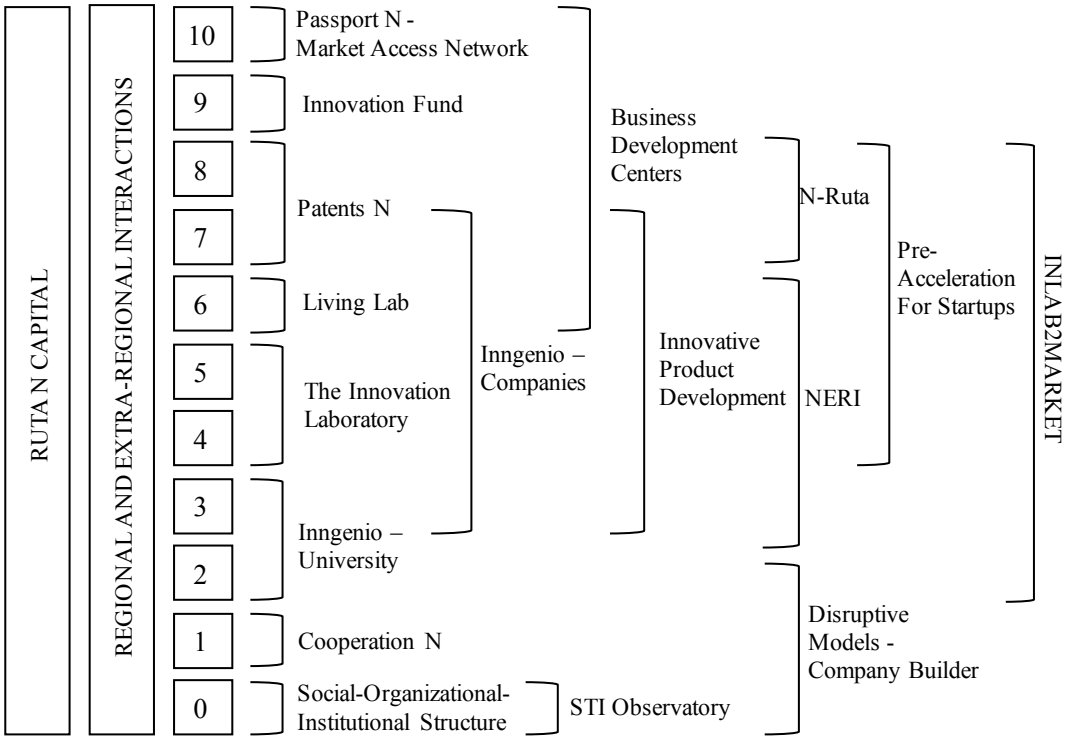


Figure 19. Technology Readiness Levels (TRLs) and Ruta N Programs. Source: own design.

Ruta N has designed and implemented programs that are embedded into a broader and more complex strategy (see Figure 20). Ruta N strengthens the technological innovation process with the following strategy. First, the Science, Technology, and Innovation Observatory provides technology watch and competitive intelligence, screening potential opportunities for the local actors in the regional innovation system not only in the three strategic sectors identified in the STI Plan—ICT, health, and energy—but also in emerging markets. The STI Observatory provides local actors with potential opportunities at the early stage of the innovation process, namely the Technology Readiness Levels ranging from 1 to 4. Indeed, the STI Observatory allows actors to redirect research efforts into specific technological trajectories in which the city can reach a competitive position. Second, Ruta N identifies through public calls innovative actors that can carry out specific scientific and technological activities beneficial to the RIS. Third, Ruta N devises and implements programs on two strategic axes. The first type of programs aims to strengthen the scientific and technological capacities of innovative actors to reach higher TRLs. The Ruta N's programs that target technological and scientific capabilities have relied in the identification of weaknesses in regional capacities within the TRL framework, in the identification of regional and extra-regional actors possessing the needed knowledge to allow the regional actors to move up along the TRL, and in the knowledge tropicalization to facilitate the knowledge absorption into the RIS. Moreover, Ruta N has also created programs to promote interactions between innovative actors in the RIS to facilitate the diffusion of that knowledge. Ruta N has also provided through co-financing, lending, and subsidies mechanisms funding to the regional actors to support them in moving along the TRL and in becoming more innovative. In addition to promoting technological innovations, Ruta N has created programs to affect the evolution of the socio-institutional structure to the novel techno-economic paradigm.

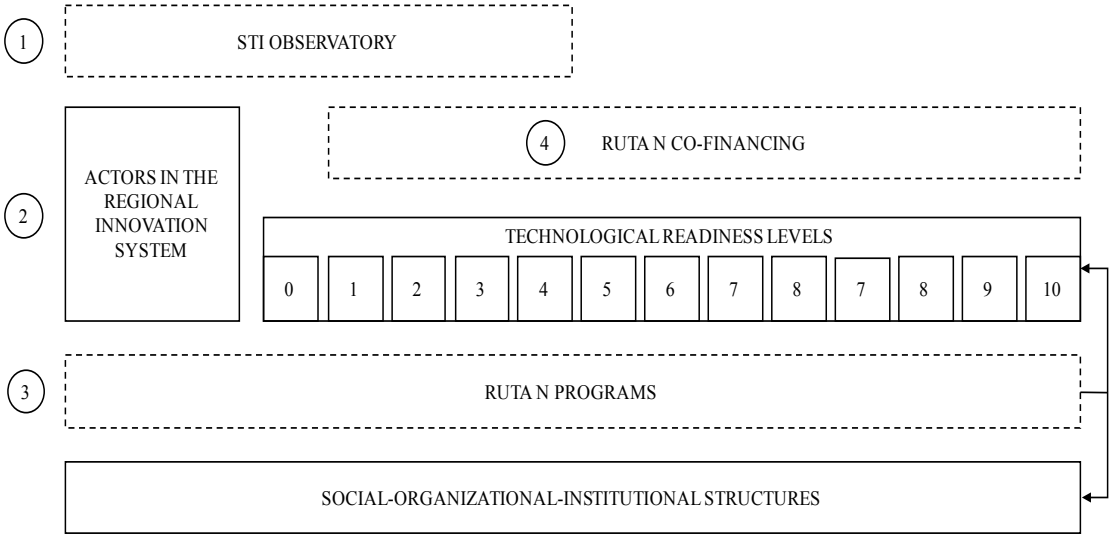


Figure 20. Ruta N's Overall Strategy. Source: own design.

7.5.1. Facilitating the Co-evolution of the Socio-Institutional Structure.

Medellín is transitioning from an industrial city towards a more service-based and knowledge-based city (see 4.4. Medellín's Regional Innovation System and 7.5. The Evolution of Science, Technology, and Innovation). The conceptual framework stresses the role of the entrepreneurial region in supporting radical socio-institutional changes for that two reasons. First, the entrepreneurial region has to align the socio-institutional structure with the new industrial path development in order to support the RIS' absorptive capacity to fully exploit extra-regional knowledge. Second, the entrepreneurial region has to limit transitional failure resulting from the regional structural change in the economy. Regional structural change implies rapid path creation and path destruction that affects the socio-institutional structure, which, in turn, through cumulative causation will affect future path development. The socio-institutional structure refers to the evolutionary structures that co-evolve with the techno-economic structure. The socio-institutional structure involves three knowledge-driven structures: (i) the social structure that refers to informal institutions, (ii) the organizational structure that refers to organizational features within private organizations, and (iii) the institutional structure that refers to the organizations that implement and/or devise formal institutions.

Ruta N has created programs to affect the evolution of the socio-institutional structure for two reasons. First, structural change in the economy, which implies rapid paths creation and path destructions, affects the socio-institutional structure. Second, the socio-institutional structure affects the regional capacity to acquire, absorb, and exploit extra-regional knowledge leading to new industrial path development and regional structural change in the economy through cumulative causation. Ruta N's programs aim to reduce the distance between social, organizational, and institutional structures in Medellín and leading RIS around the world that have further evolved socio-institutional structures, such as Austin, Boston, Paris, London, or Tel Aviv. Ruta N has devised programs to induce the evolution of the regional social, organizational, and institutional structures by selecting traits in further co-evolved socio-institutional structure from regions at the technological frontier. The programs aim to accelerate the co-evolution of the socio-

economic structure with the new industrial path development to reduce inefficiencies and instabilities that can result from the regional structural change. In addition to affecting knowledge-driven structures, Ruta N has designed the Medellinnovation district to create a high-quality urban space with high-quality amenities to facilitate interactions between a wide range of diverse actors in the RIS in order to support the diffusion of the novel socio-institutional structure.

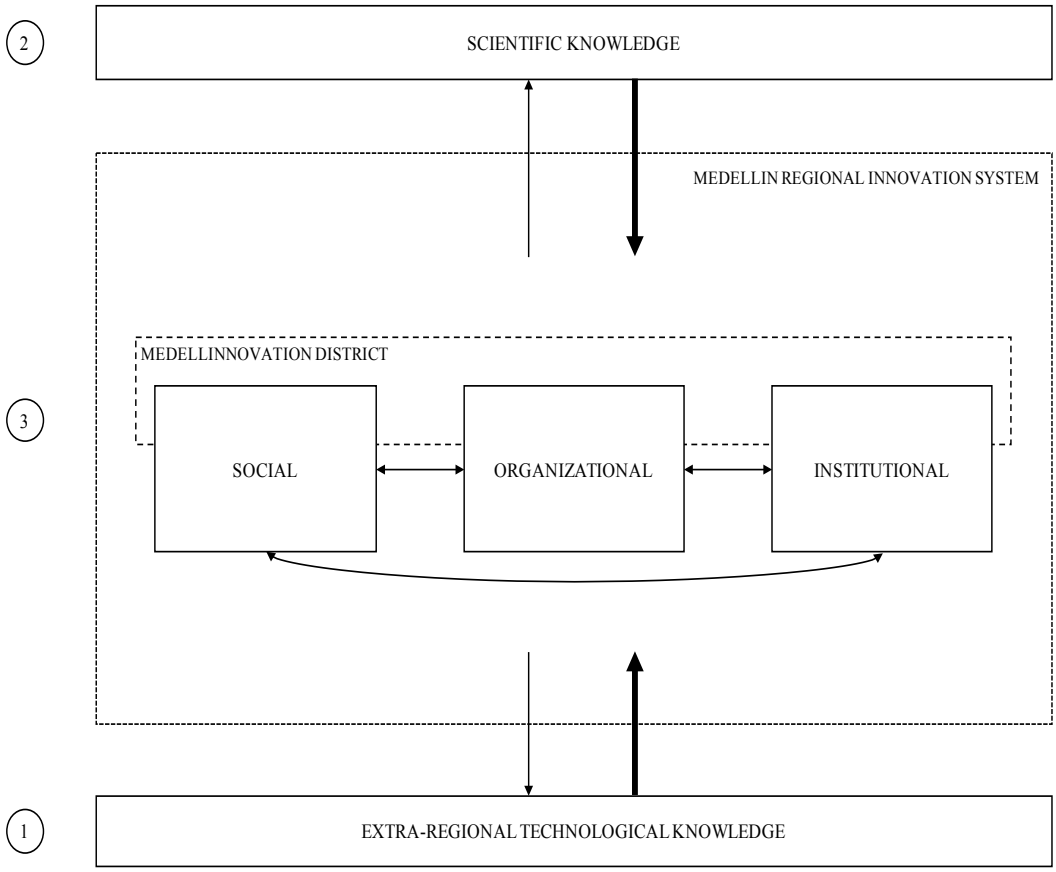


Figure 21. Extra-Regional Scientific and Technological Knowledge and Absorptive Capacity. Source: own design.

Programs to accelerate the co-evolution of the social structure with the novel techno-economic paradigm were devised by the innovation culture working area to foster in "the civil society specific attitudes towards innovation" (Angélica Jaramillo, Ruta N, personal communication, August 24, 2017). The Medellín's residents, or Paisas, are known for their inward-looking culture. As pointed out, "for the MIT faculty and students, the world is a village. For the Paisas, this village is the world" (Juan Pablo Ortega, Ruta N, personal communication, July 7, 2017). The programs have targeted residents of Medellín, university students, and middle and high school students. Some of the programs intended to affect the evolution of the social structure are, for instance, the Ruta N's Innovation Awards, Horizons, the Medellinnovation Festival, Startup Weekend, and N-Lab. The Ruta N's Innovation Awards is a program intended to reward innovators in Medellín to position them as aspiration leaders for other actors in the region. The program Horizons exposed public middle and high school students to high-demand skills in robotics, engineering, and nanotechnology. Horizons aimed "to inspire students to form new imaginaries, which can foster new attitudes, so that the students can internalize their roles in the innovation process" (Angélica Jaramillo, Ruta N, personal communication, August 24, 2017). The program Horizons aimed to generate aspiration for middle and high

school students to pursue science, technology, engineering, and mathematics (STEM) careers. The Medellinnovation Festival was a week-long event with multiple events, workshops, and conferences across the city to diffuse innovation concepts and an innovation culture to the civil society. The program Startup Weekend aims to influence university students to pursue entrepreneurship and to create their startups. The programs N-Lab or Innovation Challenge aimed to connect students with private companies to answer to specific challenges and to promote entrepreneurship. Ruta N has conducted several communication campaigns, such as "if you imagine it, it is possible" or "to innovate, it comes from people like you", around the city to diffuse an innovation culture.

<table>
<tr><td>Structure</td><td colspan="4">SOCIAL</td></tr>
<tr><td>Target</td><td>Civil Society - Medellinnovation District</td><td>Civil Society - Medellin's Residents</td><td>Students - University</td><td>Students - High School</td></tr>
<tr><td rowspan="9">Ruta N Programs</td><td colspan="4">Great Pact for the Innovation</td></tr>
<tr><td colspan="4">Communication Campaigns</td></tr>
<tr><td colspan="4">Ruta N Innovation Awards</td></tr>
<tr><td colspan="2">Innovation Week Medellinnovation Festival</td><td>Startup Weekends</td><td>Horizons</td></tr>
<tr><td colspan="2">Living Lab</td><td>N-Lab</td><td>Interchange</td></tr>
<tr><td>Community-Led Planning</td><td>Communa Innova</td><td>Talents N</td><td>Innobotica</td></tr>
<tr><td>Distrito Lab</td><td>The Creation Laboratory</td><td>Innovation Challenge</td><td>Ingeneria a la N</td></tr>
<tr><td>Open Kitchen</td><td>Innovation Manager</td><td>Bootcamp Web</td><td>ICT Fair</td></tr>
</table>

Table 23. Ruta N Programs to Affect the Social Structure. Source: own design.

Ruta N has created programs to accelerate the co-evolution of the organizational structure with the novel techno-economic paradigm. Programs have targeted large companies, SMEs, and startups. Some of the programs intended to affect the social structure are Innovation is for Everyone, Innovation Seminars, Innovation Managers, Innovation Management, SCRUM, the Great Pact for Innovation, Social Lab and Intellectual Property. The programs Innovation is for Everyone, Innovation Seminars, and Innovation Managers aimed to diffuse and to democratize key concepts of

technological innovation to the employees of private companies. Innovation Managers targeted 221 companies and provided training in methodology, best practices, knowledge concepts, and tools for 8 months to foster innovative business strategies. The Argentine company Kleer provided training to companies to accelerate software development through the SCRUM methodology. The Swedish company Idealaboratoriet led the program Innovation Management to promote an entrepreneurial culture within private companies through lateral and agile thinking methodologies. In 2014, the Great Pact for Innovation was signed by more than 1400 local actors to participate in the innovation effort for Medellín to reach 3% of its GDP in R&D spending in 2021. The pact was widely celebrated and communicated as a collective effort to achieve "a common vision of the future" (Headrik, 1988, p. 13). In the social lab program, Boston College transferred methodologies to large companies to adopt corporate social responsibility practices. Finally, the program in intellectual property, CATI, provides a methodology to identify within companies potential patentable innovations and to promote a culture favorable to the protection of intellectual property. The common objective of the programs is to transform the companies' organizational structure into a structure favorable to a culture of continuous innovation and entrepreneurial thinking.

> "When we did Innovation Seminars, we were at a moment of Ruta N's history when we wanted to democratize innovation, that is, to have everyone understands innovation. It was very large groups in which we taught face-to-face seminars about innovation, what it is, how to do it, but because our purpose was to democratize, we decided to virtualize the course with the program Innovation is for Everyone" (Catalina Carmona, Ruta N, personal communication, August 9, 2018).

> "We looked at the different innovation indicators of the OECD, and we saw the gap between Medellín and the different countries of the OECD. We won't close the gap by creating many programs but by giving the responsibility to others, so the Great Pact for the Innovation was like a symbol" (David Sierra, Ruta N, personal communication, July 25, 2017).

Structure	ORGANIZATIONAL		
Target	Large Company	SMEs	Startups
Ruta N Programs	Innovation is for Everyone		
	Great Pact for the Innovation		
	Innovation Seminars		
	Ruta N Innovation Awards		
	SUNN		
	STI Observatory		
	Passport N		
	Market Access Network		
	Smart Capital Network		
	Social Lab	CATI	
	Inceller	Mentorship for SMEs and Startups	
	Innovation Managers		Platform for Cultural and Creative Entrepreneurs
	Innovation Management		
	SCRUM		Bootcamp Web
	Innovative Procurement	Apps.co	
	Living Lab	Patents Team	
	Technology Watch and Competitive Intelligence		

Table 24. Ruta N Programs to Affect the Organizational Structure. Source: own design.

Ruta N has created programs to accelerate the co-evolution of the institutional structure with the novel techno-economic paradigm. Programs have targeted the city of Medellín, educational institutions, linkage organizations, and technological research centers. The institutional structure of the city of Medellín has been affected by programs such as Citiesfor.life, MiMedellín, MEData, the Fast-Track Institute, or the Innovation Laboratory for Government. Citiesfor.life is an event that was held in Medellín in 2015 where international urban experts and mayors were invited to exchange public best practices. The web platform Citiesfor.life was launched to enable cities to exchange best practices for urban challenges. MiMedellín is an open innovation web platform that allows citizens to participate in co-creating urban projects responding to the city's challenges. The program MEData aims to foster a data-driven governance strategy for the city of Medellín. The Fast-Track Institute is a spinoff from the Singular University in San Francisco and seeks to find exponential solutions to urban challenges in transportation, health, and sustainability for the city of Medellín. Educational institutions, namely universities and high schools, have been affected by programs such as SCRUM, Acceleration Program, Innovacampus, Spinoff Colombia, and Generation N. The Argentine company Kleer transferred the SCRUM methodology to disrupt the education sector through ICT. Cambridge University led the acceleration program to mentor local universities in developing disruptive projects. The program Innovacampus aimed to foster innovative capacities in local universities through the exchange of best practices with German universities. Through the program Spinoff Colombia, Ruta N has enabled the adoption of a national policy facilitating the creation of university spinoffs. Additionally, the program Spinoff Colombia supports university research centers through a methodology in bringing research inventions to market. The program Generation N aims to train high school teachers in project-based learning as a pedagogical tool for teaching STEM classes. Linkage institutions, including Ruta N, have been affected through the Diagnostic for Regional Innovation Systems and the program Innovation Management for Institutions. The OECD and T2 Venture Capital provided consulting to recommend improvements in programs to build a stronger regional innovation system. Innovation Management for institutions aims to generate capacities for linkage institutions to offer consulting services. Finally, the Monterrey Institute of Technology led the program Encurso to provide health professionals at technological research centers a methodology to conduct efficient clinical trials.

> "In the Innovation Laboratory for Government, we want to have the entities of the local government, Secretaries, and decentralized entities, to start thinking about innovation. Citizens often perceive the government as a very archaic and massive thing. We went there to motivate the Secretaries to start implementing innovative processes, connecting them with citizens to listen to them and to prioritize goals, and most importantly to find solutions" (José Willington, Ruta N, personal communication, August 3, 2018).

Structure	INSTITUTIONAL				
Target	City of Medellin	Education - Universities	Education - High-School	Linkage Institutions	Technological Research Centers
Ruta N Programs	Great Pact for the Innovation	Great Pact for the Innovation	Generation N	Great Pact for the Innovation	Great Pact for the Innovation
	Citiesfor.life	SCRUM	Horizon Circles	Observatory of Innovation Systems	Encurso
	MiMedellin	Innovation Challenge	The Innovation Laboratory for Education	Indicators	Intellectual Property
	Open Data - MEDATA	Spinoff Colombia		Innovation Mangement for Institutions	R&D Capacity
	Social Lab	Acceleration Program - Cambridge University		Fast-track Institute	Market Place
	Fast-Track Institute	Innovation Management for Institutions		Diagnostic for Regional Innovation Systems	STI Observatory
	Inceller	Innovacampus		R&D Capacity	Technology Watch and Competitive Intelligence
	IADB	Encurso		Market Place	
	The Innovation Laboratory for Government	STI Observatory		STI Observatory	
	Indicators	Technology Watch and Competitive Intelligence		Technology Watch and Competitive Intelligence	
	Innovative Procurement				

Table 25. Ruta N Programs to Affect the Institutional Structure. Source: own design.

In 2012, Ruta N unveiled its plan to create an innovation district around the Ruta N's innovation center (Ruta N, 2012). In 2015, the innovation district, dubbed as the Medellinnovation District, aims to redevelop an area of 172 hectares with a population of 12,244 inhabitants, comprising the districts of Chagualo, Jesús Nazareno, Sevilla, and San Pedro in the northern part of the city (Ruta N, 2015a). The innovation district is planned around the Ruta N innovation center, a 33,140-square-meter three-building complex that houses Ruta N offices, EPM-UNE and university research laboratories, the ViveLab animation learning center, international companies, and international startups. One of the objectives of the Medellinnovation District and the Ruta N's innovation center is to create an urban environment conducive to frequent and repeated interactions

between a wide range of actors in the RIS to accelerate the spread of tacit knowledge. Geographical proximity, in this sense, can be understood as an enabler for socio-institutional changes and of path development since it facilitates the exchange of tacit knowledge, which is critical in shaping knowledge-driven structures and evolutionary processes. Ruta N building complex is, to some extent, the arrival gate of the global knowledge pipelines, which are then diffused into the RIS through local buzz within the Medellinnovation District.

The socio-institutional structure has considerably evolved in the past decade (see Table 26). From the interviews conducted with expert stakeholders in the regional innovation system, the role of Ruta N in supporting socio-institutional change has been positive. Ruta N has been more successful in transforming the socio-organizational structure than the institutional structure. In the past decade, the socio-organizational structure has evolved towards a more positive perception of innovation and entrepreneurship, as pointed out: "Ruta N has been successful in generating in a short period a critical mass of persons and companies interested in topics related to innovation and entrepreneurship" (Alejandro Mazo, Parque E, personal communication, August 22, 2018). The organizational structure has evolved to more entrepreneurial and investment to innovations thanks to the successful transfer from Ruta N of methodologies to private companies. For the institutional structure, while "Ruta N is an institutional innovation", Ruta N has failed to collaborate with institutional actors in the RIS due to its strong paternalistic vision towards other actors in the RIS. Moreover, the non-alignment of some public organizations with the GEA's interests led to resistance to changes promoted by Ruta N, which is seen by those public organizations as too aligned with the GEA. Ruta N has, however, been successful in generating more citizens' participation and co-creation with the program MiMedellín and more recently with the Innovation Laboratory for Government.

Socio-Institutional Changes		
	2009	2018
Social Structure	"There were mental barriers in Medellin for the innovation process to take place, such as risk aversion, status quo, and norms hindering the creation of startups and research and development projects".	"The residents of Medellin have started to understand the power of innovation, the strategic importance of innovation. It has allowed to internally position the topic of innovation".
Organizational Structure	"Private companies are now willing to take risks with entrepreneurs, which was not the case 10 years ago. When we were doing courses in business models 10 years ago, the entrepreneurs came with very traditional business models" .	"In 2009 and 2010, these large companies [from the GEA] didn't have a department in charge of innovation but today all of them have one".
Institutional Structure	"In the beginning, Ruta N was conceived as an intermediary institution working with actors of the system, the City of Medellin, CTA, Chamber of Commerce, CREAME, Parque E to strengthen them in order for them to operate the programs".	"Ruta N generated a lot of conflicts between the different actors, nothing alarming, but a lack of coordination and a lot of rivalities between the different actors in the innovation ecosystem".

Table 26. Selected Quotes from Interviews to Illustrate Socio-Institutional Changes. Source: own design.

7.6. Ruta N's Unique Role in the RIS.

Ruta N has two primary roles to perform in its RIS. Ruta N's first role is to play the role of a public knowledge gatekeeper that is "tropicalizing knowledge" to support new industrial path development. Ruta N's second role is to accelerate the co-evolution of the socio-institutional structure with the new techno-economic paradigm. Ruta N has the role to monitor extra-regional best-practices and tropicalize those practices to Medellín's and Colombia's context. Martin, Aslesen, Grillitsch, and Herstad (2018) point out that different types of RIS differ in their propensity to access and absorb extra-regional knowledge. Regions on the knowledge periphery are less exposed to knowledge from regions at the technological frontier, and, as a result, need some kind of interventions. The creation of Ruta N in Medellín is the type of intervention that aims to increase extra-knowledge flows and to improve the RIS's absorption capacity. In contrast with other knowledge gatekeepers, such as leader firms or universities, in which a lag persists in leaking knowledge, the public knowledge gatekeepers directly transfer the extra-regional knowledge to the actors in the RIS. This role of the RIA is sometimes difficult to understand for experts coming from regions in the knowledge core.

> "When we have people coming from abroad, especially from Europe, in the meetings I have with them, they don't understand well Ruta N. Probably because the levels of development are different. For instance, with the Germans, they were asking me but 'what is Ruta N? What do they do?'" (Santiago Echavarría, CTA, personal communication, July 12, 2017).

In addition to playing the role of a public knowledge gatekeeper, Ruta N has, over the years, developed internal capacities to create and implement its own programs as well as to influence national innovation policies. The programs Innovation Managers, MiMedellín, the Great Pact for the Innovation, the Living Lab, and the Innovation Laboratory, among others, have been created and implemented by Ruta N with little help from national and international actors. The programs that have been developed from Ruta N leadership have even spurred national policies and strategies. The national strategy "Vive Digital" and the "ViveLab" to develop national capacities for the digital economy spurred by the Ministry of ICT and Colciencias, was initially promoted by Ruta N. The program Spinoff Colombia enabled changes in national policy that allowed public universities in Colombia to create spinoffs and professors to receive royalties from the creation of the spinoff. Spinoff Colombia is similar to the Bayh-Dole Act that was implemented in the United States in the late 1980s. The program Spinoff Colombia offers support from experts in the legal incorporation and accompaniment of the Spinoff.

The Evolution of Science, Technology, and Innovation. Medellín is slowly transitioning from being an industrial city towards becoming a service-based and knowledge-based city (see 4.4. Medellín's Regional Innovation System). In 2004, Medellín started a process of technological catch-up with regions in the knowledge core. As highlighted in the interviews, although Medellín is still far from having caught up with regions in the knowledge core, this technological catch-up process has accelerated in the past years. In the past years, R&D and STI spending in the City of Medellín have increased from 0.75 percent of the GDP in 2014 to 2.14 percent of the GDP in 2017, thus becoming the city in Colombia that most invest in innovation (Ruta N, 2018c). The technological catch-up process is not only felt at the scientific and technological level but also at the level of the socio-institutional structure.

> "Max Planck, Fraunhofer from Germany are now here in Medellín, the University of Wisconsin is also here, we thought it was going to take 20 years to bring those organizations, but they are now here" (Elkin Echeverrí, Ruta N, personal communication, July 27, 2017).

> "We have some targets year by year until 2021 to give you an idea of science and technology activities, it started at 0.75 in 2014, today we are at around 1.8 and in three years the goal is to reach 3% of the GDP in 2021. If you reach 3% in 2021, you are far in front of other regions in Latin America and you start being higher than many regions in Europe" (Elkin Echeverrí, Ruta N, personal communication, July 27, 2017).

> "Private companies are now willing to take risks with entrepreneurs, which was not the case 10 years ago. When we were doing courses in business models 10 years ago, the entrepreneurs came with very traditional business models. Today, thanks to all the work that has been done, entrepreneurs are

> looking to generate high economic value-added in their industries" (Alejandro Mazo, Parque E, personal communication, August 22, 2018).
>
> Medellín has had a relatively consistent strategy with efforts coming from the public and private sector. The early conversation that we started to have in science, technology, and innovation for the last 15 years has led to the fact that Medellín is now recognized in the national context and in some cities in Latin America (Juan Camilo Quintero, Ruta N, personal communication, 23 August 2018).

The different indicators that can be used to measure the Science, Technology, and Innovation, either in inputs, namely R&D and STI spending, and outputs, namely patents and trademarks registered, have considerably increased in the Antioquia Region (see Tables 28, 29, 30, 31, and 32). Indeed, between 2009 and 2016, R&D spending as a percentage of the GDP has increased by 50%, compared with 42% in Colombia; STI Spending as a percentage of GDP has increased by 68%, compared with 58% in Colombia; and the number of patents registered has increased by 420%, compared with 372% in Colombia. Moreover, the Antioquia Region has closed the innovation divergence and even surpassed Bogotá in R&D and STI spending. The Antioquia region has also diverged greatly from Valle del Cauca Region, where Cali is located. Moreover, the number of trademarks registered in Antioquia has increased more than in Bogotá D. C., Cali, and Colombia as whole. Trademarks can be used as an indicator for measuring innovation and industrial change (Mendonça, Pereira, & Godinho, 2004), and more specifically, service innovation (Flikkema, De Man, & Castaldi, 2014). Medellín has not performed as well in scientific indicators (see Tables 33 and 34). In the increased in the number of article publications in health, engineering, and mathematics, Medellín has lagged behind Bogotá but performed better than Cali. In the increased in the number of master students enrolled in health, engineering, and mathematics, Medellín has lagged behind Cali and Bogotá. However, the number of companies created in Antioquia has exponentially grew since 2008 (see table 27).

It does not mean that we can infer from the indicators that Ruta N has had a causal effect on Antioquia's innovative capacity, but they show that since the creation of Ruta N, the Antioquia Region has greatly diverged from its initial trajectory in becoming more innovative in terms of measured inputs and outputs (see Tables 28, 29, and 30). It shows, however, that Ruta N is part of a long-term process that has accelerated Medellín's regional transformation. Moreover, the increasing number of trademarks registered shows that Medellín is increasingly becoming more service-based (see Tables 31 and 32).

> "Every Friday, the *Cacaos* [the CEOs of the largest companies in Medellín who are part of the GEA] were meeting at Proantioquia and they were telling us in 2009, 'what you are doing is very important for the region, we don't want it to have anything to do with us, but do it'. In 2009 and 2010, these large companies didn't have a department in charge of innovation but today all of them have one. This does not mean that it has anything to do with Ruta N, but that Ruta N was the first to speak about the necessity to innovate" (Juan Pablo Ortega, Ruta N, personal communication, July 7, 2017).

	2002	2004	2006	2008	2010	2012	2014	2016	Percentage Change (2002-2016)
Number of Companies Created	2947	3707	3720	3060	5284	6358	7359	8350	183,3
Number of Companies Liquidated	1121	1120	1048	834	930	1039	1330	1596	42,4

Table 27. Number of Companies Created and Liquidated per Year from 2002 to 2016 in the Antioquia Region. Source: Antioquia Region (2016).

	Antioquia	Bogota D. C.	Valle del Cauca	Colombia
2000	0,25	0,23	0,10	0,13
2001	0,26	0,23	0,10	0,13
2002	0,26	0,25	0,11	0,14
2003	0,27	0,28	0,13	0,16
2004	0,27	0,28	0,11	0,15
2005	0,27	0,27	0,11	0,15
2006	0,26	0,28	0,10	0,15
2007	0,29	0,33	0,12	0,18
2008	0,40	0,35	0,13	0,19
2009	0,38	0,32	0,12	0,19
2010	0,39	0,32	0,13	0,19
2011	0,38	0,35	0,13	0,20
2012	0,42	0,40	0,15	0,22
2013	0,38	0,59	0,13	0,28
2014	0,76	0,37	0,15	0,30
2015	0,64	0,34	0,15	0,29
2016	0,57	0,35	0,15	0,27

Ruta N

Table 28. R&D as Percentage of the GDP. Source: OCyT (2018).

	Antioquia	Bogota D. C.	Valle del Cauca	Colombia
2000	0,46	0,77	0,41	0,38
2001	0,47	0,63	0,41	0,34
2002	0,49	0,68	0,41	0,36
2003	0,49	0,73	0,43	0,39
2004	0,50	0,84	0,45	0,42
2005	0,48	0,95	0,41	0,44
2006	0,50	0,82	0,39	0,40
2007	0,73	0,90	0,40	0,46
2008	0,84	0,97	0,38	0,49
2009	0,74	0,91	0,32	0,45
2010	0,75	0,96	0,35	0,47
2011	0,71	1,03	0,35	0,48
2012	0,89	1,12	0,42	0,54
2013	0,71	1,39	0,38	0,62
2014	1,29	1,14	0,42	0,70
2015	1,29	1,04	0,53	0,74
2016	1,24	1,05	0,45	0,71

Ruta N

Table 29. Spending in STI Activities as a Percentage of the GDP. Source: OCyT (2018).

	Antioquia	Bogota D. C.	Valle del Cauca	Colombia
2000	14	42	8	84
2001	6	47	8	73
2002	6	55	7	88
2003	12	42	8	82
2004	8	47	8	83
2005	16	75	36	157
2006	24	96	13	168
2007	15	76	13	138
2008	20	69	11	125
2009	24	63	7	126
2010	18	59	10	129
2011	39	89	11	201
2012	37	99	11	209
2013	44	112	29	242
2014	66	116	20	269
2015	76	144	30	322
2016	124	189	46	545
2017	125	233	30	595

Ruta N

Table 30. Patents Registered. Source: Superintendencia de Industria y Comercio (2018).

	Antioquia	Bogota D. C.	Valle del Cauca	Colombia
2000	927	2374	562	10063
2001	1404	4047	883	16216
2002	1626	3936	836	15151
2003	1717	3975	1104	14824
2004	1803	4539	1175	15427
2005	1836	5634	1243	17026
2006	2344	5219	1221	17763
2007	2460	5667	1246	19121
2008	2759	6535	1511	22557
2009	2780	6733	1398	22224
2010	2652	6418	1548	21778
2011	2821	6719	1454	22997
2012	3524	7418	1558	27264
2013	2542	5472	1210	22512
2014	3701	8598	1774	32368
2015	4295	9135	1859	34879
2016	3143	6639	1397	27356

Ruta N

Table 31. Trademarks Registered. Source: Superintendencia de Industria y Comercio (2018).

Indicators	Regions	2001	2009	2016	Difference in percentage (2001-2016)
R&D spending as pecentage of GDP	Antioquia	0,26	0,38	0,57	119,2
	Bogotá D. C.	0,23	0,32	0,35	52,2
	Valle del Cauca	0,1	0,12	0,15	50,0
	Colombia	0,13	0,19	0,27	107,7
STI spending as percentage of GDP	Antioquia	0,47	0,74	1,24	163,8
	Bogotá D. C.	0,63	0,91	1,05	66,7
	Valle del Cauca	0,41	0,32	0,45	9,8
	Colombia	0,34	0,45	0,71	108,8
Number of local patents registered	Antioquia	6	24	124	1966,7
	Bogotá D. C.	47	63	189	302,1
	Valle del Cauca	8	7	46	475,0
	Colombia	73	126	545	646,6
Number of Trademarks registered	Antioquia	1404	2780	3143	123,9
	Bogotá D. C.	4047	6733	6639	64,0
	Valle del Cauca	883	1398	1397	58,2
	Colombia	16216	22224	27356	68,7

Table 32. Key Innovation Indicators. Source: Superintendencia de Industria y Comercio (2018) and OCyT (2018).

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Difference in Percentage (2005-2015)
Antioquia												
Health	46	101	43	48	44	99	64	98	99	115	127	176,09
Engineering	78	98	135	132	185	150	204	246	244	371	382	389,74
Mathematics	46	92	118	104	83	111	109	115	124	139	127	176,09
Valle del Cauca												
Health	39	77	35	31	61	79	99	93	119	134	96	146,15
Engineering	29	38	39	54	56	60	111	258	205	200	244	741,38
Mathematics	25	46	22	17	28	29	87	71	81	89	96	284,00
Bogota D. C.												
Health	94	63	101	87	156	148	200	192	185	264	353	275,53
Engineering	328	428	379	560	458	463	902	1 016	634	612	867	164,33
Mathematics	143	189	228	258	237	300	283	280	240	331	286	100,00

Table 33. Number of Master Students in Selected Majors. Source: OCyT (2018).

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Difference in Percentage (2006-2016)
Antioquia												
Medical and Health	526	647	807	943	1 147	1 292	1 369	1 649	1 805	1 665	1 290	145,25
Engineering	373	507	713	842	957	1 021	1 145	1 230	1 308	1 480	1 129	202,68
Natural Sciences	512	572	863	976	1 103	1 246	1 360	1 597	1 814	1 929	1 567	206,05
Valle del Cauca												
Medical and Health	319	392	471	481	553	683	643	731	762	702	737	131,03
Engineering	323	414	455	558	668	678	708	851	780	853	690	113,62
Natural Sciences	434	493	557	623	758	839	868	944	989	1 045	899	107,14
Bogota D. C.												
Medical and Health	1 118	1 471	1 886	2 290	2 562	2 830	3 178	3 479	3 919	4 586	3 111	178,26
Engineering	1 083	1 399	1 870	2 351	2 848	3 297	3 954	3 843	4 247	5 025	3 652	237,21
Natural Sciences	1 301	1 568	2 206	2 639	3 140	3 728	4 600	4 575	5 048	6 427	4468	243,43

Table 34. Number of Article Publications in Selected Disciplines. Source: OCyT (2018).

7.7. Discussion of the Results.

The academic literature in evolutionary economic geography (EEG) and regional innovation systems (RISs) are increasingly concerned with providing targeted policy recommendations to encourage new industrial path development leading to regional structural change (Asheim, Boschma, & Cooke, 2011; Balland, Boschma, Crespo, & Rigby, 2017; Isaksen, Tödtling, & Trippl, 2018; Martin, Aslesen, Grillitsch, & Herstad, 2018; Neffke, Henning, & Boschma, 2011). The case of Ruta N Medellín adds to the academic literature on how the regional government in a developing country supported new industruial path development. It stresses the importance to distinguish between regions in the knowledge core and on the knowledge periphery. In contrast to core regions, regions on the knowledge periphery are remote from some of the main sources and users of knowledge, have limited extra-regional knowledge linkages, knowledge infrastructures, and have limited capacity to absorb extra-regional knowledge (Grillitsch & Nilsson, 2015). Ruta N has supported new industrial paths in five sectors—ICT,

health, energy, nanotechnology, and digital animation and video games—by supporting the acquisition, diffusion, and absorption of extra-regional knowledge into the RIS. In Medellin, the RIA has acted as a knowledge gatekeeper that has "tropicalized" extra-regional knowledge to facilitate its absorption into the RIS. The knowledge gatekeeper is in charge of supporting new regional industrial path development by connecting local actors with international leaders, while monitoring and facilitating knowledge transfer. These findings confirm the importance of extra-regional knowledge and absorptive capacity in regions outside diversified and organisationally thick RISs for path development (Trippl, Grillitsch, & Isaksen, 2017) while emphasising the importance of the creation of specific institutional arrangements and capacities to pursue such strategies for path development. Additionally, the case adds to the academic literature that regional government can play the role of a knowledge gatekeeper.

The case explores the policy strategies that the regional government through Ruta N has implemented to accelerate the evolution of the socio-institutional structure during a period of regional structural change. During regional structural change, the socio-institutional structure and the techno-economic structure are temporarily decoupled due to the relative inertia of the socio-institutional structure compared to rapid changes in the techno-economic structure (Perez, 2004, 2010). This decoupling creates a system failure, called transitional failure, that results from suboptimal interactions in the system setting up a new rationale for government intervention. The city of Medellin (Colombia) is undergoing regional structural change reorganizing its industrial activities towards more knowledge-based and service-based activities. During this period of regional structural change, Ruta N has been devising programs to accelerate the co-evolution of the socio-institutional structure with the novel techno-economic paradigm. This case adds to the academic literature by uncovering a new system failure and by pointing out the importance of the role of the regional government in accelerating the evolution of the socio-institutional structure to limit inefficiencies, instabilities, and inequalities within the region that can result from regional structural change. The role of the government to support socio-institutional changes can be especially suited in regions on the knowledge periphery, as those regions can learn and contextualize place-based policies from regions at the knowledge

Part III
Regional Innovation Agencies for Regions on the Knowledge Periphery

8. The Framework for the Regional Innovation Agency.

Regional Innovation Agencies for Regions in the Knowledge Periphery. Regions that could benefit from a regional innovation governance structure and institutional arrangement similar to Ruta N are regions that are located on the knowledge periphery. Regions on the knowledge periphery refer to regions that are geographically remote from the main sources of scientific and technological knowledge. Regions in the knowledge core can have for proxy, regions with significant patenting activities, such as the Top-100 cluster by patent filing in the world, regions that are geographically proximate (within a 200 kilometers radius) to the Top-100 cluster by patent filing in the world, and the regions receiving significant knowledge flows from regions in the Top-100 cluster by patent filing in the world (see Bergquist, Fink, & Raffo, 2017 for the list of Top-100 cluster by patent filing in the world). In contrast with core regions, regions on the knowledge periphery have limited extra-regional knowledge linkages, knowledge infrastructures, and capacity to absorb that extra-regional knowledge (Grillitsch & Nilsson, 2015; Isaksen, Tödtling, & Trippl, 2018; Martin et al., 2018). As a result, global cities and innovation hubs would not benefit from such a regional innovation governance structure and institutional arrangement since they already possess a large and diverse knowledge base allowing the generation of new industrial path development from path-dependent market-forces.

The regional innovation systems that would most benefit from a public organization, like Ruta N, are regional innovation systems that are located on the knowledge periphery, which lack the required extra-regional knowledge flows to upgrade not only the regions' technological and scientific capabilities but also the regions' socio-institutional structure. The regional innovation systems that would benefit the most from the creation of a regional innovation agency are: first, the regions that have been extremely isolated due to embargoes or extreme violence, such as, for example, regions in Cuba, Mexico, Venezuela in Latin America or Libya in North Africa or Syria and Iran in the Middle East. Second, the regions that have been at the periphery of the world economy, such as regions with second-tier cities in Latin America, Central Asia, Africa, and Asia. Third, regions that are undergoing structural change in their economics, from industrial to knowledge-based, such as regions in Western Europe, Eastern Europe, and Russia. Fourth, the peripheral regions of the European Union that have increasingly diverged from the knowledge core, such as regions in Southern Europe, South Italy (for instance, Bari, Cagliari, Catania, Naples, and Palermo would be good candidates), some regions in Spain, Greece, and Portugal.

> "People admire how an entity [Ruta N] in just 6 years has managed to transform its ecosystem, something that has not worked in any other part of Latin America. Policymakers from Ivory Coast, from Senegal, came to look at the model, and they told me, 'look, we are a former colony of France, and they help us to come to France, but coming here, I think that what is happening in Medellín and in Ruta N is much closer to the way I see the world than what they told me in France'" (Elkin Echeverrí, Ruta N, personal communication, 27 July 2017).

A RIA is a place-based and place-sensitive policy-strategy that is not an "one-size-fits-all" regional innovation policy but a "one-size-fits-many" policy strategy. Indeed, RIAs will be most relevant in regional innovation systems that possess the following sixth

conditions. First, the RIS has a distinct and proud regional culture. Second, the RIS has clear administrative boundaries. Third, the RIS has a city with a metropolitan population of at leat around 1,000,000 inhabitants. The population is here used as a proxy to evaluate the potential sophistication of the RIS and innovative threshold for the RIS to compete globally. Fourth, the RIS has existing innovative infrastructures, such as universities, large companies, research centers, public institutions, and support and intermediary organizations. Fifth, the region has some political stability to fund the agency for a period of least 15 years. Finally, the region has a middle-income or high-income with a GDP per capita in the regional innovation system of at least USD $2,000-3,000. Moreover, the RIA will be most adequate in regions that are relatively specialized and that are organizationally and institutionally thick.

8.1. The Regional Innovation Agency

Ruta N Medellín is the outcome of a shared vision for regional economic development. The organization provides a best-practice model for regional development through science, technology, and innovation for many regions around the world. Due to its innovative institutional arrangement and unique governance structure, Ruta N has, however, experienced in its development many difficulties that have hindered the organization to efficiently and systematically transform its RIS. Ruta N is a clear example of "policy running ahead of theory" that has followed more of an iterative path of trials-and-errors to define its role and mission in the RIS rather than a clear strategy. The following subsections provide a toolkit for policymakers to create their own version of a regional innovation agency in regions located on the knowledge periphery that can benefit from such an intervention (see previous section) while illustrating some examples of Ruta N trials-and-errors.

General Features. The creation of a regional innovation agency has to be the outcome of a shared regional vision involving many different leading regional actors coming from public institutions, private companies, universities, and the civil society (quadruple helix). The number of regional actors has to be wide enough to be representative of the regional innovation system. The actors should participate in defining the mission, vision, and overall strategy of the agency for the regional innovation system. Similar to an entrepreneurial discovery process in smart specialization strategy, the actors should define the priorities and participate in defining which new industrial path development to pursue. As a result, the shared regional vision should emerge from the co-creation process among the leading regional actors in the RIS.

> The creation of Ruta N is the outcome of a common vision led by Proantioquia and the CTA, involving hundreds of urban leaders, who aimed, 1) to accelerate Medellín's economic transformation, led by the business elites, namely the GEA, into more service-based and knowledge-based activities, 2) to position Medellín as a relevant and legitimate innovation system in the world, and 3) to transform Medellín into a more inclusive city.

The regional innovation agency should operate for a period of at least 15 years to significantly have an impact on its RIS. The RIA has to be, as a result, relatively independent from political changes in the municipal, regional, or national governments. The RIA has to be financially sustainable with steady streams of incomes coming from

the government and other sources without being negatively affected by election results or external events. The agency also has to directly be accountable to the civil society, and, as a public organization, to work for the common regional good and not for some vested economic or political interests or business elites.

> Proantioquia and the CTA designed Ruta N to be as financially and politically independent from municipal and regional election results as possible. The desired institutional arrangement did not materialize since Ruta N is still largely financially dependent from the municipal government. Indeed, with the election of Mayor Federico Gutiérrez (2016-2019), the period 2015-2016 was marked by a substantial reduction in municipal endowments for the agency, which limited Ruta N ability to create and to implement programs. Additionally, Ruta N has seen itself more as a startup than a public organization, which has hindered its legitimacy as a public organization, organizational effectiveness, and program delivery. Indeed, the organization has, since its creation, grown exponentially in terms of resources and manpower, reaching a total number of 122 employees (full-time and independent contractors) in 2015.

The RIA's financing structure has to come from multiple sources, namely from the municipal, regional, or national government, international development aid agencies, international and national agreements, and the RIA's own generated revenues. In regions that are experiencing significant regional corruptions and/or limited public capabilities, such as South Italy, the regional innovation agency can be conditionally funded and operated by the national government or a supranational organization, such as the EU.

> Ruta N was designed to receive funding from multiple sources of revenues, namely from the Municipal Government, EPM-UNE, the lease of offices and shops in the innovation center, partnerships, and agreements. The Municipal Agreement 048 for investment in the STI plan has never reached the agreed 7%, which limited Ruta N investment capabilities. In 2015, the reduction in municipal transfers after the election of Mayor Federico Gutiérrez led Ruta N to strategically reorganized itself to become more self-sustainable financially. Indeed, the organization had to prioritize revenue-generating working areas while drastically reducing more socially-focused working area, such as innovation culture. As a result, Ruta N has been transforming itself into an innovation-related service provider, which limits its capacity to structurally transform the regional innovation system and reduces its legitimacy to the civil society.

The employees working for the regional innovation agency have to possess the following qualities. First, they should have high academic qualifications in relevant majors at master or PhD levels. Second, they should have previous relevant professional and academic experience in leading innovation hubs around the world. Third, they should be passionate about their region and have an extensive understanding of the regional context. Fourth, they should be diverse with different professional and educational backgrounds in public policy, public affairs, entrepreneurship, science, innovation management, social psychology, and public management. Fifth, they should have the capacity to become knowledge gatekeepers by translating extra-regional knowledge to make it relevant to the local actors in the regional innovation system.

> While Ruta N has had the capacity to attract talents compared to the regular public sector in Medellín, the organization has not managed to hire the talents needed to properly create, implement, and evaluate programs. Despite their good intentions, a large proportion of Ruta N's employees tend to lack the professional, educational, and international experience to efficiently work as knowledge gatekeepers and to generate international networks. While Ruta N's employees are good project managers, they are overly embedded in their programs and have difficulties in understanding the bigger picture of the role and the function of the organization in the RIS. In addition to a lack of internal capabilities, there is a high staff turnover due to Ruta N's practice of hiring temporary staff to implement programs, which further hinder the development of Ruta N's much-needed capabilities. Moreover, there is also a sense of political instabilities due to Ruta N's political dimension where new directors are appointed with each new Mayor election.

The RIA has to work closely with a regional research organization in the creation of new programs, such as a regional institute for innovation. The regional institute for innovation has to provide scientific evidence to support the RIA to make the best decisions for the RIS. The regional institute for innovation can be a research group from a regional university that has the roles to monitor weaknesses in the RIS, to monitor international best-practices, to screen potential international actors with knowledge relevant for the RIS, to screen trends in emerging technologies, to screen trends in place-based and place-sensitive policies, to monitor trends in the academic literature on regional economic development, and to provide tools to evaluate the RIA. As a result, the regional institute works as an information-system for the RIA to pursue the most relevant strategic decisions. The regional institute for innovation has the role to gather scientific evidence and thus work on more basic research, while the RIA has a more applied role.

> Ruta N has heavily relied on internal capacities to make decisions regarding its strategies and the creation of programs. This has been counterproductive and inefficient on many different levels. Indeed, Ruta N's core internal skill is project management and applied work, not basic research, which has led to many misunderstanding of its role in the RIS as well as the misunderstanding of the existing innovation and scientific capacities in the RIS. Ruta N has misunderstood its role as a knowledge gatekeeper thus limiting the policy effectiveness of brokering extra-regional knowledge to support new industrial path development. Ruta N has misunderstood its role in accelerating the evolution of the socio-institutional structure thus leading to organizational inefficiencies. Moreover, Ruta N has misunderstood the innovative capacities of the actors in the RIS leading to ill-adapted program offering. Understanding this weakness, Ruta N launched in 2018 the program called "intelligence" to more systematically design data-driven programs on evidence-based and potential emerging opportunities. The program "intelligence" is, however, relying on internal capacities that are not the organization's core competencies, and which, will further contribute to the inward-looking approach that has been taken by the organization since its creation. The regional institute for innovation can be modeled after Orkestra Institute of Competitiveness in the Basque Country. In Medellín, the Center for Political Analysis at EAFIT University can perform the basic research for

> Ruta N. The interactions between Ruta N and a research group at a regional university dedicated to regional development would greatly improve Ruta N decision-process and programs.

Ruta N's undeniable achievement has been the creation of the Ruta N innovation center. The creation of an innovation center, such as the Ruta N Building Complex, has four main benefits. First, it anchors the RIA into the urban fabric and provides a science, technology, and innovation showcase for the RIA and the actors in the RIS. Second, it facilitates regional interactions between the agency and the startups, universities, research centers, and private companies located in the innovation centers, thus creating a sense of "local buzz" that continuously provides feedback to the agency on its actions. Third, it provides the RIA with a stable revenue stream from renting office and retail spaces. Fourth, the innovation center provides considerable media exposure from local and international media outlets. Fifth, the innovation center symbolizes the political determination to science, technology, and innovation to the region, which is a concrete public benefit for the residents and provides confidence in the government to foreign investors.

Framework for Selecting New Industrial Path Development. One of the RIA's primary objectives is to support new industrial path development in the region. The new industrial path development can be selected according to the concept of Entrepreneurial Discovery Process (EDP) of the Smart Specialization Strategy (S3), based on the framework developed by Balland, Boschma, Crespo, and Rigby (2017) (see Figure 22). The new industrial path development have to be selected in the following manner. First, the selected technological trajectories have to have high product complexity in order for the region to reach high benefits from pursuing the new industrial path development. Second, the ratio of low relatedness versus high relatedness has to be 1 to 3. Indeed, unrelated technological trajectories are risky since the region does not have prior capabilities and relies on extra-regional knowledge to build capabilities. Related technological trajectories that are more complex are less risky while offering high benefits to the region. The unrelated technological trajectories have to be selected where the product has the most links to other products following the product space theory (Hidalgo, Klinger, Barabási, & Hausmann, 2007). The role of the regional innovation agency is to support the selected sectors or subsectors to reach higher complexity through the recombination process between internal with external knowledge. Moreover, an observatory such as the STI Observatory should be created to generate a regional instrument for continuous Entrepreneurial Discovery Process since the paths selected are constantly evolving.

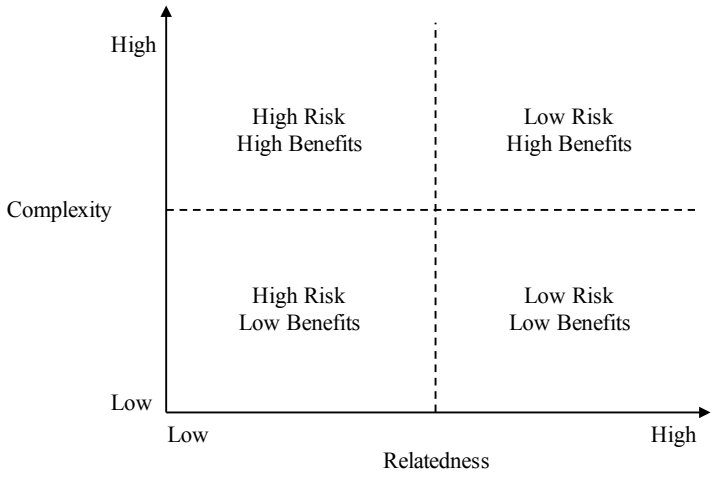


Figure 22. A Framework for Smart Specialization. Source: (Balland, Boschma, Crespo, & Rigby, 2017).

> Ruta N has pursued the development of related and unrelated new industrial path development. The related technological trajectories—ICT, health, energy—were selected in the STI Plan 2011-2021 because of the region's prior capabilities and potential growth. The STI observatory has facilitated local actors to screen potential opportunities in emerging subsectors working thus as a sort of continuous entrepreneurial discovery. The nanotechnology and digital animation and video games sectors were unrelated to the region since the region didn't have prior capabilities in the sectors. The digital animation and video game sector was selected on the recommendation of a successful entrepreneur from Medellín who created his video game publishing startups in the United States and the study of best-practice in Guatemala. The Nanotechnology sector was selected out of the leadership of EPM. Indeed, the public multi-utility company wanted to pursue the development of nanotechnology in the region before transferring the responsibility to Ruta N.

The new industrial path development not only have to be selected according to the previous framework but also have to be the outcome of a common regional vision involving many different actors, coming from public institutions, private companies, universities, and the civil society. The selected new industrial path development have to stir passions and to bind together the actors in the RIS to the shared vision for the region. As a result, the selected new industrial path development can not only be the result of rigid data-driven and rational decision-making but also of a collective co-creation process that plays with the "animal spirit" and "regional aspirations" of the actors in the RIS. The regional innovation agencies can preselect a number of potential paths for the region that will be later discussed and selected by regional leaders in order to compromise between scientific data-driven decision-making and the regional's animal spirit.

> The Science, Technology, and Innovation (STI) plan 2011-2021 was drafted in 2010 from a collective effort involving more than 250 regional leaders, namely, entrepreneurs, business leaders, policymakers, and academics to identify new industrial path development. The STI plan has the objective "to promote and coordinate policies to support research and scientific,

> technological and innovative development in Medellín, with a view towards the identification and exploitation of new knowledge-based businesses" as well as to transform Medellín into the "most innovative city in Latin America" (Pineda & Scheel, 2011). Ruta N is currently in the process of internally drafting the new STI plan 2021-2031 making the mistake to want to rely on data-driven decision making to select new industrial path development without involving in the process the regional actors in the RIS. If carried out without the involvement of regional leaders, the new STI plan 2021-2031 will have the outcome to further isolate Ruta N in the RIS.

8.2. The Roles of the Regional Innovation Agency.

The RIA should work as an intermediary organization in the RIS. More specifically, the RIA should work as a knowledge gatekeeper that is not directly involved in implementing programs but rather has the following roles. First, the RIA has to constantly screen successful innovation systems around the world. Second, the RIA has to identify weaknesses in the actors of the RIS. Third, the RIA has to support local actors to acquire extra-regional knowledge. Fourth, the RIA has to play the role of a knowledge gatekeeper that supports the assimilation, or "tropicalization", of the relevant extra-regional knowledge into the RIS. The term "knowledge tropicalization" can be used for regions that are located between the tropics of the Cancer and the Capricorn. The process of tropicalization involves the RIA's assistance to the international actors implementing programs to contextualize the extra-regional knowledge to facilitate its absorption into the RIS. Fifth, the RIA has to strengthen the region's socio-institutional structure to further facilitate the acquisition, assimilation, and exploitation of extra-regional knowledge in the RIS. Finally, the RIA has to be a platform to facilitate regional and extra-regional interactions to create a sense of "local buzz" and to support the creation of regional and international networks

> Over the years, Ruta N's role has evolved from being an intermediary organization into being a support organization that creates and implements its programs. Ruta N's change of its strategic role in the RIS was initiated for two reasons. First, Ruta N perceives itself as a startup that should constinuously grow and be involved in new disruptive projects. Second, Ruta N has had the desire since its inception to become financially self-sustainable from the Municipal Government. The RIA should only implement programs when the capacities to implement the program do not exist in the RIS and when the program is short term. Indeed, it is preferable to bring an extra-regional actor to implement programs while at the same time transferring the capacity to a local actor rather than for the RIA to directly implement programs. The RIA's primary role should be that of an intermediary organization that plays the role of a knowledge gatekeeper in the RIS. Moreover, Ruta N's role has been confusing for its employees and even more so for individuals outside the organization who frequently refer Ruta N as a research or innovation center. This confusion derives from Ruta N's branding statement, "Innovation and Business Center". Although the Ruta N building complex is an innovation center (see Morisson, 2018), Ruta N should be branded as a regional innovation agency that plays the role of a knowledge gatekeeper to improve regional innovative capacities.

The RIA has to continuously identify weaknesses in the RIS. The RIA is thus an intermediary organization that aims to continually upgrade the innovative capacities of the different actors in the RIS. As a result, the RIA has to closely collaborate with different actors in the RIS and has to determine the current regional innovation capabilities in the RIS to accordingly respond with a program. The RIA can face five possibilities when identifying weaknesses in the RIS and should act accordingly for each possibility. First, the RIA identifies a weakness in the RIS that can be addressed with a short-term program and can be implemented by an existing regional actor in the RIS. In this case, the RIA has to support the regional actor to create and to implement the program by benchmarking international best-practices in collaboration with the regional institute for innovation or by co-creating the program with an extra-regional actor. Second, the RIA identifies a weakness in the RIS that can be addressed with a short-term program and can be implemented by an extra-regional actor. In this case, the RIA has to support the extra-regional actor to tropicalize its program and to support the knowledge transfer to a regional actor that, if needed, could repeat the program in the future. Third, the RIA identifies a weakness in the RIS that can be addressed with a short-term program but cannot be implemented by an existing regional or extra-regional actor. In this case, the RIA can create and implement a pilot program by benchmarking international best-practices in collaboration with the regional institute for innovation. Fourth, the RIA identifies a weakness in the RIS that can be addressed with a long-term program and can be implemented by an existing regional actor. In this case, the RIA has to support the regional actor to create and to implement the program by benchmarking international best-practices in collaboration with the regional institute for innovation or by co-creating the program with an extra-regional actor. Fifth, the RIA identifies a weakness in the RIS that can be addressed with a long-term program and can be implemented by an extra-regional actor. In this case, the RIA has to support the creation of a regional organization dedicated to addressing the weakness in the RIS while tropicalizing the knowledge transferred by the extra-regional actor. The RIA has the role to draft the regional's plan, mission, role, and mandate in collaboration with the regional institute for innovation and the extra-regional actor.

> Over the years, Ruta N's role in the RIS has deviated from upgrading the capacities of the actors in the RIS towards directly implementing programs. In doing so, Ruta N has committed five errors. First, Ruta N has not been able to correctly assess the existing capacities in the RIS and has offered programs that were too complex for the actors in the RIS. Second, Ruta N has not been successful in collaborating with other support organizations in the RIS, such as the Chamber of Commerce, CREAME, Parque E, CTA, or the City of Medellín. Third, Ruta N has offered programs that directly competed with the existing offerings of other support organizations in the RIS. Fourth, Ruta N has over-communicated on its brand as synonymous with the only actor responsible for innovation resulting in marginalizing the role of many other actors in the RIS that support innovation. Fifth, Ruta N has over-communicated on its programs wanting to turn them into wannabe self-fulfilling prophecies. The innovation district, the digital animation and video game sector, the most innovative city in Latin America are some examples in which Ruta N has over-communicated and over-promised while failing to demonstrate concrete results.

The RIA should also facilitate the co-evolution of the socio-institutional structure with the new industrial path development. The programs should affect the evolution of the regional social, organizational, and institutional structures by selecting socio-institutional changes in regions located at the technological frontier. In periods of structural change in the economy, the RIA has to recouple the socio-institutional structure with the novel techno-economic structure to limit inefficiencies and instabilities resulting from structural change the regional economy. In addition, the RIA has to accelerate the evolution of the socio-institutional structure to strengthen the local actors' capacity to acquire, to exploit, and to absorb extra-regional knowledge. The RIA's roles are significantly different from the role of the regional investment promotion agency that aims to attract international companies and Foreign Direct Investments (FDIs) into the RIS. Both regional innovation agency and regional investment promotion agency should, however, collaborate closely and follow a shared vision for the region.

> Medellín is undergoing a regional structural change. Ruta N has accelerated the co-evolution of the socio-institutional structure with the new industrial path development by devising programs to induce the evolution of the social, organizational, and institutional structures with the novel techno-economic paradigm. Ruta N has, however, not fully grasped its role in accelerating the co-evolution of the socio-institutional structure Additionally, in 2016, Ruta N has restructured itself and has considerably reduced its budget for the co-evolution of the social structure by merging the working area innovation culture with organizational innovation. This strategy to eliminate non-revenue generating programs that were accelerating the co-evolution of the social structure reduces the legitimacy of the public organization as an "engine for transformation" for the civil society. Moreover, it reduces the legitimacy of the organization as a public organization promoting social inclusion and aiming to reduce inequalities between Medellín's most influent and most impoverished neighborhoods. In transforming itself into an innovation-related service provider, Ruta N has diminished its legitimacy to claim to structurally transform the RIS.

Local Buzz and Global Pipelines. The RIA has to foster interactions among regional actors and between regional and extra-regional actors. The RIA has to foster a sense of "local buzz," which refers to the information and communication ecology created by face-to-face contacts, co-presence and co-location of people and firms within the same industry and place or region, which thus, facilitate the exchange of tacit knowledge (Storper & Venables, 2004). The regional sense of local buzz is thus achieved by promoting face-to-face interactions between different actors. The RIA has to foster the creation of local networks, local events, and local initiatives that promote the sense of regional buzz. As a result, the RIA can promote regional networks connecting different actors in the RIS working towards specific technologies. Local events can range from networking events, conferences, monthly innovation lunches, to a weekly event dedicated to innovation. The regional initiatives should primarily promote repeated face-to-face interactions between private companies-universities-public institutions-civil society working towards specific technologies. The RIA can also promote regional interactions by creating an innovation center and/or an innovation district. The RIA promotes regional face-to-face interactions or the sense of "local buzz" to accelerate the diffusion of global pipelines and thus to foster the recombination process between extra-regional knowledge and regional knowledge.

Ruta N has promoted both local and extra-regional interactions in many ways (see 7.3.3. Diffusing Knowledge in the Regional Innovation System). First, local interactions are encouraged at the spatial/urban level with the Ruta N innovation center and the Medellinnovation district. Second, Ruta N has created the Regional Innovation Initiatives (RII) to connect private companies-universities-public institutions within Key Enabling Technologies (KET) to discuss and adopt innovations. Third, Ruta N has promoted the development of web platforms, such as SUNN or Brainbook to foster interactions among regional actors and between regional and international actors. The web platforms have been, however, under Ruta N's management, which competes with the RIA's primary roles. Moreover, the creation of web platforms for promoting interactions is a risky strategy since it requires network effects to be widely adopted in the RIS. The web platform MiMedellín has, however, achieved more success since MiMedellín does not require a significant network effect to provide benefits to its users.

8.3. The Organizational Structure of the Regional Innovation Agency.

The regional innovation agency should be structured as followed (see Figure 23). The board of directors should be headed by an elected official, from the municipal or regional government. The board should include funding partners, such as national government, when funds come from the National government, or supranational entity, when funds come from a development bank. If funds come from a public company, such as it is the case for Medellín, then the public company should be in the board. The board should include regional associations representing the business, cultural, civil society, and entrepreneurial interests not only to bring more legitimacy to the agency but also to improve the RIA's capacity to rally and to reach key decision leaders. The board should include regional universities since they are the research and training instrument of any successful innovation system. Finally, the board should consist of diverse public-private organizations that work in innovation-related or research activities. The board of directors is responsible for setting priorities and strategic missions.

The support functions should include an executive director who is appointed by the board, and who directly oversees the marketing and communications and the administration and finance areas. Marketing and Communications have the role in promoting the agency and the innovation system in regional, national, and international media outlets, on social media, to sponsor regional events, to conduct communication campaigns, and to supervise the agency's websites. The chief operation director works as a project management office (PMO) overseeing the RIA's daily operations and is in charge of the RIA's evaluation. The chief strategy director closely collaborates with the regional institute for innovation to screen, monitor, and find weaknesses in the RIS. The chief strategy director sits in each quadruple helix committee. The chief strategy director provides mentorship when designing new programs and supports working function directors in delivering programs. The chief strategy director is in collaboration with the regional institute for innovation looking for new potential disruptive projects in the regional innovation system. The chief strategy director also oversees consulting projects from outside organizations that aim to replicate the RIA's model or programs. The chief strategy director directly oversees the working sub-function, disruptive projects. The

chief strategy director is also with the executive director the main representative of the regional innovation agency abroad.

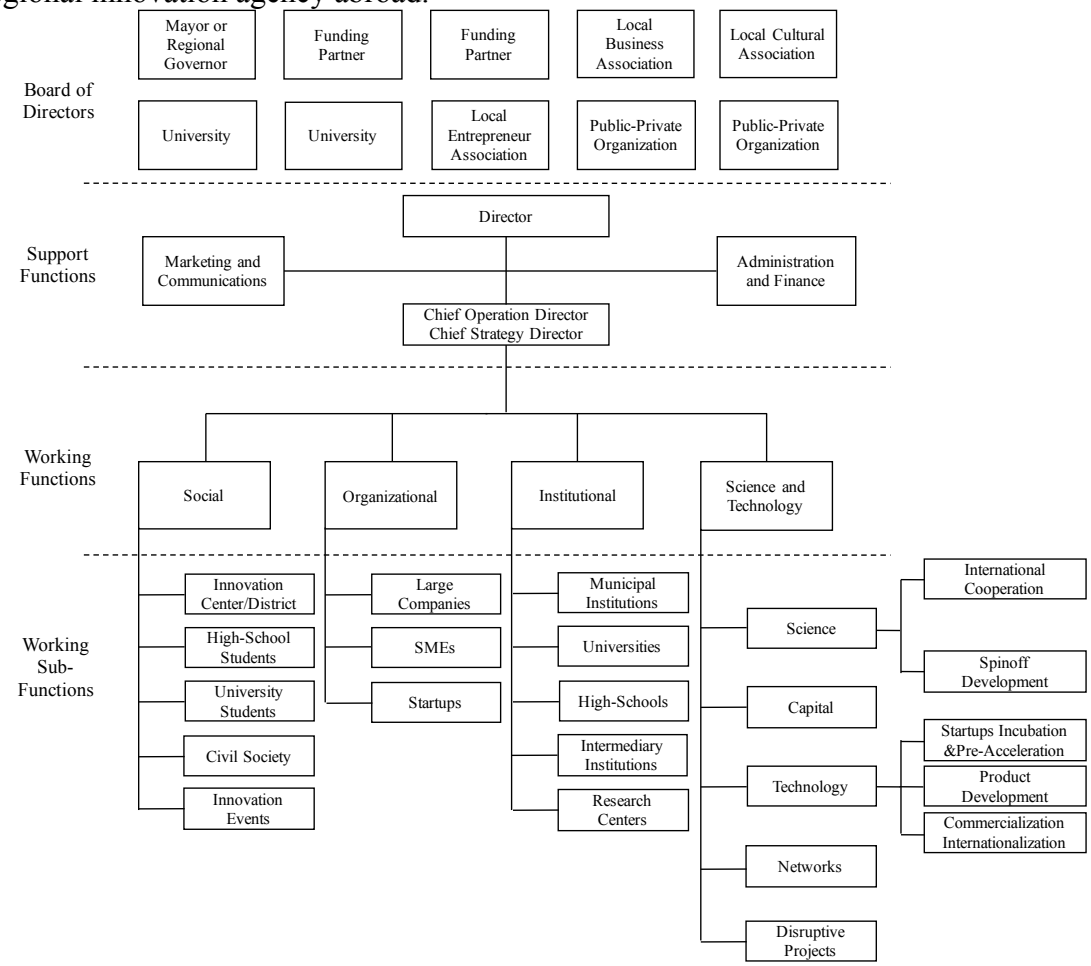


Figure 23. The Organizational Structure of the Regional Innovation Agency. Source: own design.

The working functions should include four areas: social, organizational, institutional, science and technology. The social working function should adapt the social structure to changing economic paradigms through creating programs to adapt the culture, norms, values, and of diffusing the novel culture, norms, and values into the RIS. The organizational working function should support the development of internal processes facilitating the innovation process at the level of large companies, SMEs, and startups. The institutional working function should support public, public-private, and not-for-profit organizations that implement formal institutions to become more efficient and innovative in the new economic paradigm. The institutional working function supports the organizations that devise formal institutions with policy recommendations to promote science, technology, and innovation in the RIS. The science and technology working function has the mission to directly impact the scientific and technological capabilities as well as new industrial path development in the RIS. Furthermore, employees should be given the opportunity to rotate to other function areas every 18 months to facilitate the diffusion of knowledge within the organization.

In total the RIA should employ between 40 to 56 employees who should be divided as followed depending on the regional context and existing innovation capabilities:

- Support functions: 12 to 18 employees.

- Social working function: 6 to 8 employees.
- Organizational working function: 6 to 8 employees.
- Institutional working function: 6 to 8 employees.
- Science and Technology working function: 10 to 14 employees

Ruta N has grown exponentially since its creation from a dozen employees in 2010 to 122 employees (full-time and independent contractors) in 2015. The RIA should have a maximum of 56 full-time employees to conduct its operations efficiently in the RIS and to limit the use of public resources. The RIA should have its working areas clearly defined to reduce potential conflicts with other intermediary and support organizations in the RIS. The scope and mandate of Ruta N's working areas have not been clearly defined leading to many inefficiencies and conflicts in the RIS. Moreover, Ruta N's working areas have been working in knowledge silos that didn't collaborate leading to the replication and the pursuit of similar programs. The organizational innovation working area, for instance, has not a clearly defined mandate and is implementing programs to strengthen the social, institutional, and organizational structures rather than just focusing on organizational innovations.

8.4. Designing the Programs.

The design of the programs should be the outcome of an institutional arrangement that involves all the most important actors in the RIS through multiple quadruple helices (see Figure 24). The RIA has to monitor the weaknesses in the RIS through gathering primary data from all the most important actors in the RIS. The weaknesses in the RIS are identified by the regional institute for innovation, the internal monitoring of best-practices conducted by the chief strategy director, and the quadruple helix advisory boards in each working functions and working sub-functions. Each quadruple helix advisory board has to include at least 10 different actors that are performing significant activities in the working function and in the working sub-functions. Each quadruple helix advisory board has to meet four times a year. In the quadruple helix advisory boards at the level of working functions, the advisory boards will be responsible for deliberating on a plan of action to respond to the priorities set by the board of directors. In the quadruple helix advisory boards at the level of working sub-functions, the advisory board will be responsible to define the programs to address the lines in the plan of action. For instance, the quadruple helix social working function advisory board has to include, the RIA's director, the RIA's chief strategy director, the RIA's working area director, urban planners, directors of media companies, deans of local universities, directors of local high schools, the Secretary of Culture, social entrepreneurs, curator of modern art museums, and not-for-profit organization in the cultural sector. For instance, the quadruple helix advisory board innovation events working sub-function has to include, the RIA's chief strategy director, the RIA's working area director, the RIA's project manager for innovation events, media/marketing companies, entrepreneurs, under-Secretary of Culture, neighborhood associations, professors in entrepreneurship and innovation, museums, and support organizations. The quadruple helix advisory boards have to be as diverse as possible while being adapted to the context of the RIS.

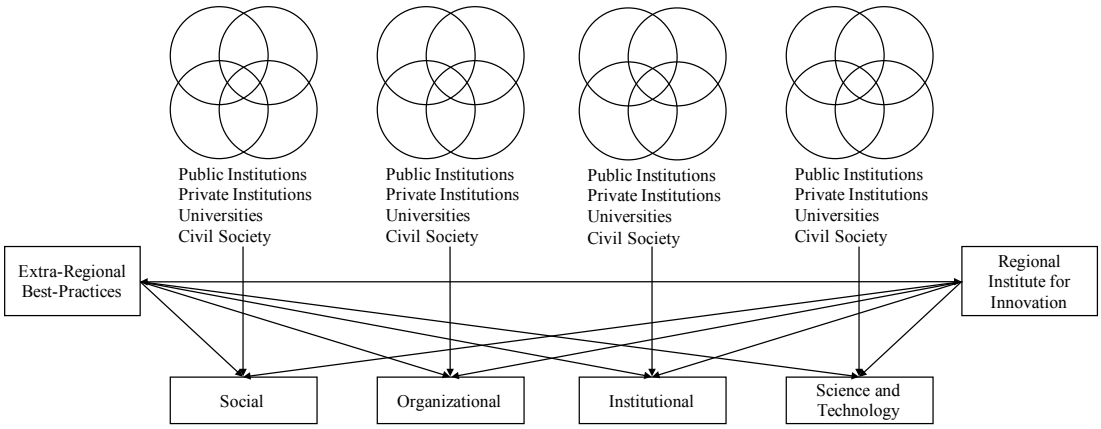


Figure 24. The Institutional Arrangement for Deliberating the Plan of Action. Source: own design.

The design of new programs has to be the outcomes of the following institutional arrangement involving quadruple helix advisory boards at each step of the process. First, the board of director sets the strategy and priorities. Second, the quadruple helix advisory board in each working function identifies the weaknesses in the RIS, deliberates on the regional or extra-regional actor to address the weaknesses, and discusses the recommendations provided by the regional institute for innovation and the chief strategy director. The quadruple helix advisory board in each working function should outline a plan of action for the quadruple helix advisory board in each working sub-function to support them in the definition of the plan of action in the specific sub-function. The quadruple helix advisory board in each working function includes, for instance, the RIA's director, the RIA's chief strategy director, the RIA's working area director, private companies that are relevant for the working function, universities and research centers that are relevant for the working function, a representative of the local government who is relevant for the working function, and not-for-profit organizations that are relevant for the working function. Third, each quadruple helix advisory board in each working sub-function drafts the program to address the weakness in the RIS. Fourth, the quadruple helix advisory board in the working functions revise and validate the program to address the weaknesses. Fifth, the board of directors validate the programs. The institutional arrangement of having multiple quadruple helix advisory boards has for weakness to be more time consuming than internal decision-making and organizationally complex to put in place. The process of having multiple quadruple helix advisory boards has, however, three main benefits that outweigh its costs. First, it rallies all the most important actors in the RIS behind the RIA thus giving legitimacy to the organization. Second, it allows the RIA to become the node in the RIS thus facilitating the coordination and collaboration between the different actors of the RIS. Third, it will enable the RIA to design programs that are adapted to the regional context and that clearly address weaknesses in the RIS.

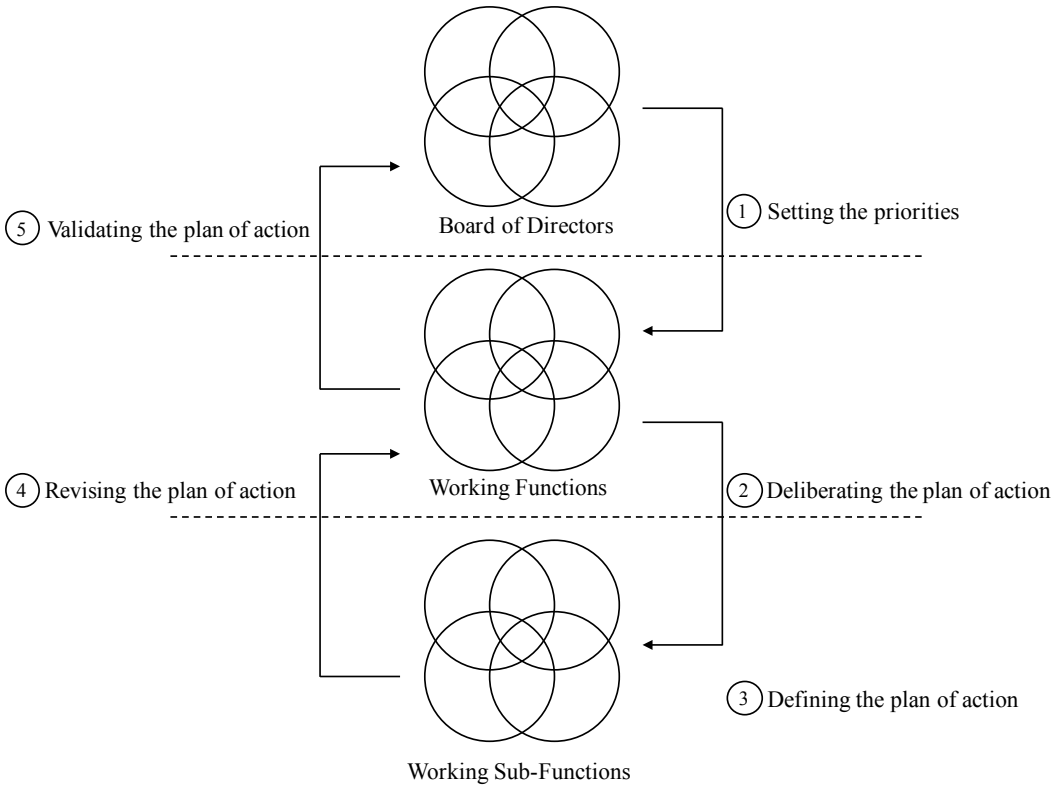


Figure 25. Institutional Arrangements for Designing New Programs. Source: own design.

In designing programs, Ruta N has made three mistakes. First, there is no systematic strategy to design the programs. Indeed, programs have frequently emerged from the initiative of project managers rather from a thorough assessment of the weaknesses in the RIS. Second, Ruta N has designed programs internally within working area silos. Ruta N's working areas involve project managers who are often narrowly focusing on their programs, which has resulted in a limited understanding of other programs within the organization and even sometimes within their working areas. Third, Ruta N has not collaborated enough with other actors in the RIS. This has led to three problems. First, the actors in the RIS did not understand the role of Ruta N in the RIS. Second, Ruta N has devised programs that directly competed with the existing offerings of the actors in the RIS. Third, Ruta N has not properly evaluated the existing innovative capabilities in the RIS leading to maladapted offerings. This situation led in 2016 Mayor Federico Gutiérrez (2016-2019) to drastically reduce the fund allocated to Ruta N. From the recognition of these organizational issues, Ruta N has adopted organizational changes under the ADN strategy to, A, attract capacities, D, develop capacities, and N, respond to the city's challenges. Ruta N is also planning to transform itself into a "fluid organizational structure" adopting a "holacratic" organizational structure. These organizational changes imply that employees won't work within working areas but rather on project-based programs that are validated and monitored by a project management office (PMO). This new organizational structure doesn't address, however, one of Ruta N's core organizational problems, that is, its inward-looking decision-making process and its lack of collaboration with other actors in the RIS.

8.5. The Programs.

The regional innovation agency has not for vocation to implement programs but rather to support other actors in the RIS to identify, to design, to implement, and to monitor programs that address relevant weaknesses in the RIS. In rare cases, however, when the RIA identifies a weakness in the RIS that can be addressed with a short-term program and cannot be implemented by an existing regional or extra-regional actor, the RIA can create and implement a pilot program by benchmarking international best-practices in collaboration with the regional institute for innovation. Each RIA should address specific weaknesses in their RIS, the paragraphs below are some examples of the weaknesses that could be addressed by each working function and sub-function.

The working function social structure will be in charge of supporting the acceleration of the co-evolution of the social structure with the new industrial path development. Each component of the working sub-function social structure has a quadruple helix advisory committee that meets four times a year to decide on the programs to implement. The team in the social function will be dedicated, to run the innovation center, to support programs for high-school and university students, to support programs for the civil society, and to support the organization of innovation-related events. The innovation center should be a sufficiently large space to cluster actors from the quadruple helix, that is, private companies-public institutions-universities-civil society. Moreover, the innovation center has to have spaces for international companies, soft landing spaces for startups, amenities, coffee-shop, restaurants, conference rooms, and so on. The innovation-related events can take the form of a week per year dedicated to innovation, startups weekends, and disruptive challenges addressing structural problems in the regional innovation systems. Finally, the programs for students and the civil society have to reduce the cultural distance between the regional culture and successful RIS around the world, not only from Western culture, Silicon Valley, Boston, Austin, London, Munich, Paris but also Eastern culture, namely China, Shenzhen, Japan, Tokyo, Singapore, and South Korea, Seoul.

The working function organizational structure will be in charge of supporting the acceleration of the co-evolution of the organizational structure with the new industrial path development. Each component of the working sub-function organizational structure has a quadruple helix advisory committee that meets four times a year to decide on the programs to implement. The team in the organizational function will be dedicated, to support programs for private companies to appropriate their technological innovations, to acquire an innovation culture, to run efficiently innovation-related projects, to set-up R&D laboratories, and to transfer specific methodologies to be more efficient in innovation-related projects. The programs to appropriate technological innovations are related to intellectual property to identify and protect innovations. The programs for the innovation culture has to address the structural inertia from management to avoid pursuing more radical innovations. The programs to run efficient innovation-related projects should include transferring methodologies and best-practice to manage innovation-related projects. Finally, the team should motivate the actors within the regional innovation system to spend resources in innovation-related projects and set-up R&D laboratories since it is through innovation that higher competitiveness can be achieved.

The working function institutional structure will be in charge of supporting the acceleration of the co-evolution of the institutional structure with the new industrial path development. Each component of the working sub-function institutional structure has a quadruple helix advisory committee that meets four times a year to decide on the programs to implement. The team in the institutional function will be dedicated, to foster capabilities in municipal organizations to adopt radical innovations, to provide municipal organizations with the capabilities to draft sound innovation policies and strategies, to provide high-school and universities the capabilities to pursue radical innovations, to improve the innovation process within research centers, and to provide linkage organizations with methodologies to become more efficient and innovative. The programs that aim to foster capabilities to adopt radical innovations relate the training of public managers and the screening of best practices around the world in public management that could be adopted into the RIS. The RIA should also lobby the local government to adopt innovation-related policies and train public managers into making sound decisions related to science and technology in the RIS. The programs should also aim at transferring specific capabilities to high-school and universities in order for them to deliver classes more efficiently, to stir research into relevant topics for the RIS, and to become more entrepreneurial. The programs should also focus on providing methodologies to research centers and to linkages institutions to become more efficient in delivering programs and innovation-related projects.

The working function science and technology structure will be in charge of supporting new industrial path development. Each component of the working sub-function science and technology structure has a quadruple helix advisory committee that meets four times a year to decide on the programs to implement. Depending on the existing regional capacities, the team in the science and technology function will be dedicated, to foster scientific capabilities, to provide funding to science and technology organizations, to support the innovation process at the level of private and public firms, to generate local and international interactions and networking opportunities, and to find potential disruptive projects to the region. Depending on the existing capabilities and actors in the regions, the team should support ten programs. First, the program, International Cooperation, aims to support research teams to conduct field trips to and create partnerships with relevant innovation systems around the world. Second, the program spinoffs aims to support the creation of viable companies from research activities. Third, the program pre-acceleration for startups aims to prepare startups to refine their business models, prototypes, and pitch to venture capital firms and startups accelerators. Fourth, the program to SMEs aims to support the development and commercialization of new innovative prototypes. Fifth, the program prototyping aims to support private companies in their prototyping capabilities. Sixth, the program knowledge transfer aims to support private companies to have access to extra-regional knowledge in refining their products and services. Seventh, the internationalization program aims to support knowledge-based companies internationalize themselves. Eight, the program networks aims to foster local and extra-regional interactions and generate networks. Ninth, the program capital aims to fund startups, spinoffs, and SMEs to move up the TRLs. Funding can be conditional on co-financing and royalties or other benefits for the RIA. Tenth, the program disruptive projects aims to support the region to adopt and to adapt potential disruptive technologies into the region. As Figure 26 shows, the science and technology programs aim to support regional actors into moving up their TRLs.

The regional innovation agency has to draft the programs in collaboration with the regional or extra-regional implementing actor to adapt the program to the local context and to improve regional absorptive capacities to facilitate the knowledge transfer process. When a regional actor does not exist to appropriately implement a program, the regional innovation agency has to select an extra-regional actor. In that case, in addition to selecting the program's targeted actors, the RIA has to select a regional actor to participate to the program that will be able to replicate the program from the knowledge transferred from the extra-regional implementing actor. The extra-regional implementing actor should be selected according to their capacities rather than their brand image. The extra-regional implementing actors should, however, come from innovation hubs around the world. The extra-regional implementing actors can be universities, companies, consultancy firms, startups, or technology centers. Universities are good partners since the relationship tends to trickle down to students, research objectives, and informal networking. Consultancy firms, especially large ones, tend to stick to only delivering programs and thus, should be avoided except when alternatives do not exist. Finally, companies, startups, and technology centers can be good partners, especially when they are looking for locating one international branch abroad. Moreover, all extra-regional implementing actors should be ready to collaborate with the RIA to adapt their programs.

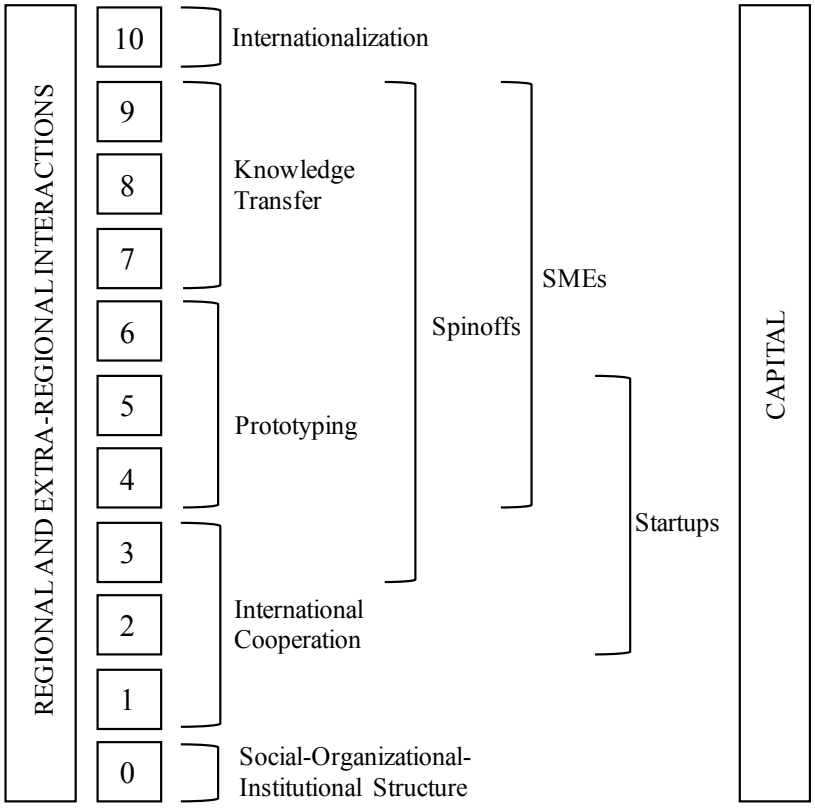


Figure 26. TRLs and Science and Technology Programs. Source: own design.

In implementing programs, Ruta N has followed an iterative process of trials-and-errors. Indeed, since its creation, Ruta N has implemented many programs and drafted many more. The large number of programs has not been, however, the outcome of strategic thinking but rather the consequence of the organization continuous on-the-job learning-by-doing. Many programs were abandoned before even being implemented and many others were implemented for just one or two years, which consequently resulted in

the RIA to squander more resources than needed (human and financial) and to hinder the possibility of evaluating the programs. Moreover, the programs that have been implemented by extra-regional actors have not been transferred to a regional actor that could repeat the program if needed. The extra-regional implementing actors have also been selected in an iterative process of trial-and-errors rather than being the outcome of a clear strategy. The regional actors that participated in the programs were not pre-selected before the design of the programs but after the RIA had already selected the implementing actors. It led Ruta N to select the regional actors participating into the program to match the implementing actor rather than the other way around. The iterative process of trials-and-errors has, however, allowed the RIA to create very unique and innovative programs.

8.6. Evaluating the Regional Innovation Agency.

The RIA should be evaluated in a formative and summative manner. The RIA will operate for at least 15 years, and for that reason, needs to continuously evolve to respond to the needs emerging in the RIS. Formative evaluation will be performed to improve in an incremental manner the trajectory of the organization, while the summative evaluation will allow for new dynamics and more radical approaches to emerge. The RIA should evaluate its impact on three different levels. Indeed, RIA should monitor its impact at the level of the RIS, at the level of the agency, and at the level of the programs. The evaluations should take into account that the RIA ultimately has a limited impact on the RIS, a moderate impact on the agency, and a high impact on the programs.

Ruta N has not conducted thorough evaluations of its impact on the RIS. The only systematic evaluation that Ruta N has conducted is on its branding and positioning in the RIS. Ruta N has contracted Technopolis Group to design key performance indicators (KPIs) but has not pursued the implementation of the KPIs. Since 2017, Ruta N is conducting an annual survey to measure innovation activities and needs at the level of companies in the Aburrá Valley.

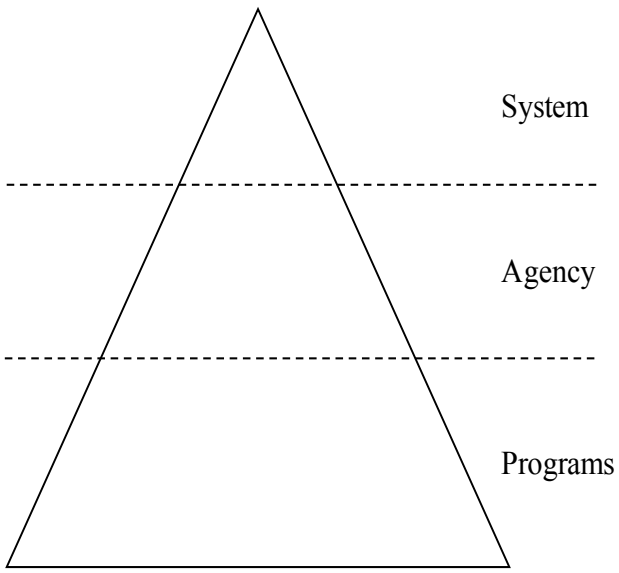


Figure 27. The RIA's Evaluation Triangle. Source: own design.

Evaluations at the level of the system. The RIA should monitor at the level of the RIS, the following indicators:

Innovation and scientific indicators, such as innovation inputs and outputs; R&D spending; spending in science, technology, and innovation; employment in high-tech sectors; student's perception of entrepreneurship; patents registered; trademarks registered; seed capital (in $); venture capital (in $); and number of high growth startups (gazelles). Scientific indicators, such as number of articles published in SCOPUS, number of researchers in STEM, number of international faculty in STEM, number of student in STEM, number of students at Bachelor, Master and PhD levels.

Indicators of international knowledge flows, such as importation of high-technology products and services (in % of total importations); exportations of high-technology products and services (in % of total importations); technological balance of payments; number of companies exporting high-technology products and services; international co-patenting activities; international cooperation for local companies (in %); share of international workers; and share of international workers with PhDs.

The evaluation of the regional innovation system has to be made in comparison with other regions at the national level and with benchmarked regions and reference regions around the world. The innovation indicators can adopt indicators from the European Regional Innovation Scoreboard (ERIS), which can be interesting for regions outside the European Union wanting to benchmark themselves with regions in the European Union.

Evaluations at the level of the agency. The RIA should monitor at the level of the agency, the following indicators:

Indicators related to the new industrial path development selected, such as the number of employees and companies in the new industrial path development, the number of new companies created, R&D and STI expenditures, the number of employees in R&D, the number of patents, the number of innovations introduced, exportation, and internationalization.

Indicators related to all the companies that have participated to the RIA's programs, such as an annual survey to monitor satisfaction and needs, an annual survey to monitor the innovation capacities of the companies, an annual survey to monitor concerns and trends, and an annual survey to propose new services to the RIS.

Indicators related to the actors in the RIS, such as an annual survey to monitor satisfaction of the RIA for the actors in the RIS and annual survey for the actors in the RIS to evaluate RIA's SWOT analysis. Indicators related to the satisfaction of the RIA's employees, such as an annual survey of the RIA's employees.

Evaluations at the level of the program. Following a developmental evaluation approach that focuses on "ongoing adaptation to a changing environment and changing dynamics under the presumption that there will never be a fixed model" (Patton, 2010, p. 28), each program developed has to be evaluated in a formative and summative manner. The formative evaluation will allow for the constant improvement of the program in an evolutionary manner. That is, the formative evaluation will monitor the

changes needed to improve the program or/and the new trajectories that the program should take to make the highest impact as possible. The formative evaluation can be done through a survey given to the participants. The summative evaluation will be performed when the program is reaching a level of maturity in addressing the specific weakness in the RIS. The summative evaluation will be performed to assess the program effectiveness in terms of outcome and impact evaluation.

Conclusions.

Answer to the Research Question. From the 1970s to 2000s, Medellín was isolated from global knowledge flows due to a period of extreme violence, as well as due to idiosyncratic cultural, social, and geographical factors. This isolation contributed to the cognitive and political lock-ins of the industrial sector, which hindered the city's new industrial path creation and path branching towards more knowledge-based activities. The limited diffusion of extra-regional knowledge into a RIS contributes to system failures, which require, as in the case of Medellín, some type of policy interventions. The reorganization of the GEA's strategic priorities, the threat from 'narco-elites' to the GEA vested interests, and the elections of Mayor Fajardo (2004-2007), Alonso Salazar (2008-2011), and Aníbal Gaviria (2012-2015), which were backed by the GEA, playing the role of an institutional entrepreneur, and have led to structural reforms in education, social urbanism, social inclusion, and innovation-led policies, have paved the way to Medellín's economic transformation into more knowledge-based and service-based activities. The institutional proximity and shared vision between the private sector, namely, the GEA and Proantioquia, and the public sector, namely, the City of Medellín and EPM-UNE, has facilitated the creation of an institutional instrument, that is, Ruta N, to connect Medellín to innovation hubs around the world and to accelerate Medellín's transition into a knowledge city. Ruta N is the regional innovation governance structure that emerged from an institutional arrangement characterized by the proximity between the municipal government under the leadership of Alonso Salazar (2008-2011) and the GEA under the leadership of Nicanor Restrepo Santamaría (1978-2015). The institutional proximity between the local government and the GEA emerged from the paternalistic sense that traditionally possesses the Antioquia elites towards regional economic and social development.

The entrepreneurial region can support new industrial regional path development through the acquisition, diffusion, and absorption of extra-regional knowledge in RISs that are located on the knowledge periphery, as they lack the sufficient extra-regional knowledge flows and the capacity to absorb the extra-regional knowledge. In Medellín, Ruta N has played the role of a knowledge gatekeeper that has "tropicalized" extra-regional knowledge to facilitate its absorption into the RIS. The act of tropicalizing knowledge, which refers to the hybridization of the tacit extra-regional knowledge with the local knowledge, aims to facilitate regional absorptive capacity. The knowledge gatekeeper is in charge of supporting new industrial regional path development by connecting local actors with international leaders while monitoring and facilitating knowledge transfer. These findings confirm the importance of extra-regional knowledge and absorptive capacity in regions outside diversified and organizationally thick RIS for path development (Isaksen, Tödtling, and Trippl, 2018; Martin et al., 2018; Trippl, Grillitsch, & Isaksen, 2017) while emphasizing the importance of the creation of specific institutional arrangements and capacities to pursue such strategies for path development. The creation of Ruta N in Medellín is the type of intervention that has aimed to increase extra-knowledge flows and their absorptions into the RIS. In contrast with other knowledge gatekeepers, such as leader firms or universities, in which a lag persists in leaking knowledge, the extra-regional knowledge from public knowledge gatekeepers is directly transferred to the actors in the RIS. The public knowledge gatekeeper, Ruta N, has three roles: to support the acquisition of extra-regional knowledge, its "tropicalization", and its diffusion into the RIS. For the RIA, the brokerage of extra-regional knowledge has three objectives: first, to improve the capacity of the RIS to

acquire, absorb, and diffuse extra-regional knowledge; second, to connect Medellín and Ruta N to significant innovation hubs around the world, such as Boston, Austin, Silicon Valley, Israel, or Cambridge, to generate formal and informal networks between regional and international actors; and third, to improve the visibility of Medellín and Ruta N as an important innovation system in the world.

Path development is not done in a vacuum since it affects and is affected by the socio-institutional structure, which is a path-dependent and evolutionary structure. The academic literature has pointed out the importance of socio-institutional changes to facilitate technology transfer and new industrial path development (Cortinovis et al., 2017; Dahlman & Nelson, 1995; Headrick, 1988; Seely, 2003). The socio-institutional structure suffers from inertia, and thus co-evolve less rapidly than technological change during periods of structural change in the economy characterized by rapid path creation and path destruction (Geels 2002, 2004, 2005; Kemp, 1994; North, 2005; Perez, 1983, 2004). In regions that are located on the knowledge periphery, the coupling of the socio-institutional structure with the techno-economic structure must be facilitated by the entrepreneurial region. Indeed, contrary to core regions at the technological frontier that experience trials and errors when dealing with recoupling their socio-institutional structures with the new technological paradigm, regions on the knowledge periphery that are catching-up can learn from the errors of core regions by selecting the traits that are most important for an efficient coupling.

In Medellín, the public organization Ruta N, which is the entrepreneurial organization of the Mayor's office, has created programs to accelerate the evolution of the social, organizational, and institutional structures. The social structure was affected to make residents have more innovative attitudes, entrepreneurial spirits, and to aspire to pursue STEM careers. The organizational structure was affected to transform existing private companies, namely large companies and SMEs, into entrepreneurial entities that are continuously innovating. The organizational structure was affected by providing employees' training in innovation management and transferring of methodologies to foster innovations. The institutional structure was affected by creating programs that target local institutions, namely the City of Medellín, educational institutions, linkage institutions, and technological research centers. Finally, Ruta N is building an innovation district as a high-quality urban space clustering innovative actors to promote face-to-face interactions and to speed up the exchange of tacit knowledge. The dimension of geographic proximity is an enabler of the socio-institutional structure since it facilitates repeated and frequent interactions and thus the exchange of tacit knowledge contributing to the adoption and diffusion of new knowledge. Finally, the socio-institutional structure affects each other through feedback loops and cumulative causation mechanisms. As a result, the social, organizational, or institutional structures cannot fully co-evolved without the concurrent co-evolution of the other two.

Ruta N is a regional innovation governance structure that has the primary mission to support Medellín's transformation into a knowledge city (see Figure 28). The two underlying instruments to transform Medellín into a knowledge city are the creation of new industrial path development and the acceleration of the evolution of the socio-institutional structure. The activities that Ruta N has performed to affect the two instruments are, to monitor Medellín's RIS and successful RIS around the world in order to identify the main weaknesses in the RIS, to support the RIS to acquire the capacity to address these weaknesses by devising programs, to support the assimilation of the extra-

regional knowledge by tropicalizing knowledge, to support the diffusion of that knowledge by promoting interactions in the RIS, and to finally evaluate the impact and effects of the programs on the RIS. Ruta N has been highly creative and innovative at developing its own programs embodying the essence of the entrepreneurial region. Ruta N has been successful on many different levels, namely in positioning Medellín as a relevant RIS in the world thanks to the soft landing program and various programs involving international actors, in making the different actors in the RIS understand the importance of technological innovation for regional economic development, in thinking about unique, entrepreneurial, and innovative programs to transform the RIS in a systematic and in an in-depth manner, such as Cooperation N, the STI Observatory, innovation management for companies, or the innovation laboratory, which has received an international recognition from Fast Company (2018).

> "Ruta N has been very important in understanding successful innovation ecosystems around the world. Ruta N has invested a lot to capture best-practices in the world, to have good consultants to understand the world, to generate methodologies in innovation, and to involve people" (Rafael Aubad, Proantioquia, personal communication, 8 August 2017).

> "Ruta N has achieved to position well Medellín in the world. The residents of Medellín have started to understand the power of innovation, the strategic importance of innovation. It has allowed to internally position the topic of innovation" (Santiago Echavarría, CTA, personal communication, July 12, 2017).

> "Ruta N has been successful in generating in a short period a critical mass of persons and companies interested in topics related to innovation and entrepreneurship [...] Ruta N has allowed the ecosystem to have experience from international actors and to have access to international trends in innovation activities since Medellín is a relatively closed ecosystem (Alejandro Mazo, Parque E, personal communication, August 22, 2018).

> "Ruta N has done successfully technology watch and competitive intelligence to find opportunities for investors in smart capital and entrepreneurs. Ruta N has done successfully programs for companies to improve their capacities in innovation management. Ruta N has done successfully the training of many employees within companies in practical projects related to innovation. Ruta N has done successfully the attraction of companies and entrepreneurs in new knowledge and technological areas in Medellín" (Santiago Acosta Maya, EPM, personal communication, August 16, 2018).

Ruta N is a classic example of policy running ahead of theory, which has led to many difficulties and misunderstandings in performing its main activities (see 8. The Framework for Regional Innovation Agency). Indeed, Ruta N has experienced some difficulties in performing its activities due to an inward-looking organizational structure, a lack of internal capabilities, and the misunderstanding of some of its core activities. Ruta N has perceived itself as a startup rather than a public organization, which has led to two major problems. First, Ruta N started to see itself as the city's innovation planner and started to compete with other actors in the RIS. Second, Ruta N didn't collaborate

enough with the actors in the RIS and has relied too much on internal capacities and on learning-by-doing following a process of trials-and-errors. This has led Ruta N to misjudge the existing innovative capacities of the actors in the RIS and thus to design an offer that didn't have a demand. Ruta N has faced some difficulties in "tropicalizing" knowledge due to a lack of internal capabilities to translate extra-regional knowledge and due to a misunderstanding of its role as a knowledge gatekeeper. In its infancy, Ruta N has also misjudged the innovative capacities of many actors in the RIS and thus their capacities to effectively absorb extra-regional knowledge, which resulted in limiting the policy effectiveness of brokering extra-regional knowledge into the RIS. In the diffusion process, Ruta N, identifying itself as a start-up, has created multiple web platforms, Brainbook, SUNN, MiMedellín, and Cities for Life. Brainbook and SUNN have been extremely expensive and require a network effect to be widely adopted, which will be unlikely. In addition, Ruta N has over-communicated on its potential future impact and excluded other actors in the RIS while demonstrating little concrete results, which has led to resentment from other actors in the RIS. Finally, in the evaluation process, Ruta N has failed to consistently and systematically monitor its impacts and effects at the system level, at the agency level, and at the program level, thus reinforcing organizational inefficiencies through unchecked negative feedback loops.

> "In the years 2009 to 2014, Ruta N distracted itself in its strategy and it seemed that it was doing everything. It was difficult to understand the strategic role of Ruta N and because in the city there are private venture capital companies, start-up accelerators, start-up incubators, technological development centers, and research groups, it generated a lot of conflicts between the different actors, nothing alarming, but a lack of coordination and a lot of rivalries between the different actors in the innovation ecosystem. Later, another mistake was that Ruta N declared itself as the innovation planner of the ecosystem and this is an enormous mistake because nobody can organize the innovation ecosystem" (Santiago Acosta Maya, EPM, personal communication, August 16, 2018).

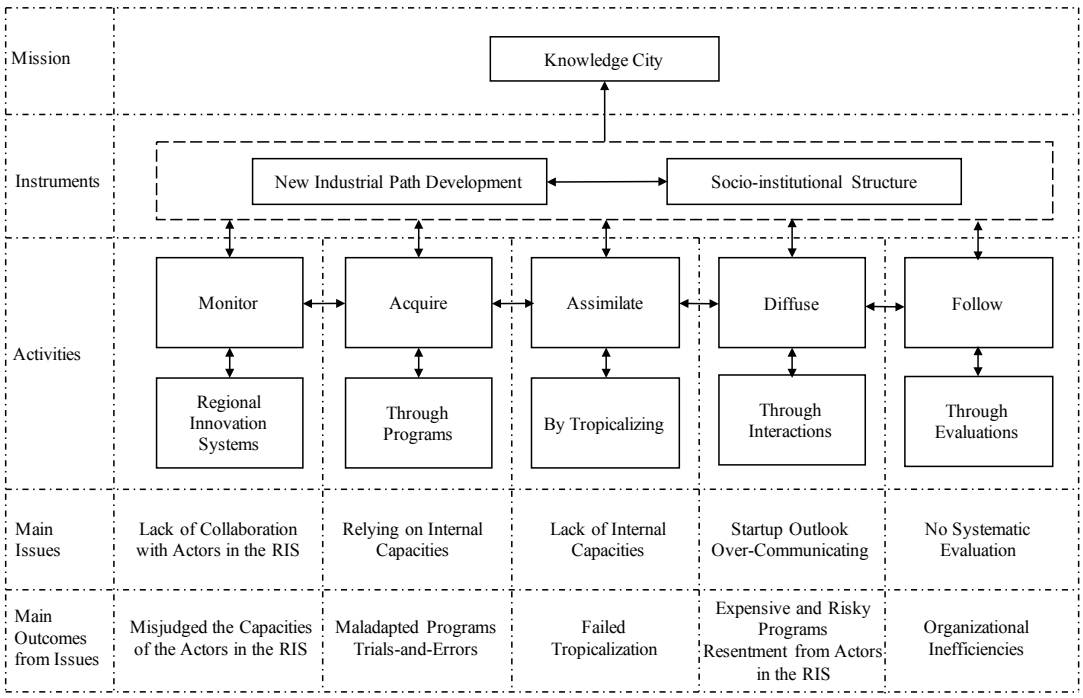


Figure 28. Ruta N's mission, instruments, and activities. Source: own design.

Policy Implications. Local and regional policymakers often overestimate their regional innovation systems' capacity to develop new ideas and to produce technological innovations. Local and regional innovation policies would actually be more efficient in promoting the local's absorptive capacity and in adapting to their contexts existing innovations (Mahroum et al., 2008). This thesis provides a place-based instrument, the regional innovation agency, through which regions on the knowledge periphery can catch-up technologically with regions in the knowledge core by supporting new industrial regional path development and by accelerating the evolution of the socio-institutional structure. The regional innovation agency has to perform the activities of monitoring, acquiring, assimilating, and diffusing knowledge, which are conditional on the agency's capabilities, willingness, and legitimacy to carry out regional economic development and structural change. The regional innovation agency, which has a wide mandate to affect the innovation process, applies the concept of the entrepreneurial state to the regional level. Regional innovation agency in regions located on the knowledge periphery have to support the acquisition, assimilation, and diffusion of extra-regional knowledge to facilitate new industrial path development since regions on the knowledge periphery are less exposed to extra-regional knowledge from regions at the technological frontier due to limited knowledge capacities and knowledge infrastructures, and, as a result, need some type of interventions. This thesis confirms the importance of extra-regional knowledge in new industrial path development (Trippl, Grillitsch, & Isaksen, 2017). Entrepreneurial regional governments in regions on the knowledge periphery that are catching-up must accelerate the co-evolution of the social, organizational, institutional structures with the novel techno-economic structure to limit instabilities and inefficiencies resulting from structural change in the economy. The entrepreneurial region can thus create programs and policies to reduce the lag between rapid techno-economic changes and the inertia in socio-institutional changes. The entrepreneurial region can learn from and transfer knowledge from regions that are at the technology frontier and have thus already transitioned or have socio-institutional structures further co-evolved to reduce this lag. The entrepreneurial region facilitates co-evolution through selecting traits that are deemed important in further evolved regions and induce them into the regional innovation system to reduce decoupling between the socio-institutional and the techno-economic structure during structural change in the regional economy.

This thesis is relevant for the academic literature to understand the multifaceted issue of technological catch-up for regions on the knowledge periphery. The policy concepts of smart specialization (Foray, 2009) and new industrial path development (Asheim, Boschma, & Cooke, 2011; Boschma, Balland, & Kogler, 2014) have not provided regions on the knowledge periphery with a policy response to spur convergence. While smart specialization presumes the existence of a smart region (Morgan, 2017) that has the capacity to specialize in a "smart way" (European Union, 2011, p. 7), path development is assumed to be a path-dependent process (Boschma, Balland, & Kogler, 2014). Regions on the knowledge periphery lack the institutional capacity to implement smart specialization (Charron, Dijkstra, & Lapuente, 2014; Rodríguez-Pose, Di Cataldo, & Rainoldi, 2014) and the required diversified knowledge base to foster path-dependent path branching and creation (Boschma & Lambooy, 1999). This thesis provides policymakers in specialized and organizationally thick RISs that are located on the knowledge periphery with a policy instrument and a policy strategy to address the shortcomings of the literature on path development and smart specialization strategy (S3). In regions located on the knowledge periphery, RIAs can be regional innovation governance structures that support new industrial path development by facilitating the

acquisition, diffusion, and absorption of extra-regional knowledge into the RIS. Although the institutional arrangement of a public knowledge gatekeeper offers benefits in the short-term for the regions on the knowledge periphery, it can hinder the emergence of leader firms and universities that act as knowledge gatekeepers in the RIS. The public knowledge gatekeeper should thus be a temporary policy intervention to better connect the RIS with global knowledge hubs.

> "If you were asking me what the role of Ruta N should be, I would answer that Ruta N's role is to coordinate and to create the conditions for innovation. Let me put it to you that way, if Ruta N were to be successful, it should cease to exist (Juan Pablo Ortega, Ruta N, personal communication, 19 July 2017).

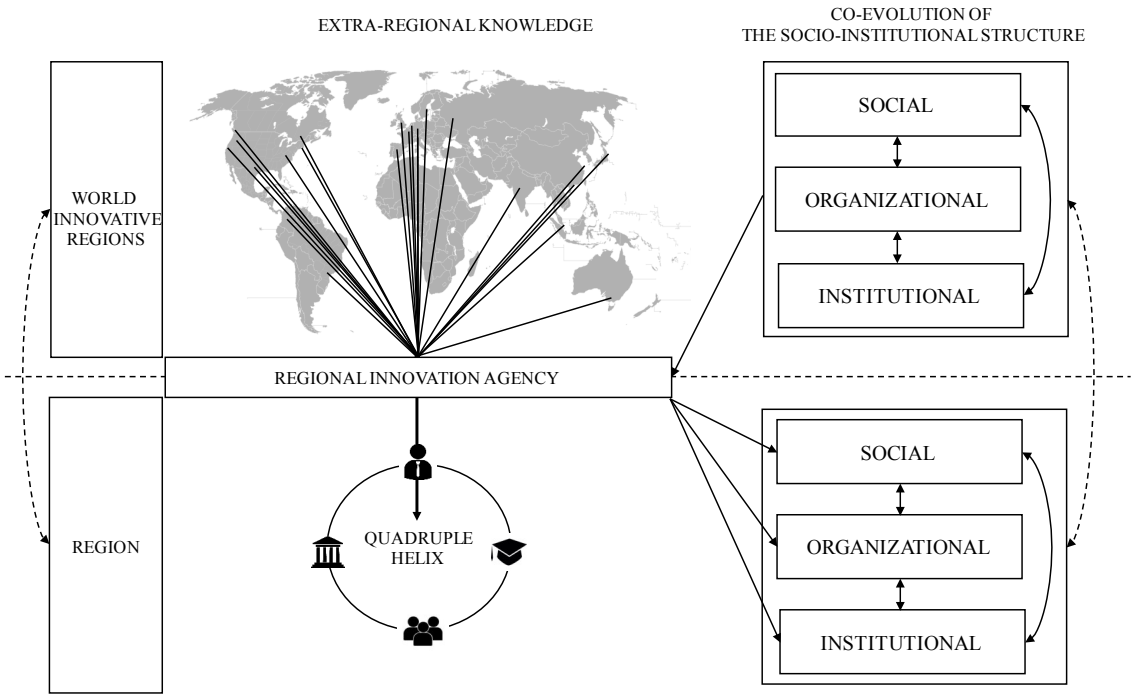


Figure 29. The Two Main Roles of the Regional Innovation Agency. Source: own design.

This thesis proposes a framework for regions that are located on the knowledge periphery to design their own version of a regional innovation agency based on the hypothesis that regional governments can play a fundamental role in affecting regional structural change. The framework to design a regional innovation agency is embedded into a contextually rich case study, Ruta N, in Medellín, Colombia. The description-rich case study and framework to design such a regional innovation agency allow policymakers to design their own version of a regional innovation agency. Institutions are context-specific. For that reason, decision-makers should listen to a wide range of experts and should not blindly follow best-practices when reforming their institutions (Dixit, 2009). Policymakers should merge elements of international best-practices with context-specific features to reform and to design successful institutions (Dixit, 2009). The regional innovation agency is a place-based strategy that is not a "one-size-fits-all" regional innovation policy but a "one-size-fits-many" policy strategy. Indeed, RIAs can only be relevant in regional innovation systems that are located on the knowledge periphery in which the following sixth conditions are present. First, the RIS has a distinct regional culture. Second, the RIS has clear administrative boundaries. Third, the RIS has a city with a metropolitan population of at least around 1,000,000 inhabitants. Fourth,

the RIS has existing innovative infrastructures, such as universities, large companies, research centers, public institutions, and support and intermediary organizations. Fifth, the region has some political stability to fund the agency for a period of least 15 years. Finally, the region has a middle-income or high-income with a GDP per capita in the regional innovation system of at least USD $2,000-3,000. Moreover, the RIA will be most adequate in regions that are relatively specialized and that are organizationally and institutionally thick.

Limitations and Future Research Directions. This thesis aims to convey a very positive message, illustrating that since Medellín has successfully managed to transform itself, many cities around the world can do it too. This thesis has, however, five main limitations. The first limitation lies in the fact that it is based on only one case. The policy implications can only thus be applied to regions with similar contexts and prior capabilities as Medellín. The second main limitation is that Medellín has not yet caught up with the rest of the developed world, thus cannot be hailed as a unique success story. Many dark sides of Medellín still persist, inequality is still very high, crime is still ubiquitous, and narco-trafficking is still an important source of revenue in the city. The third limitation lies in the abstract theoretical approach to the technological catch-up process and the limited number of indicators to quantitatively measure the effect and impact of the regional innovation agency, Ruta N, on its regional innovation system. Ruta N has not conducted evaluations of its impact, moreover, it is difficult today, to find a causality between the role of the regional innovation agency and the higher innovation activities in the city. The fourth limitation lies in the fact that the researcher didn't conduct interviews with companies that have participated in the programs but only with actors in the RIS or the actors that have implemented the programs. The fifth limitation lies in the limited numbers of indicators to fully measure innovation activities, the quality of the new industrial path development, and the extra-regional knowledge flows in Medellín.

From this thesis, three future research directions and projects could be undertaken. The first potential research project is to empirically categorize regions in the knowledge core, on the knowledge semi-periphery, and on the knowledge periphery to provide better innovation policy-responses to regions in the global South. The categorization should be contingent of the amount of knowledge flows from regions in the knowledge core to other regions. The regions in the knowledge core are regions that are significant producers and users of technological innovations, such as top regions in patenting activities around the world (see Bergquist, Fink, & Raffo, 2017 for the list of Top-100 cluster by patent filing in the world). The regions on the knowledge semi-periphery are regions that are receiving significant knowledge from regions in the knowledge core. The regions on the knowledge periphery are receiving little knowledge from regions in the knowledge core. Although dealing with some highly sensitive materials, the second potential research project is to investigate through a multiple case study approach the divergence between Medellín and Cali. Indeed, the two cities were relatively similar in that they are specialized old-industrial RIS. Medellín has, however, significantly diverged from Cali in terms of the percentage of GDP contributing the national GDP. One possible explanation is that while the industrial and business elites from GEA remained independent from narco-elites, the industrial elite in Cali merged their activities or have largely been influenced by the narco-elites. Finally, the third potential research project is to investigate through a multiple case study approach, multiple regional

innovation agencies in different regional innovation systems to generalize the findings of this thesis.

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Appendices.

Appendix 1. List of Interviews Conducted in 2017.

NAME	POSITION	COMPANY	DATE
Alejandro Hincapié Baena	R&D	Ruta N Medellin	24/08/2017
Ana Salazar	R&D	Ruta N Medellin	01/08/2017
Andrés Montoya	Ex-Director Ruta N Medellin	Ruta N Medellin (2009-2011)	17/07/2017
Andres Calle	Knowledge Business	Ruta N Medellin	26/07/2017
Angelica Jaramillo	Ex-Director Innovation Culture	Ruta N Medellin (2013-2016)	24/08/2017
Carlos Castro	R&D	Ruta N Medellin	24/08/2017
Carlos Franco	Special Projects	Ruta N Medellin	28/07/2017
Carlos Ratti	Professor	MIT	15/10/2017
Carolina Bernal Sierra	Knowledge Management Director	ACI	01/09/2017
Catalina Gutierrez	Ex-Knowledge Business	Ruta N Medellin (2010-2013)	28/07/2017
Catalina Hernandez	R&D	Ruta N Medellin	01/08/2017
Catalina Vega	Organizational Innovation	Ruta N Medellin	22/08/2017
David Murcia	Professor	EAFIT University	19/07/2017
David Sierra	Director Special Projects	Ruta N Medellin	25/07/2017
Diego Gomez	Director	ECSIM	17/08/2017
Elkin Echeverri	Director Prospection and Planification	Ruta N Medellin	27/07/2017 29/08/2017
Iván Rendon	Innovation District	Ruta N Medellin	23/08/2017
Jorge Mesa	Professor	EAFIT University	24/07/2017
Jorge Suarez	Prospection and Planification	Ruta N Medellin	06/07/2017 27/07/2017
José Willington Ramirez	Organizational Innovation	Ruta N Medellin	09/08/2017
Juan José Henao	Knowledge Management	ACI	01/09/2017
Juan Manuel Salazar	Organizational Innovation	Ruta N Medellin	01/08/2017
Juan Pablo Ortega	Ex-Director Ruta N Medellin	Ruta N Medellin (2009-2013)	19/07/2017
Kit I Sin	Knowledge Business	Ruta N Medellin	02/08/2017
Marcela Embus	Organizational Innovation	Ruta N Medellin	25/07/2017 30/08/2017
Maria Isabel Palomino	Prospection and Planification	Ruta N Medellin	27/07/2017
Mario Vargas	Professor	EAFIT University	23/08/2017
Oscar Eduardo Quintero	Director	Tecnnova	30/08/2017
Paola Pollmeier	Special Projects	Ruta N Medellin	11/08/2017
Patricia Zuluaga	Professor	EAFIT University	12/07/2017
Paulina Villa	Director Innovation District	Ruta N Medellin	27/07/2017
Rafael Aubad	Director	Proantioquia	08/08/2017
Rocio Arango Giraldo	Innovation Culture	Ruta N Medellin	01/08/2017
Rubén Villegas	Organizational Innovation	Ruta N Medellin	25/07/2017
Samuel Urquijo	Plan CTi	Ruta N Medellin	11/08/2017
Santiago Echavarria	Director	CTA	12/07/2017
Santiago Pelaez	Organizational Innovation	Ruta N Medellin	01/09/2017
Susana Ortiz	Knowledge Business	Ruta N Medellin	04/08/2017

Appendix 2. List of Interviews Conducted in 2018.

NAME	POSITION	COMPANY	DATE
Adolfo Moreno	Cluster Health City	Chamber of Commerce	18/07/2018
Alejandro Delgado	Prospection and Planification	Ruta N Medellin	23/07/2018
Alejandro Mazo	Director of Innovation	Parque E	22/08/2018
Alonso Salazar	Mayor of Medellin (2008-2011)	City of Medellin	17/08/2018
Ana Isabel Maya	Organizational Innovation	Ruta N Medellin	09/08/2018
Ana Salazar	R&D	Ruta N Medellin	21/08/2018
Andrés Arias	Director Innovation and Entrepreneurship	City of Medellin	16/08/2018
Carlos Franco	Prospection and Planification	Ruta N Medellin	01/08/2018
Catalina Carmona	Organizational Innovation	Ruta N Medellin	09/08/2018
Catalina Hernandez	R&D	Ruta N Medellin	21/08/2018
Claudia Betancur	Director	Biointropic	25/07/2018
David Sierra	Special Project	Ruta N Medellin	08/08/2018
Diana Morales	Cluster Energia	Chamber of Commerce	19/07/2018
Elisa Bustamante	Acceleration Director	CREAME	03/08/2018
Elisa Sierra	Organizational Innovation	Ruta N Medellin	09/08/2018
Elkin Echeverri	Director Prospection and Planification	Ruta N Medellin	23/08/2018
Iván Rendon	Innovation District	Ruta N Medellin	30/07/2018
Jaime Echeverri	VP Planning and Development	Chamber of Commerce	16/07/2018
Jorge Areiza	Prospection and Planification	Ruta N Medellin	26/07/2018
Jorge Suarez	Prospection and Planification	Ruta N Medellin	17/07/2018
José Willington Ramirez	Organizational Innovation	Ruta N Medellin	03/08/2018
Juan Camilo Quintero	Director	ANDI	23/08/2018
Juan José Llisteri	Consultant	IADB	31/07/2018
Kit I Sin	Knowledge Business	Ruta N Medellin	24/07/2018
Liliana Beltrán	Marketing and Communication	Ruta N Medellin	08/08/2018
Marcela Embus	Organizational Innovation	Ruta N Medellin	02/08/2018
Mauricio Muñoz	Business Development	CIDET	03/08/2018
Melisa Arango	Prospection and Planification	Ruta N Medellin	17/07/2018
Monica Sánchez	Cluster Energia	Chamber of Commerce	18/07/2018
Oscar Gaviria	Knowledge Business	Ruta N Medellin	10/08/2018
Rubén Cadavid	Cluster TIC	Chamber of Commerce	03/08/2018
Rubén Villegas	Organizational Innovation	Ruta N Medellin	13/08/2018
Santiago Acosta Maya	Director of Innovation	EPM	16/08/2018
Santiago Echavarria	Director	CTA	24/07/2018
Valentina González	Organizational Innovation	Ruta N Medellin	28/08/2018

Appendix 3. Semi-Structured Interviews directed towards Ruta N's Employees.

Date of Interview: _____
Name of Interviewee: _____
Function of Interviewee: _____
What does you work area do?
What does your work consist of?
What are the programs in your work area?
Can you describe each program mentioned?
For each program, who were the actors targeted?
For each program, who were the actors implementing the program?
How did the actors implement the program?
What was the role of Ruta N in creating and implementing the program?
For you, what is Ruta N?

Appendix 4. Semi-Structured Interviews directed towards the organizations/actors that participated or implemented Ruta N's programs.

Date of Interview: _____
Name of Organization: _____
Name of Interviewee: _____
Function of Interviewee: _____
In what program did you collaborate with Ruta N?
Can you describe each program mentioned?
For each program, who were the actors targeted?
For each program, who were the actors implementing the program?
How did the actors implement the program?
What was the role of Ruta N in creating and implementing the program?
For you, what is Ruta N?

Appendix 5. Semi-Structured Interviews directed towards the organizations/actors that participated in the creation of Ruta N.

Date of Interview:	
Name of Organization:	
Name of Interviewee:	
Function of Interviewee:	

Who were the actors who participated in the creation of Ruta N?

What were the motivations for creating Ruta N?

What was the role or your organization in the creation of Ruta N

What were the models, theories, and best -practices used in the creation of Ruta N?

What was supposed to be the role of Ruta N in the regional innovation system?

How did Ruta N' role change over time?

What did Ruta N do good and bad?

For you, what is Ruta N?

Appendix 6. List of Ruta N Programs from November 2009 to August 2018.

- **Innovation Platforms (*Plataformas de Innovación*).**

Draft the Science, Technology, and Innovation Plan

Draft the Science, Technology, and Innovation (STI) Plan			
Year Implemented	Program's Description	Implemented by	Targets
2010, 2011	The program supported the drafting of the Medellin STI Plan of 2011-2021 in collaboration with 500 different actors in the regional innovation system. The STI Plan is a strategic roadmap to guide Ruta N's strategic priorities in three sectors: Energy, Health, and ICT, and emerging subsectors.	EGADE-Monterrey Institute of Technology (Mexico); Del Rosario University (Colombia)	Regional Innovation System

Technology Watch and Competitive Intelligence

Technology Watch and Competitive Intelligence			
Year Implemented	Program's Description	Implemented by	Targets
2010, 2011, 2012, 2013	The program aimed to support knowledge transfer and training in Technology Watch and Competitive Intelligence for the G8 universities through the program ERICA, a Spanish development aid program to the Antioquia Region.	Program ERICA (Spain); Polytechnic University of Valencia (Spain); Articá Center of Excellence	G8 Universities, Tecnnova, CTA, Large Private Companies

Technological Commercialization

Technological Commercialization			
Year Implemented	Program's Description	Implemented by	Targets
2011, 2012, 2013	In November 2011, the IC² Institute signed a contract with Ruta N to provide technology commercialization training. The Practical Training Program in Commercialization (PTPC) offers: a three-day research visit and short workshop; a six-week technology commercialization training and a nine-week long-distance assistance training, and a two-week internship at the IC² Institute in Austin for the winning team. In October 2012, the IC² Institute provided a technology commercialization training: the Extended Practical Training in Commercialization Program (EPTCP).	IC2 (University of Texas at Austin; USA)	Universities, Research and Development Centers

SCRUM

SCRUM			
Year Implemented	Program's Description	Implemented by	Targets
2012	The SCRUM methodology aims to accelerate the development of Software companies through capacity-building and case-studies. Ten companies beneficiated from the methodology in late 2012.	Kleer Company (Argentina)	Private Companies
2013	The SCRUM methodology aims to disrupt the education sector through ICT. Eafit University, EIA University, Pontifical Bolivarian University, University of Medellín, National University of Colombia, and Jaime Isaza Cadavid Colombian Polytechnic participated to the program.	Kleer Company (Argentina)	Universities

Intellectual Property

Intellectual Property			
Year Implemented	Program's Description	Implemented by	Targets
2011, 2012, 2013, 2014	The program intellectual property aims to support knowledge transfer and capacity-building for universities and research centers to protect newly created knowledge. The program in supporting Intellectual Property resulted in five patents, two industrial designs, three brands, and three business secrets, from Argos, Laboratorios Ecar, Fibratore, CES, and EIA Universities.	Colciencias (Bogotà), Tecnnova, and the National Institute for Industrial Property (Brazil)	Universities, Research and Development Centers, Large Private Companies

Diagnostic of the Regional Innovation System

Diagnostic of the Regional Innovation System			
Year Implemented	Program's Description	Implemented by	Targets
2013	The diagnostic of the RIS made by Greg Horowitt, consultant and author the book, The Rainforest, made recommendations to Ruta N and other actors in the RIS.	T2 Venture Capital (Silicon Valley)	Regional Innovation System
2014, 2015	The diagnostic of the RIS made by the OECD LEED Center in Trento made recommendations to Ruta N in order to improve the RIS.	OECD (France, Italy), EAFIT University	Regional Innovation System

Innovation Week

Innovation Week			
Year Implemented	Program's Description	Implemented by	Targets
2010, 2011, 2012	The program Innovation Week aimed to diffuse the innovation culture to the civil society and to the actors in the regional innovation system. It involves events and seminars with international experts, entrepreneurs, and innovation leaders sharing best-practices. N Talks has featured speakers such as Henry Chesbrough, Kenneth Morse, and Carter Williams.	City of Medellin, Diverse Actors	Civil Society, Regional Innovation System

Startup Weekend

Startup Weekend			
Year Implemented	Program's Description	Implemented by	Targets
2012, 2013	The program Startup Weekend aims to expose students to the entrepreneurial culture and how to create and to develop their startups. In the Startup Weekend Medellin in 2013 at EAFIT University, the main speaker told one of the participants who asked him if he was going to steal his idea, “stop being such a paisa, brother, here nobody is going to steal anything, everyone is focused on what they are doing”.	Universities	Students

Medellín Solar Challenge

Medellin Solar Challenge			
Year Implemented	Program's Description	Implemented by	Targets
2011, 2012	The Medellin Solar Challenge is a competition for schools to build a solar-powered vehicle. The winning team participated to international competition in Australia (2011) and South Africa (2012).	EPM and Discience Foundation	Students

Inngenio - Institutions

Inngenio - Institutions			
Year Implemented	Program's Description	Implemented by	Targets
2013	The program targeted educational and research institutions. The objective is to transfer a design thinking methodology to develop new products.	Idelaboratoriet (Sweden)	Universities, Consulting Firms, Technology Development Centers

Innovation Management for Institutions

Innovation Management for Institutions			
Year Implemented	Program's Description	Implemented by	Targets
2013	The Program Innovation Management for Institutions aimed generate capacities for Technology Development Centers and universities to offer innovation consulting services.	Desai Group (Hartford; USA)	Universities, Consulting Firms, Technology Development Centers

Social Lab

Social Lab			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014	The program Social Lab aimed to foster knowledge transfer in social innovation to create a social innovation laboratory and find solutions to social challenges.	Boston College (Boston; USA), Santa Clara University (San Francisco; USA)	Universities, Private Companies, Social Entrepreneurs, Local and Regional Governments

INLAB2MARKET

INLAB2MARKET			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014	InLab2Market is a 12 to 15 month program that aimed to support the commercialization of research projects with potential market application. The participants received co-funding up to COP $250 million and received training in intellectual property, technology watch, competitive intelligence, and commercialization.	CTA, Tecnnova, Oxford University Innovation (UK), ITI - Instituto Tecnológico de Informática (Spain)	Universities, Technology Development Centers

COMUNA INNOVA

COMUNA INNOVA			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014, 2015	The program Comuna Innova is a social and participatory program to develop innovative community-driven strategies that incubate social and technological innovation.	INSITU, Ciclo, KAIROS (UK)	Residents from Comunas

Innovative Product Development

Innovative Product Development			
Year Implemented	Program's Description	Implemented by	Targets
2015	The program Innovative Product Development focused on strengthening the development of new products or services. The program comes from the merging of the programs Inngenio and InLab2Market.	CTA, Tecnnova	Entrepreneurs, Research Centers, Private Companies

Innovation Seminars

Innovation Seminars			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015, 2016, 2017	The Innovation Seminars program aimed to give the civil society some knowledge on the concepts about innovation, such as prototypes, business models, or intellectual property.	Innmagina, Pearson V. T. (UK)	Students, Academics, Entrepreneurs, Civil Society

Encurso

Encurso			
Year Implemented	Program's Description	Implemented by	Targets
2014	The program Encurso was a virtual training in international standards clinical trials. The methodology comes from the Monterrey Institute of Technology. The virtual class aimed at health professionals who participate in clinical research.	Monterrey Institute of Technology (Mexico)	Researchers

Innovacampus

Innovacampus			
Year Implemented	Program's Description	Implemented by	Targets
2014	The program Innovacampus aimed to foster innovative capacities in higher education institutions with the support from international experts in education. 12 higher education institutions that participated in the program Innovacampus went to Germany to identify best-practices in German Universities, their educative transformations, and their partnerships with the private sector.	Unistaff Associates (Germany)	Universities

- **Knowledge Business (*Negocios del Conocimiento*).**

N-Lab

N-Lab			
Year Implemented	Program's Description	Implemented by	Targets
2010	The Program N-Lab matched MBA students to private companies in order for them to define a strategy of internationalization. The program replicated a program at MIT.	G8 Universities	SMEs

Innovation Fund

Innovation Fund			
Year Implemented	Program's Description	Implemented by	Targets
2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018	The Innovation Fund was funded by the City of Medellin and administred by Ruta N in order to find venture capital partners. The innovation fund aims to provide financial capital in exchange for participation in startups with high science and technology contents, oriented towards strenthening the capacities of innovation in the city strategic clusters and emerging sectors.	Velum Ventures, Odiseo Fund Manager	Startups

N-Ruta

N Ruta			
Year Implemented	Program's Description	Implemented by	Targets
2011	The program N Ruta aimed to create successful spinoffs attractive to national and international investors.	Local Partners	Universities, Research and Development Centers

Inngenio - Companies

Inngenio - Companies			
Year Implemented	Program's Description	Implemented by	Targets
2011	The Centre for Research in Innovation Management (CENTRIM) of the University of Brighton (United Kingdom) provided a methodology to improve research, development, and innovation capacities through innovation management practices.	CENTRIM-Brighton University (United Kingdom), Innpulsa	SMEs
2012, 2013	PenZa Group supported capacity-building for private companies to develop product, prototypes, concepts, and processes through the Design Thinking Methodology. Ruta N offered COP $100 million to help companies to develop a working prototype.	PenZa Group (Israel), Zenit Design (Sweden), Clarizen (San Francisco; USA)	SMEs

New Enterprises Based on Research Results (NERI)

New Enterprises Based on Research Results (NERI)			
Year Implemented	Program's Description	Implemented by	Targets
2011	The program NERI aimed to foster the creation of Spin-offs from University research projects. In total five projects were selected to participate to the program N Ruta.	Parque E	Universities, Research and Development Centers

Structuring the Digital Entertainment Industry

Structuring the Digital Entertainment Industry			
Year Implemented	Program's Description	Implemented by	Targets
2010, 2011, 2012	The program aimed to structure the development and promotion of a digital entertainment industry in Medellin. Pipeline Studios offered training and selected startups travelled to Canada and San Francisco.	Digital Domain (USA), Pipeline Studios (Canada), Pascual Bravo Technological Institute	Students

Pre-acceleration Programs for Startups

Pre-acceleration Programs for Startups			
Year Implemented	Program's Description	Implemented by	Targets
2012, 2013	The Pre-acceleration program targets entrepreneurs and startups. In 2012, seven mentors from the USA participated in the Founder Institute in Medellin in order to offer mentorship and scaling-up the selected startups.	Founder Institute (Silicon Valley; USA)	Startups
2013, 2014	The Pre-acceleration program targets entrepreneurs and startups. NXTP Labs was selected to lead the acceleration program through consultancy and mentorship after the Founder Institute.	NXTP Labs (Argentina)	Startups

Program Apps.co

Program Apps.co			
Year Implemented	Program's Description	Implemented by	Targets
2012, 2013, 2014	The Program Apps.co targets start-ups in ICT and SMEs that operated for at least a year. The selected companies have 5 working sessions with Penza Perception Lab and video conferences for a period of 18 weeks to scale up their companies using the Design Thinking and Fostering Goods methodologies as well as capacity building in business models, business strategy, legal advice, potential networking, and venture capital pitch.	PenZa Group (Israel), MinTIC	SMEs, Startups

ViveLab

Program ViveLab			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014, 2015, 2016, 2017, 2018	The ViveLab Medellin is a projects of the Vive Digital from the Ministry of ICT to develop the gaming and animation industry in Medellin. The ViveLab Medellin has received COP $100 million from the Ministry of ICT. The ViveLab participates in the wider strategy promoted to reduce the digital divide in Colombia. The ViveLab is a training center located within the Ruta N building that has 27 learning work stations and focuses on training in animation 3D, 2D, and stop motions and videogames. In 2018, The ViveLab started to give classes in Intelligence Artificial (IA) in collaboration IRPA for the disruptive business model DAPI.	Pipeline Studios (Canada), University of Southern California (Los Angeles; USA), Unity 3D (San Franciso; USA), Naska Digital (Bogota), Paramotion (Spain), Bwstudios (Argentina), Other International Experts	Startups, Students

Innovation Management

Innovation Management			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014	The program Innovation Mangement aimed to promote an entrepreneurial culture within companies through Lateral Thinking methodology. The company Sumicol, winner of the Dragon's Den, won a tour of the Scandinavian innovation ecosystem.	Idealaboratoriet (Sweden)	SMEs, Large Companies

Acceleration Program – Cambridge University

Acceleration Program - Cambridge University			
Year Implemented	Program's Description	Implemented by	Targets
2013	The program involved an acceleration program from the University of Cambridge for three universities in Medellin, namely EAFIT University, University of Antioquia, and the Pontifical Bolivarian University. The final part of the mentoring program from the Cambridge Enterprise Limited the program involves a pitch for management to present the projects. In the second part of the project, Ruta N will invest COP $65 million for the realization of projects.	Cambridge Enterprise Limited (UK)	Universities

With Vive Digital Medellín, Talents are in IT

With Vive Digital Medellin, Talents are in IT			
Year Implemented	Program's Description	Implemented by	Targets
2014	The program “With Vive Digital Medellin, Talents are in IT” aimed to train 600 persons in Android, iOS, Microsoft, Oracle, Blackberry, and Adobe.	Ministry of ICT (Bogotá), Colciencias (Bogotá), Intersoftware	Students

Passport N

Passport N			
Year Implemented	Program's Description	Implemented by	Targets
2013	The program Passport N aimed to support private companies to internationalize and reach new markets through training in business models, internationalization strategies, and case studies.	INALDE Business School (Bogotá)	SMEs, Startups
2014	The program Passport N aimed to help private companies to internationalize and reach new markets through training in business models, internationalization strategies, and case studies. The program Passport N also had the objective to transfer knowledge from international experts to local experts. The two international experts also trained two local consultants, Santiago Ramirez and Alexander Tabares, in order to offer similar consulting services in internationalization.	Consultants (Boston, USA), Santiago Umaschi, North-South Consulting, Scott McDermott, Boston College.	SMES, Startups

The Market Access Network

Market Access Network			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016, 2017, 2018	The Market Access Network is a global network that offer knowledge and specialized services for the local companies that want to internationalize themselves. Ruta N connects and recommends local companies to their partners. In 2016 and 2017, Ruta N organized in the building the Market Access Network Fair in order for partners to have stands and present their offers to local companies wanting to internationalize themselves. The program also matches local companies with business school students from Edinburg (Scotland), Burgundy (France), and Laval (Quebec) to draft internationalization plans.	More than 50 Partners around the World (Namely Government Agencies, Not-for-Profit Organizations, Universities, Law Firms)	SMEs, Startups

Business Development Center

Business Development Center			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015, 2016, 2017, 2018	The Digital Business Development Center-Social Atom Venture-focuses on the acceleration of ICT startups. Social Atom Venture helps startups in ICT to bring to the market a viable product and/or service. Social Atom Venture offers training, mentorship, international experience, networks, talent hiring, fundings and intellectual property to the startups. Ruta N has the mission to connect entrepreneurs to the Digital Business Development Center as well as providing business opportunities to make the Digital Business Development Center viable. The acceleration program lasts for a period of 2 years with 4 weeks in one of the Atom House in New York or Mexico City.	Social Atom Venture (New York, Mexico, Medellin)	Startups
2015, 2016, 2017, 2018	The Biotech Business Development Center-Biointropic-focuses on the acceleration of biotech startups. Biointropic helps biotechnology startups or spinoffs to bring to the market a viable product and/or service. Biointropic offers training, mentorship, international experience, networks, talent hiring, fundings, clinical trials, clinical tests, and intellectual property to the startups, SMEs, and Spinoffs. Ruta N has the mission to connect entrepreneurs to the Biotech Business Development Center as well as providing business opportunities to make the Biotech Business Development Center viable. Biointropic is supported by the CES University.	Biointropic, CES University	SMEs, Startups, Spinoffs
2015, 2016, 2017, 2018	The High-Impact Business Development Center-Endeavor-focuses on the acceleration of high-impact/ growth startups. Endeavor helps SMEs to scale-up and accelerate their growth. Endeavor offers training, mentorship, international experience, networks, talent hiring, and fundings. Ruta N has the mission to connect entrepreneurs to the High-Impact Business Development Center as well as providing business opportunities to make the High-Impact Business Development Center viable. Endeavor selects high-Impact SMEs/startups from an internationl pool of applicants.	Endeavor (New York, USA, Medellin)	High-Impact/Growth SMEs, High-Impact/Growth Startups
2018	The Business Development Center in Health focuses on innovative startups and companies that operates in specific Health innovation cells, such as bioengineering, pharmaceutical technologies... The Business Development Center offers funding, incubation, and mentorship.	CREAME, ECSIM, Capitalia	Innovative companies/spinoffs in the Health Sector

Smart Capital Network

Smart Capital Network			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015, 2016, 2017, 2018	The Smart Capital Network is a network that involves venture capital companies, seed capital accelerators and angel investors. The network aims to map investment opportunities (Inversometro) for high-impact startups and to close potential gaps in financing opportunities. There are more than 18 partners in the network. Ruta N aims to connect potential investors with local stratups or SMEs.	Ruta N	Venture Capital, Seed Capital, Angel Funds

Inceller

Inceller			
Year Implemented	Program's Description	Implemented by	Targets
2015	The program Inceller was implemented by Jay Rao from Babson University to transfer entrepreneurial methodologies to large companies and to decentralized organizations from the Municipality of Medellin, such as Metroparques, Isvimed, ESU, and APP.	Babson College (Boston, USA)	Large Private Companies, Large Municipal Organizations

Ruta N Capital

Ruta N Capital			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016, 2017, 2018	The program Ruta N Capital-Financing Expansion aims to finance through loans, private companies, startups, and SMEs with high component in Science, Technology, and Innovation to scaleup and sell in national and international markets. Ruta N first selects and approves the company depending on specific requirements (Scoring N, Technology Readiness Level) before being financed by Bancolombia and Ruta N.	Ruta N, Bancolombia	Private Companies, SMEs, Startups in Medellin/Aburrá Valley
2015, 2016, 2017, 2018	The program Ruta N Capital-Financing Technological Commercialization aims to finance private companies, startups, SMEs, and research centers at universities for the commercialization of newly patented products or services. Ruta N first selects and approves the organization depending on specific requirements (Scoring N, Technology Readiness Level). Ruta N then finances the organizations and creates an agreement with the organization for joint commercialization, receiving royalties from the commercializations, or licensing rights.	Ruta N	Private Companies, SMEs, Universities in Medellin/Aburrá Valley
2017, 2018	The program Ruta N Capital-Financing Growth aims to finance through loans, startups to accelerate their growth. Ruta N first selects and approves the company depending on specific requirements (Scoring N, Technology Readiness Level) before being financed by Bancoldex.	Bancoldex	SMEs, Startups
2017, 2018	The program Ruta N Capital-Financing the Acceleration aims to finance through loans, startups and SMEs to develop a prototype into a commercializable product. Ruta N first selects and approves the company depending on specific requirements (Scoring N, Technology Readiness Level) beforing fianncing the project.	Ruta N, CTA	SMEs, Startups
2018	The program Ruta N Capital-Financing Specialized Talents aims to finance through loans, specialized training for employees in companies. Ruta N evaluates the proposals from the companies. The human capital skill development has to be short courses in highly innovative sectors such as big data, artificial intelligence, cybersecurity, cloud computing...	Sura	Large companies, SMEs

- **Innovation District (*Distrito de Innovación*).**

Soft Landing Platform

Soft Landing			
Year Implemented	Program's Description	Implemented by	Targets
2012, 2013, 2014, 2015, 2016, 2017, 2018	The soft landing program was established in 2012 to attract knowledge-intensive international startups to the Ruta N building complex. In the Ruta N building complex, there are three floors dedicated to the landing platforms comprising 660 workstations. The landing program aims to connect arriving international startups to the wider innovation ecosystem. Ruta N prioritizes international startups from three sectors, namely, ICT, health, and energy. International startups can rent a flexible number of workstations for a period of up to two years at a competitive price. After the period of two years, the knowledge-intensive startups can then rent spaces through Space N with Ruta N's partners in other parts of the city. From 2012 to 2017, the number of international companies participating in the landing programs increased from seven to more than 90. In total, since the inception of the landing program, 197 companies from 27 countries landed, generating more than 4,216 jobs. The landing program is managed by Ruta N innovation district team and the ACI. In 2014, Ruta N and the ACI visited 7 countries to promote Medellin as a hub for innovation and the landing program.	ACI, Ruta N	International and National Startups in ICT, Health, Energy

Master Planning for the Innovation District (POT)

Master Planning for the Innovation District (POT)			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014, 2015	The program aimed to offer a diagnostic of existing assets (environmental, population, economic, density, transportation, public spaces, and urban amenities) as well as potential real estate developments and urban upgrades in the Medellinnovation District in order for the masterplan to be adopted in the Territorial Planning Plan, Plan de Ordenamiento Territorial (POT), which defines future urban growth. The municipal agreement 048 of 2014 of the POT adopted the Medellinnovation District as a subzone of Rio Center Zone of the MED Rio Macroproject. The decrees 2053, 1483, and 1739 of 2015 includes specific urban norms and tax financing mechanisms.	Ruta N, EDU, City of Medellin	Innovation District's Residents and Companies

Formulating the Strategy for the Innovation District

Formulating the Strategy for the Innovation District			
Year Implemented	Program's Description	Implemented by	Targets
2012, 2013, 2014	Through the program ERICA, a Spanish development aid program to the Antioquia Region, experts from 22@ Barcelona came to Medellin to transfer their knowledge on building a successful innovation district. The transfer lasted 24 weeks. In November 2012, experts from 22@ came to Medellin. In January 2013, experts from Ruta N went to Barcelona, and in late 2013, experts from Barcelona came to Medellin. In 2014, the City of Barcelona, Barcelona Activa, and Ruta N signed a cooperation agreement to exchange best-practices in innovation districts and urban policies.	22@ Barcelona (Spain), Barcelona Activa (Spain), City of Barcelona (Spain), ERICA (Spain)	Ruta N
2013	In early 2013, experts in urban planning from MIT, Dennis Frenchman, MIT, Michael Joroff, MIT, Senseable City Lab, MIT Carlo Ratti, prepared a masterplan document for Ruta N. The consulting team traveled to Medellin for a one-week workshop. The consulting work lasted 21 weeks.	MIT Senseable Labs (Cambridge; USA), MIT (Cambridge; USA), Carlo Ratti Associates (Turin, Italy)	Ruta N

Community-Led Planning for the Innovation District

Community-Led Planning for the Innovation District			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015	The planning of the Medellinnovation District included co-creation with more than 2,000 of its residents. Ruta N innovation district's team conducted interviews, observations, focus groups, innovation bazars, creative lunches, census, co-creation activities, and conferences with the inhabitants and associations in the Medellinnovation District. The co-creation process included four phases: approaching the community, co-creating with the community, communicating with the community, and including the community in the development of the innovation district.	Ruta N, EDU, University of Antioquia	Innovation District's Residents

Events for the Residents of the Medellinnovation District

Events for Residents of the Medellinnovation District			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014, 2015	Ruta N innovation district's team also organizes events such as the innovation conferences in order to explain the innovation process, intellectual property, and competitive intelligence to the inhabitants of the innovation district. In 2014, the innovation bazar where city's innovation institutions presented their conceptions of innovation in an interactive manner with the inhabitants of the Medellinnovation District.	Ruta N, Associations, Entrepreneurs, Local Institutions, Innmagina	Innovation District's Residents

DistritoLab

DistritoLab			
Year Implemented	Description	Partners	Targets
2014, 2015	The DistritoLab program was conducted in 2014 and in 2015 to promote science, technology, and innovation to the students living in the Medellinnovation District. DistritoLab is a program that involves the participation of local high school students to find urban solutions and to create innovative prototypes for the innovation district. The students participating in the program learned to use 3D printing machines and laser cutters in order to create working prototypes for the innovation district.	Pygmalion, Ruta N	Innovation District's Residents

Ruta N 2

Ruta N 2			
Year Implemented	Program's Description	Implemented by	Targets
2016, 2017, 2018	Ruta N 2 is a program that aims to build a second innovation center modeled after the Ruta N building complex in the Medellinnovation District on a land owned by Ruta N.	Ruta N, Real-Estate Developers	Ruta N

Living Lab

Living Lab			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	The Living Lab aims to transform the Medellinnovation District into a testbed for products of large private companies. Comfama, Haceb, and Corona, Timfood participated in the pilot program. Ruta N team did a referencing of best-practices living labs in France, Belgium, and South Africa.	Ruta N, Jaguar, Tomorrow Territories (France)	Large Private Companies, Innovation District's Residents, Medellin Residents

Open Kitchen Program

Open Kitchen Program			
Year Implemented	Program's Description	Implemented by	Targets
2017	In 2017, Ruta N innovation district’s team launched the open kitchen program in order to help existing restaurants and bars to adapt their offerings through capacity-building courses and coaching to the new demand that is generated by the newly arrived knowledge workers employed in the Medellinnovation District. The main objective of the open kitchen program is to make existing restaurants and bars full participants of the development of the innovation district.	Ruta N, Restaurants	Innovation District's Restaurants

Spaces N

Spaces N			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	The program Spaces N mapped the offer of coworking spaces and other spaces for international startups and startups participating in the landing program to find office space in the city.	Ruta N	International Startups, Startups in the Soft Landing Program

Infrastructure

Infrastructure			
Year Implemented	Program's Description	Implemented by	Targets
2018	The program infrastructure aims to receive technical assistance from the World Bank and the Inter-American Development Bank to finance infrastructures in the Medellinnovation District and to find a viable business model for building Ruta N 2.	World Bank (Washington, USA), Inter-American Development Bank (Washington, USA)	Ruta N, Infrastructures in the Medellinnovation District

Community N

Community N			
Year Implemented	Program's Description	Implemented by	Targets
2018	The program Community N aims to be a one-stop shop for companies that have participated in Ruta N's programs and to connect them with Ruta N's current programs. It aims to support companies to find the right infrastructures, to support business development and networking, and to support social and cultural adaptation.	Ruta N	Companies from Soft Landing, companies that have participated in Ruta N's programs.

- **Innovation Culture (*Cultura de Innovación*).**

Horizons

Horizons			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015	The objective of the Horizons program is to strengthen the vocation and interest for engineering and STEAM majors for the young people of Medellin. The Program Horizons is the umbrella program for Innobótica, Ingeniería N and Interchange. The strategy is aimed at students in grades six to eleven (Ages 11 to 17) who attend public schools in the city and involved methodologies to spur STEAM framework (Science, Technology, Engineering, Art and Mathematics). In June 2014, more 1,900 students participated in the Horizontes meetings in the Botanic Garden of Medellin. Vanessa Restrepo Schild, who participated to the program Talent N, is now a researcher at Oxford University shared her experience with the participants. In 2014, more than 3,500 students participated in the program Horizontes. In 2015, 2000 high-school students and 132 public education institutions participated to the program Horizontes.	Pygmalion, Parque Explora	Public Schoolchildren, Public High-School Students

Interchange

Interchange			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015	Interchange is a program with international faculties that aimed to familiarize students in Nanotechnology. Purdue University with the Professor Carol Handwerker participated in the event Interchange in the Libraries España for students from one of the poorest comuna in Medellin. The program interchange was inspired by the Nanodays at Purdue University. In 2014, 14 students who participated to the Program Interchange won a field trip to Purdue University to participate to the Scientific Camp Pulsar II.	Arukay (Bogotá), Purdue University (Indiana, USA), Harvard University (Boston, USA)	Public Schoolchildren, Public High-School Students

Innobotica

Innobotica			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015	The program Innobotica, with the support from the City of Medellin and the Secretary of Education, aimed to spur interest in robototics, automation, and software development in young students. Ruta N launched the Robotics and Innovation Week in which the organization presented their work in the Medellinnovation challenge. The winner of the challenge participated to the RoboRAVE competition in Alburquerque in the United States.	Pygmalion, Parque Explora	Public Schoolchildren, Public High-School Students

Ingeneria a la N

Ingenieria a la N			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015	The program Ingenieria a la N aimed to familiarize students to think as engineers. Students are accompanied by experts from EAFIT University to find engineering solution to real-world challenges	EAFIT University	Public Schoolchildren, Public High-School Students

Medellinnovation Festival

Medellinnovation Festival			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014	The Medellinnovation Festival offered events related to science, technology, and innovation in 2013 and 2014. The events included Medelab, a creative laboratory, Comuna Innova, an event to connect with residents from the poorest neighborhoods of the city, workshops Medellin Futurista in order to co-create maps with children for the Medellinnovation district, Innovation the Swedish Way, an event promoted by the Swedish Embassy with companies such as Ericsson, Electrolux, Volvo, Spotify, and Scania, exposition on the community heroes of Comuna 13, the ICT Fair in order to present research from university students in Medellin, the Forum on innovation and social entrepreneurship, stratup weekend, Medellinnovation Conecta in order to connect entrepreneurs with venture capital, interchange for students in Nanotechnology of the Pontifical Bolivarian University to discuss with experts from the EAFIT University, UPB, and the Center for Nanotechnology Brick at Purdue University, the Hackathon, and Start-up Nation-Israel Economic Miracle, with the presentation of Saul Singer, Robotic in Public Libraries with workshops on coding and robots, Charla N with the MIT Technology Review presenting 10 disruptive technologies, Innovation Land with international experts Barry Katz, Hitendra Patel, Rowan Gibson, and Stegan Lindergaard, and the forum for news press.	Ruta N, Diverse Partners (Universities, City of Medellin, EPM)	Medellin's Residents, Actors in the Regional Innovation System

Ruta N Innovation Awards

Ruta N Innovation Awards			
Year Implemented	Program's Description	Implemented by	Targets
2013	The awards are targeting different actors in the RIS, namely innovative actors in the RIS, research groups, and innovative actors in Latin America. The goal of the innovation awards is to position the Ruta N awards as the most prestigious recognition for innovation in Latin America.	Ruta N, CAF Latin America, Ezentiz Group (Spain)	SMEs, Startups, Research Groups

Talents N

Talents N			
Year Implemented	Program's Description	Implemented by	Targets
2013	The program Talents N offered scholarships to high-potential students and academics in STEM. Vanessa Restrepo Schild received a scholarship to study at Oxford University in the United Kingdom.	Ruta N	Students, Academics

Robotics Week

Robotics Week			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014	The Robotics Week aimed to familiarize high-school students to Robotics through competitions.	Pygmalion	Public Schoolchildren, Public High-School Students

ICT Fair

ICT Fair			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014	In 2014, the ICT Fair involved the participation of 700 children from Medellin, Antioquia, and 13 other countries, such as Italy, Mexico, Egypt, Honduras, and Brazil. The event was sponsored by the City of Medellin, EPM, and the Parque Explora and aimed to generate innovation culture through the participation in research and innovation processes. The event allows winning teams to participate in international competitions such as Intel ISEF, ISWEEEP, and RoboRave in the United States, Expoingeniería in Costa Rica, or la Feria Escolar in Peru. The events involved the participation of Nobel prize winners such as Dr. Richard Roberts and Dr. Martin Chalfie.	Parque Explora, Pygmalion	Public Schoolchildren, Public High-School Students

The Creation Laboratory

The Creation Laboratory			
Year Implemented	Program's Description	Implemented by	Targets
2015	The Program Creation Laboratory was an initiative for capacity-building for local residents in the Medellinnovation District in the social appropriation of technologies. It involves co-creation of projects with over 15 work sessions with the community to develop prototypes to social problems.	Jaguar	Medellin Northern Districts' Residents

The Horizon Circles

Horizon Circles			
Year Implemented	Program's Description	Implemented by	Targets
2015	The program Horizon Circles aims to unite teachers and students to find science, technology, and innovation solutions for the private sector. The program aims for teacher to know how to motivate and to present science, technology, and innovation projects to their students.	Corporación Kairos, The Gestión y Competitividad Company, CES University, Nutresa Foundation	Teachers

- **STI Plan (*Plan CTi).***

Key Performance Indicators

Key Performance Indicators			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014	The KeyPerformance Indicators aimed to find metrics to measure the impact of Ruta N on fostering technological innovations and quality of life (Technopolis) and on international rankings (2ThinkNow).	Technopolis (UK), 2ThinkNow (Australia	Ruta N

Regional Innovation Initiatives (RII)

Regional Innovation Initiatives			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014, 2015, 2016, 2017, 2018	The Regional Innovation Initiatives (RII) aim to connect the relevant actors of Key Enabling Technologies (KET) to discuss potential opportunities and to create network, alliances, joint-venture, and spinoffs. The Regional Innovation Initiatives (RII) aim to accelerate the development of high-value added products, process, and services through technological innovations. Each RII comprises private companies, public institutions, and universities. The STI plan has identified the Nano N for nanotechnology, FabLab N for manufacture, Scalen N for Biotechnology, and Photo N for Photonics. The Nano N was the first one to be implemented in which participated 15 companies and 13 universities.	Ruta N	Private Companies, Universities, Public Institutions

General System of Royalties

General System of Royalties			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014, 2015	Ruta N also received funding to manage the General System of Royalties for Antioquia. On March 18, 2013, Ruta N was designated through the Agreement 004 to allocate COP $25,178 million for the execution of the Macro-Health Project, which involved 17 projects such as Artica, Tele-Health, Biobanco, and so on. On August 23, 2013 through the Agreement 008, Ruta N allocated COP $4,036 million for the Solar Panel Cell Project. On October 18, 2013 through the Agreement 011, Ruta N allocated COP $46,366 million for four macro-health projects projects. Ruta N has managed a total amount of COP $75,581 million from the Science, Technology and Innovation Fund of the General Royalty System that has been allocated by Collegiate Body of Administration and Decision. In 2013, Ruta N organized with the Antioquia Region and the City of Medellin a forum for the General System of Royalties in order to screen potential projects and the actors in the regional system of innovation. Potential projects were first evaluated by the Codecyt (Concejo Departamental de Ciencia y Tecnología). In 2013, Ruta N led the Telemedicine conference with national and international partners such as the Universidad of Antioquia, the national government, the CICUT, Cluster Latin American Higher Education Collaboration in Telemedicine, and la Universidad abierta de Catalunya. The National Department of Planning ranked Ruta N as the best entity in managing the Royalties for Science, Technology, and Innovation, and was ranked third in managing royalties among regional government, local government, and public entities.	Ruta N	Private Companies, Research Centers, Universities, mainly in the Field of Health

Network & Partnerships

Network & Partnerships			
Year Implemented	Program's Description	Implemented by	Targets
2014	The objective of network and partnership is to support researchers to realize missions abroad and to bring researchers and research institutes from strategic innovation hubs, such as Brazil, France, Germany, Spain, Sweden, Israel, the United States. The Fraunhofer Society (Germany), DNDi (Brazil), Fund Newton Caldas (UK), Max Planck Institutes (Germany), University of Wisconsin (Madison, USA), Purdue University (USA) are some of the partnerships formed from the initial program launched by the STI plan to find international partners to participate in STI projects in Medellin.	Ruta N, Universities	International Research Institutes, Research Grants and Funds

STI Observatory

STI Observatory			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015, 2016, 2017, 2018	The STI Observatory targets three sectors: ICT, Energy, and Health. The Regional System of Innovation found that the three sectors are constantly evolving and are extremely wide. The STI Observatory is an information system for the city in order to screen potential opportunities in the three sectors for the local companies, universities, and research groups. In 2015, the emerging markets screened are: renewable energies, telehealth, big data, smart health, nanomedicine, and videogames apps. The markets were identified through the technology watch done by Ruta N, Tecnnova, and the Technological Watch and Competitive Intelligence Network in determining opportunities relative to the technological conditions of the local and global markets, the business models of the markets, potential partners and main actors and opportunities areas in those markets. The STI Observatory's analyses go through different phases. First, technological watch and competitive intelligence from the specialized actors. Second, Ruta N's analysis on the impact of going after the markets for the city. Third, a validation from the business sector. The documents from the STI Observatory include: key information of the opportunity area; markets of the service of product; markets of the technology; opportunities and challenges: maps of the local and international actors. The STI Observatory does market research and Technology Watch not only for Energy, Health, and ICT but also for construction, textile, tourism, air travel and others.	Tecnnova, Universities from the Technological Surveillance and Competitive Intelligence Network of Medellin	Private Companies, Universities, Research Centers, Civil Society

Brainbook

BrainBook			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016	Brainbook was a webplatform that aimed to work as a social network connecting the different actors of the regional innovation system.	Ruta N, Sapienca	Actors in the Regional Innovation System

- **Special Projects (*Proyectos Especiales).***

Great Pact for Innovation

Great Pact for the Innovation			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015, 2016, 2017, 2018	The objectives of the Great Pact for the Innovation that was signed in 2014 by 1,300 organizations were to reach 1% of the regional GDP in R&D activities in 2015, 2% of the regional GDP in R&D activities in 2018, and 3% of the regional GDP in R&D activities in 2021. The Grea Pact for Innovation was signed by different entities, such as universities, public institutions, private companies, and the civil society. The Great Pact for the Innovation was made according to OECD benchmarks and allows Ruta N to promote its programs to the organizations that signed the Great Pact.	Ruta N	Actors in the Regional Innovation System

Events for the Great Pact of Innovation

Events and Workshops for the Great Pact for the Innovation			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016, 2017, 2018	Ruta N organizes events and workshops to motivate the signing organizations to reach the goals of the Great Pact for the Innovation. One of the events was the Medellinnovation Awards, which aimed to recognized the effort made by the companies that signed the Great Pact for the Innovation in designing and implementing innovative process, business models, products or services with high-value added. There are four different categories: Joint University-Firm Research & Development, Intellectual Property, Communications, and Urban Innovation. In the category Urban Innovation, citizens will select the winners through the web platform MiMedellin. Some of the workshops organized such as Innovation Challenges and the Encounter for Innovation aims to foster best-practices in the implementation of innovations.	Ruta N, Inteligencia Creativa (Barcelona; Spain), Tecnnova	Actors in the Regional Innovation System

MiMedellín

MiMedellin			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015, 2016, 2017, 2018	MiMedellin is an open innovation web platform that allows citizens to participate in co-creating projects for the city. The MiMedellin program is part of the Medellin Smart City program. The first city's challenge of the platform MiMedellin was in partnership with the Parques del Rio and was: "how to bring vibrancy to the inferior part of the bridges that cross over the Rio Medellin?". In 2014, the platform MiMedellin reached over 10,000 users. In September 2015, the web platform, MiMedellin, for open innovation and citizen co-creation won the Effective Public Management Awards from the Organization of American States (OAS).	Ruta N	Medellin's Residents

Cities for Life

Cities For Life			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016	Ruta N and the City of Medellin organized the program Cities For Life, in which local experts, researchers, and urban leaders from different cities participate with citizen in order to share best-paractices to city challenges. The first global meeting of the Cities For Life was held in Medellin on August 31-September 1 in Medellin. The event includes the participation of the World Bank, the Development Bank for Latin America, the Inter-American Development Bank, Un-Habitat, CIDEU, international experts, and urban leaders from more than 50 cities. The events included co-creation sessions, speech for international experts, best-practices examples. The web platform, citiesfor.life, was launch in order for cities to co-create and to exchange best-practices for specific urban challenges. In 2016, Cities For Life was held in Paris (France).	Ruta N, City of Medellin	Global Cities, International Urban Experts

SUNN

SUNN			
Year Implemented	Program's Description	Implemented by	Targets
2014, 2015, 2016, 2017, 2018	The SUNN platform is an open innovation platform that aims to connect different actors in innovation systems (governments, companies, universities) to collaborate on articulating new projects, products, and services. The platform SUNN aims to work as a radar for opportunities and to facilitate connections between offers and demands for technological innovations. In 2016, Ruta N created Meet Up SUNN as to facilitate face-to-face interactions between the different actors participating in the network.	4i Latam (Spain), Tecnnova, Ruta N	Actors in the Innovation System (Regional, National, and International)

Consulting Projects

Consulting Projects			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016, 2017, 2018	Ruta N Special Projects offer consulting projects in innovation services to other cities. Ruta N has replicated MiMedellin to cities in Latin America such as Zapopan in Mexico, Quito in Ecuador, La Libertad in Peru, Bolivia, and Panama. Colciencias has identified 8 cities in Colombia to replicate Medellin's Great Pact for Innovation.	Ruta N, Colciencia	Cities and Institutions in other Cities (National and International)

- **Forecasting and Planning (*Prospectiva y Planeación*).**

Innovative Procurements

Innovative Procurements			
Year Implemented	Program's Description	Implemented by	Targets
2016, 2017, 2018	The Innovative Procurement Program aimed to promote innovation through demand through procurement of products or services that do not exist in the market. Innovative Procurement can be done from public organizations or from large private companies. The private company Conconcreto and the Metro of Medellin launched a call for innovation procurement in 2016.	IDOM (Spain), IDOM Branch in Medellin	Startups, SMES, Large Companies, Public Institutions

Indicators

Indicators			
Year Implemented	Program's Description	Implemented by	Targets
2016, 2017, 2018	The program Indicators aims to measure the impact of Ruta N on Medellin Innovation System. The Program indicators is an annual survey that aims to measure innovation in private companies in Medellin and the Aburrá Valley.	Ruta N, Centro Nacional de Consultoria	Ruta N

Fast-Track Institute

Fast-Track Institute			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	The Fast-Track Institute is a spinoff from the Singular University, the program aims to find exponential solutions to three challenges facing the city of Medellin, Health, Transportation, and Sustainability from a group of international experts formed by the Fast-Track Institute.	Fast-Track Institute, Singularity University (San Francisco, USA)	Public Institutions, City of Medellin

Disruptive Projects – Company Builder

Disruptive Projects - Company Builder			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	Ruta N aims through the Disruptive Projects to create viable business models from opportunities analyzed in the STI Observatory and to be executed by private companies or research groups. The disruptive projects have to comply with six variables. They need to be financially and environmentally sustainable, to be scalable and related to the STI plan, to create high-quality jobs, to respond to city's challenges, to use key enabling technologies, and to respond to demands in the market. Ruta N for instance, is structuring business models for advance manufacturing, talents broker, telehealth, blood bank, PITS center for health transactions, mobility...and many others... in order for them to be later executed by an organization other than Ruta N. In 2018, DAPI was created as a joint-venture between Ruta N and IRPA (USA) for outsourcing in artificial intelligence in Medellin.	Ruta N, ECSIM, Joint-Venture Partners	Private Companies, Research Groups, Startups

Observatory of Innovation Ecosystems

Observatory of Innovation Ecosystems			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	The program aims to monitor innovation ecosystem best-practices and to potentially transfer programs to Ruta N.	Ruta N	Ruta N, Regional Innovation System

Open Data - MEDATA

Open Data - MEDATA			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	The Open Data platform MEDATA aims to create for the City of Medellin a strategy for Data-Driven Governance. Part of the Medellin Smart City Strategy, the Open Data aims to create a platform to share data collected within the city. Steven Adler from IBM has collaborated on the project.	Ruta N, IBM (New York; USA)	City of Medellin

CN2 – National Center in Nanotechnology

CN2 - Centro Nacional de Nanotecnologia			
Year Implemented	Description	Partners	Targets
2017, 2018	The National Center for Nanotechnology (CN2) was opened in March 2018 in order to support the mass adoption of nanotechnology in the city. The CN2 works as a one-stop shop for companies in the field of Nanotechnology. The CN2 involves a network of experts in the field of Nanotechnology to provide services to companies. In 2017 and 2018, the CN2 surveyed companies to understand the local capacities and demand for Nanotechnology. The CN2 is partnering with MIT ILP to exchange best-practices and have access to MIT ILP network.	Ruta N, Tecnalia (Spain), MIT ILP (Cambrige, USA)	Private Companies, Research Groups

Intelligence

Intelligence			
Year Implemented	Description	Partners	Targets
2018	The program Intelligence has five objectives, to monitor key innovation indicators, to upgrade the STI observatory, to link indicators with the internal plan of action, to digitalize Ruta N, and to actualize the STI plan. For instance, the STI observatory has produced 80 documents identifying 400 opportunities but the STI observatory is static, the program intelligence aims to provide real-time and dynamic opportunities.	Ruta N	Ruta N

Inter-American Development Bank (IADB)

Inter-American Development Bank (IADB)			
Year Implemented	Description	Partners	Targets
2018	The program with IDB is a cooperation agreement that has three components. First, it aims through a consultant to support the replication of the Ruta N model and to create a school for Latin American leaders at Ruta N. Second, it aims to support a plan to build fast fiber optic infrastructure in the city. Third, it aims to actualize the STI plan of 2011-2021 to respond to the city's challenge through mission-oriented policies.	IADB (Washington, USA)	Ruta N, City of Medellin

- **Organizational Innovation (*Innovación Organizacional*).**

Bootcamp Web

Bootcamp Web			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016	The program Bootcamp Web with the World Tech Makers is a 12-weeks program that allows students to acquire knowledge in software development. The program was sponsored by diverse organizations, among which the World Bank, EPM, and the City of Medellin.	World Tech Markers (Barcelona)	Students

Innovation Managers

Innovation Managers			
Year Implemented	Program's Description	Implemented by	Targets
2016, 2017	The program Innovation Managers for Companies targeted 221 companies, which received for 8 months training and consultancy in methodology, best-practices, knowledge, concepts, and tools to foster innovation strategies. IXLCenter (Cambridge, USA)validated the methodology.	V. T. Peason (UK)	SMEs, Large Private Companies
2016, 2017	The program Innovation Managers for Higher Education offers methodology, best-practices, and knowledge for universities to adopt innovation strategies. In the program participated 19 universities with the support from Sapiencia.	Sapiencia	Universities
2017	The Program Innovation Managers for Citizens aims to develop social organizations into the innovation district. The program trained the citizens through the design thinking methodology and best-practices such as Fundación casa tres patios. The teams that have the 10 best projects traveled to Mexico.	Ruta N	Civil Society

Innovation is for everyone

Innovation is for Everyone			
Year Implemented	Program's Description	Implemented by	Targets
2016, 2017, 2018	The program Innovation is for Everyone was launched by Ruta N with the support from the City of Medellin and Sapiencia for citizens to appropriate the concept of innovation. There are 3,000 places available to participate to the program. The web platform offers free virtual learning in innovation issues with 16 modules on local and international best-practices through a game-based learning methodology. Participants receive a certification from the School of Engineering of Antioquia (EIA University).	Sapiencia, EIA University, Innmagina	Companies, Civil Society

Innovation Challenges

Innovation Challenges			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016	The program Innovation Challenges aims to orient and connect companies with academic knowledge to find opportunities in ICT, Health, Energy, and Agriculture. The program Innovation Challenge is done in partnership with Tecnnova. The Program Innovation Challenge was inspired by the DEMOLA Network (Finland). The companies and students participate to the program for a period of 16 weeks. Companies that participated to the program are: Sura, Protección, IDlink, Sirplast, Coordiutil, Avinal, Laboratorio Médico Echavarría.	Tecnnova, EAFIT University, University of Medellin	Universities, Companies

Generation N

Generation N			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	The program Generation N aims to train teachers in Project-Based Learning (PBL) as a pedagogical tool for teaching STEM classes.	Parque Explora, Ruta N	Teachers

The Innovation Laboratory for Companies, Education, and Government

The Innovation Laboratory for Companies, Education, and Government			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	The Innovation Laboratory for Companies is a makerspace that was opened in July 2017 in the Ruta N Building Complex. The Innovation Laboratory aims to train 2,000 persons and to produce 800 prototypes. The Creation Laboratory has 3D printers, 3D scanners, cutting machines, and carpentry station for prototyping. It is based in learning by doing though using the design thinking methodology with 20 courses in learning how to design, build a business model, user-interfaces, 2D and 3D designs. The Innovation Laboratory made agreements with local organizations such as ANDI, Fenalco. The Innovation Laboratory has used as a model the Fab Lab Barcelona (Spain), and benchmarked Fab Labs around the world such as MIT or Rhinofabstudio.	Ruta N, Jaguar, Sapiencia, Bosch (Germany)	Knowledge-based SMEs/Startups in Aburrá Valley
2018	The Innovation Laboratory for Education aims to provide solutions to challenges facing middle- and high-schools. The program is the continuation of the program Generation N. It involves the identification of challenges facing middle-and high- schools, the participation of the students, the selection of startups and companies to respond to the challenges, and the monitoring of how the challenge has been answered.	Ruta N, Private Companies	Middle- and High-Schools
2018	The Innovation Laboratory for Government aims to provide solutions to challenges facing public institutions in Medellin. It involves the identification of challenges facing the public sector, the participation of the citizens to select the most pressing issue through MiMedellin, the selection of startups and companies to respond to the challenges, and the monitoring of how the challenge has been answered.	Ruta N, Private Companies	City of Medellin

CATI

CATI			
Year Implemented	Program's Description	Implemented by	Targets
2016, 2017, 2018	In 2015, Ruta N launched the Center for support to Technology and Innovation (CATI) in order to support the community to understand intellectual property, such as services to the protection of inventions through patents, branding, and other intellectual property device. The CATI is a network that includes other CATI in Medellin and participate in the strategy from the World Intellectual Property Organization and the Colombian Superintendencia de Industria y Comercio (SIC).	World Intellectual Property Organization (Geneva, Switzerland), Superintendencia de Industria y Comercio (Bogotá), Tecnnova	SMEs, Entrepreneurs

Patents Team

Patents Team			
Year Implemented	Program's Description	Implemented by	Targets
2017	The Patents Team aims to detect possible patentable products or services in research centers and companies. It offers a methodology for companies to identify relevant patentable products or services.	Tecnnova	SMEs, Startups, Large Companies

Patents N

Patents N			
Year Implemented	Program's Description	Implemented by	Targets
2017	In the program Patents N, Ruta N selected 11 Law Firms to support companies and research centers in the process of patenting a product or service. Ruta N provides 80% of the funding and the company or research center provides 20% of the funding to go through the legal process of patenting its product or service.	11 Law Firms	SMEs, Research Centers, Startups, Large Companies

Spinoff Colombia

Spinoff Colombia			
Year Implemented	Program's Description	Implemented by	Targets
2016, 2017	In 2016, the program Spinoff Colombia was created to bring to market products or services created in university research centers. Ruta N will support university research centers in terms of institutional policies and technology transfer, business model, and business plan, intellectual property strategies, and legal corporations.	Ruta N, Colciencias, Tecnnova	Research Centers in University

Mentorship for Startups and SMEs

Mentorship for Startups and SMEs			
Year Implemented	Program's Description	Implemented by	Targets
2017, 2018	The mentorship program was led by Proantioquia and the Godfather program was led by ANDI to transfer best-practices and methodologies from successful entrepreneurs or mentors to local companies.	Proantioquia, ANDI	Startups, SMEs

Platform for Creative and Cultural Entrepreneurs

Platform for Creative and Cultural Entrepreneurs			
Year Implemented	Program's Description	Implemented by	Targets
2018	The program platform for creative and cultural entrepreneurs is an alliance between Comfama and Ruta to strengthen business capacities for creative and cultural entrepreneurs. The platform involves three phases. The first phase aims to identify with the creative and cultural entrepreneurs some business opportunities and some specific projects. The second phase aims to support, in collaboration the CTA and Social Lab, the entrepreneurs to pre-incubate and incubate their projects. The third phase aims to accelerate the creative and cultural entrepreneurs in their projects.	CTA, Social Lab (Chile)	Creative and Cultural Industries and Workers

- **Research and Development (*Investigación y Desarrollo*).**

Cooperation N

Cooperation N			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016, 2017, 2018	The Program Cooperation N involves two dimensions: travel grants and international agreements. In the travel grants, research groups from Medellin in the sector of ICT, Health, Energy identify an international partner to travel to. Ruta N selects after a call and the travel grants is given at the condition that the international partner travels to Medellin. International travels were conducted to 14 countries, United States, France, Spain, Brazil,Mexico, Germany, and the United Kingdom being the main ones. International cooperation programs were formalized with France, with the program COOPOL. The international agreements aim to formalize joint-research funding mechanisms such as with the Newtown-Caldas Fund from the United Kingdom., DNDI(Brazil), University of Wisconsin (USA),Max Planck (Germany), Prosperity Fund (UK),Royal Academy of Engineering (UK), and Fraunhofer Society (Germany).	Ruta N, French Embassy, United Kingdom Embassy, German Embassy	Local and International Researchers, Local and International Universities, International Research Institutes

Cofinancing STI Projects

Cofinancing STI Projects			
Year Implemented	Program's Description	Implemented by	Targets
2015, 2016, 2017	In 2015, Ruta N opened a call within the STI Plan to co-finance projects in applied research and technological development that aim to generate working prototypes. The call targeted public institutions, research centers, technological development centers, universities, higher education institutions that have an alliance with companies in Medellin or Aburrá Valley. The maximum amount of funding is COP $300 million. The program included specialized support in product or service development, access to smart capital, and new markets, and flexible funding mechanisms.	Ruta N, CTA	Public Institutions, Research Centers, Universities with an alliance with a Private Company from Medellin or the Aburrá Valley.

Proof of Concept Funding

Proof of Concept Funding			
Year Implemented	Description	Partners	Targets
2018	The program Proof of Concept funding aims to support with funding the process for validation and viability of proof of concepts for companies and research groups in developing prototypes in the phase before seed capital. Ruta N is looking for partners such as G8 universities and Colciencias to help to structure this fund.	Ruta N, Funding Partners	Private Companies, SMEs, Universities in Medellin/Aburrá Valley

R&D Capacities

R&D Capacity			
Year Implemented	Description	Partners	Targets
2018	The program R&DCapacity aims to map the existing capacities and weaknesses of the actors in the RISin R&D.It aims to provide a roadmap for the actors in the city to increase their investments in R&D.	CTA, CUEE	Regional Innovation Agency

Market Place

Market Place			
Year Implemented	Description	Partners	Targets
2018	The program Market Place is a strategy to digitalize Ruta N and the offer in innovation services from the actors in the RIS. It is a strategy to digitally transform Ruta N programs and to offer a platform for the actors in the RIS to easily access the offer in innovation services from the actors in the RIS	Ruta N	Ruta N, Regional Innovation System

- **Support Functions and Marketing and Communications (*Mercadeo y Communicaciones*).**

External Communication to Medellín's Residents

External Communication to Medellin's Residents			
Year Implemented	Program's Description	Implemented by	Targets
2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018	External Communications is done through the Ruta N website, youtube, interviews, and communication campaigns. Communication campaigns aim to sensibilize Medellin's residents to the Ruta N activities such as in 2013: "If you imagine it, it is possible", in 2015, the Documentary "Codigo Origen", or in 2017 "Innovate, it is done by people like you". Ruta N website offers news, virtual visit of the building, list of current programs, calls, and innovation ABCD.	Ruta N, City of Medellin, Advertising Agency	Residents and Actors in the Regional Innovation System

Positioning Medellín as the Most Innovative City in Latin America

Positioning Medellin as the Most Innovative City in Latin America			
Year Implemented	Program's Description	Implemented by	Targets
2012, 2013, 2014, 2015, 2016, 2017, 2018	To position Medellin as the most innovative city in Latin America through attracting international events such as EMTECH, Campus Party to the city and through public relations and international exposure.	Ruta N, Diverse Actors	Actors in International Innovation System

Strategy and Diffusion

Strategy and Diffusion			
Year Implemented	Program's Description	Implemented by	Targets
2012, 2013, 2014, 2015, 2016, 2017, 2018	The program strategy and diffusion aims to support the communication of Ruta N programs to targeted participants. Strategy and diffusion will support the right communication approach and media to target potential participants of Ruta N programs.	Ruta N	Potential Participants of Ruta N Programs

Positioning Survey

Positioning Survey			
Year Implemented	Program's Description	Implemented by	Targets
2013, 2014, 2015, 2016, 2017, 2018	Understanding the position of Ruta N in the RIS and its strengths and weaknesses for other actors in the RIS.	GoodWill Communication, Target Insights	Ruta N