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Exploring the corruption-inefficiency nexus using an endogenous stochastic frontier analysis

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Abstract

Several scholars report that, due to reverse causality, the endogeneity problem makes it difficult to identify the real effect of institutional factors at the local level, such as corruption, on firm efficiency. This study employs a panel stochastic frontier analysis that endogenizes production efficiency and robustly assesses the effect of corruption at the local level on firms' technical efficiency. We analyze a large panel of Italian firms operating in the building sector from 2013 to 2019 showing that the determinants of local institutional quality affects firms' performance, with the rule of law and control of corruption playing a preeminent role. Controlling for endogeneity, the magnitude of the effects of institutional quality factors at the local level significantly increase. Our findings are robust to alternative IV strategies, alternative specifications of the production function, and the inclusion of other factors that may affect firm efficiency.

KEYWORDS

corruption, Endogeneity, firms, production efficiency, stochastic frontier analysis

JEL CLASSIFICATION

D24, D73, L25, C23, C26

1 | INTRODUCTION

Corruption is a pervasive problem in many countries and has been linked to numerous negative economic outcomes, including decreased investment, reduced economic growth (Lambsdorff, 2003; Mauro, 1995; Pellegrini & Gerlagh, 2004), low levels of international and domestic trade (Emenalo et al., 2018; Wanchek, 2009; Wei, 2000), and increased income inequality (Gupta & Abed, 2002; Dincer & Gunalp, 2012). However, other scholars identified the positive role of corruption as a "second best" option to speed up bureaucratic procedures and to contrast inefficient regulations when institutions are weak and ill-functioning (Leff, 1964; Lui, 1985; Saha et al., 2021; Zergawu et al., 2020). These mixed insights originate from a large body of empirical literature supporting these two opposing views. Whereas Méon and Sekkat (2005), Johnson et al. (2011), and Zelekha and Sharabi (2012) support the "sand the wheels" hypothesis, while others such Méndez and Sepúlveda (2006) and Méon and Weill (2010) find evidence in favor of the "grease the wheels" hypothesis.

In this literature, we aim to contribute to the understanding of the relationship between corruption and firm efficiency. Corruption can significantly impact firm efficiency by creating an uneven playing field for businesses. When corruption is rampant, businesses engaging in corrupt practices gain unfair advantages over their competitors. This creates a situation in which inefficient and unproductive firms are more likely to succeed than firms that invest in innovation, productivity, or quality. Corruption can also increase the transaction costs of conducting business. For instance, bribery can lead to inflated costs of raw materials, permits, and licenses, ultimately increasing production costs. This, in turn, can reduce firms' profitability and discourage them from investing in the development of new products and services (De Waldemar, 2012).

Moreover, corruption undermines the rule of law, which is critical for efficient market function (Zergawu et al., 2020). When businesses cannot rely on the legal system to enforce contracts or protect their property rights, they are less likely to invest in innovation or expansion. This is because they are uncertain about the security of their investments and may lack confidence when taking risks. Several scholars studied the impact of corruption on firms' entrepreneurship, growth, and innovation extensively (e.g., Anokhin & Schulze, 2009; De Waldemar, 2012; Dincer, 2019; Paunov, 2016). However, some scholars argued that corruption can positively affect firm efficiency. For instance, in some countries, bribery is used to expedite bureaucratic processes and reduce red tape (De Rosa et al., 2010; Goedhuys et al., 2016; Pluskota, 2020). However, the overall impact of corruption on firm efficiency appears to be negative.

The empirical research supports the relationship between corruption and firm efficiency. For example, a pioneering study by Fisman and Svensson (2007) found that firms in countries with higher levels of corruption face more significant delays in obtaining the necessary permits, leading to reduced firm efficiency. Another study by Aidt and Dutta (2008) reported that corruption is associated with reduced investment and lower productivity in the manufacturing sector. Similarly, Tanzi and Davoodi (1998) found that corruption has a negative impact on the efficiency of public firms in developing countries.

Our work also analyzes the relationship between firm inefficiency and institutional quality. Since North's (1990) seminal work, the impact of institutions on economic development at the macro level has been widely investigated. Institutions can indeed matter for businesses, and interest in the institutional perspective of firms' efficiency assessment increased over time (Lasagni et al., 20152015). Although some studies showed that higher institutional quality leads to higher firm efficiency (Aldieri, Kotsemir, et al., 2020; Aldieri, Makkonen, et al., 2020; Castiglione et al., 2018; Sun et al., 2019; Zallé, 2019), little is known about the impact of corruption on firm efficiency as a determinant of institutional quality. Indeed, the main result coming from the scarce literature is that increased corruption is detrimental to firms' technical efficiency (Aldieri et al., 2022; Dal Bò & Rossi, 2007; Sharma & Mitra, 2015).

The stream of research poses a significant challenge to researchers attempting to determine causality because of the possible endogenous nature of corruption and firms' technical efficiency. Endogeneity may arise because a government's ability to curb corruption and firm efficiency can be determined simultaneously. Specifically, the main concern in assessing the relationship between measures of corruption control and firm efficiency stems from the potential endogeneity inherent in the relationship, which is determined by reverse causality dynamics. Indeed, a reasonable hypothesis is that higher levels of corruption control (i.e., lower levels of corruption) impact firm efficiency. However, variations in firm efficiency may affect a government's ability to reduce corruption. Under the same logic, reverse causality arises from the mutual influence of institutional quality and economic growth (Mauro, 1995). This setting justifies the adoption of an econometric methodology that can address endogeneity issues (Aldieri et al., 2022).

In the relevant literature, most studies use stochastic frontier analysis (SFA) to investigate the relationship between corruption and the technical efficiency of firms. However, traditional SFA is limited in that it does not address explanatory variable endogeneity (e.g., control of corruption) and could lead to considerable bias in both parameter and efficiency estimates (Kutlu & Tran, 2019).

This study contributes to this strand of the literature by using a newly developed SFA approach (Karakaplan & Kutlu, 2017a) to evaluate the impact of institutional quality and environmental corruption on firms' technical efficiency. More importantly, the proposed approach addresses endogeneity in a single-stage estimation process for stochastic frontier models, thereby enabling an unbiased appraisal of the environmental variables in an efficiency analysis (Kutlu & Tran, 2019).

Owing to the historical socioeconomic gap between the northern and southern regions, Italy is an ideal case study to explore the potential link between institutional quality, corruption, and firm performance. We thus analyze a large panel of Italian firms operating in the building sector from 2013 to 2019. To empirically assess the effects of institutional quality on firm inefficiency, we rely on data on the institutional quality index (IQI) at the provincial level, sourced from the Nifo and Vecchione (2014) database.

This study thereby provides new and more robust support for the results obtained from previous studies. Indeed, our findings, which are robust to alternative specifications of the production function and different IV strategies, suggest that increased institutional quality significantly reduces firms' inefficiency, with the rule of law and the control of corruption playing a preeminent role. However, failure to properly control for endogeneity may lead to a sub estimation of the role of local institutional quality in firms' performance.

This study contributes to existing literature in several ways. First, we examine the causal relationship between institutional factor at local level and technical efficiency of firms, addressing potential endogeneity and firm-level heterogeneity issues that traditional methods of estimating technical efficiency failed to handle. To the best of our knowledge, our study is the first to robustly examine the causal relationship between institutional factors at the local level and the technical efficiency of firms through a sounding econometric lens.

Second, we employ several IV strategies and a particularly conservative approach to evaluate the impact of institutional factors, which allowed us to develop a more comprehensive understanding of the role of environmental factors in inefficiency compared to standard SFA studies that overlook these factors.

Finally, this study is one of the first to assess Italian firms' performance in the building sector using data for the 2013 to 2019 sample period. Although relevant to the Italian economic system, the building sector has rarely been investigated in the literature.

The remainder of this article is organized as follows. Section 2 reviews the literature. Section 3 presents the methodology, and Section 4 describes the dataset and empirical approach. Finally, we report the results in Section 5 and the concluding remarks in Section 6.

2 | LITERATURE REVIEW

As previously mentioned, theoretical and empirical evidence on the effects of corruption on economic systems is mixed. One stream of literature supports the "grease the wheels" hypothesis, suggesting that corruption may be beneficial to efficiency and productivity. In a theoretical framework, Lui (1985) showed that the level of bribes represents economic agents' opportunity costs. More efficient firms can buy low-efficiency red tape. As Leys (1965) suggested, in this context, bribes may represent a highly desired incentive for bureaucrats to accelerate both the decision-making phase and its realization. Bailey (1966) suggested that, especially in transition economies, the low average wage of civil servants in comparison to the private sector may make bribes look like monetary bonuses. Under certain circumstances, economic agents may engage in competitive auctions to gain civil servants' favor (Beck & Maher, 1986). More recently, Dzhumashev (2014) showed that the positive effects of corruption occur only if the government's size exceeds the optimal level. Empirically, Méndez and Sepúlveda (2006) and Méon and Weill (2010) supported the "grease the wheels" hypothesis, reporting a positive relationship between corruption and growth.

Another stream of literature put forward the "sand the wheels" hypothesis, arguing that corruption neither increase efficiency nor compensate debouched institutions (Rose-Ackerman, 1996). In addition, bureaucrats have incentives to create distortions in the economy to maintain the demand for illegal services (Kurer, 1993). Corruption negatively affects trade (Wanchek, 2009), financial systems (Emenalo et al., 2018), and growth (Pellegrini & Gerlagh, 2004). Although corruption may resemble a competitive auction, it is very unlikely that the winner is the most efficient rather than the person who will decrease quality after receiving a license (Méon & Sekkat, 2005). In this context, efficiency and growth decrease due to the negative effects of corruption on productivity, innovation (Salinas-Jiménez & Salinas-Jiménez, 2007), and investment (Johnson et al., 2011). We contribute to such long-lasting debate in the empirical literature supporting the "sand the wheels" hypothesis. Our results show that firm performance is negatively affected by the level of corruption in the areas where firms operate.

Notwithstanding the rich literature on the effects of corruption on the economic systems, only a limited number of theoretical and empirical studies assessed the relationship between firms' efficiency and corruption. In a theoretical framework, Dal Bò and Rossi (2007) showed that higher corruption prevents efficiency of firms, changing the incentives of firms' management and depresses innovation.

From an empirical perspective, some studies investigated whether virtuous or corrupt institutions affect firm performance (Soroush et al., 2021). For instance, the effects of institutions on investment paths in human and physical capital (Ketteler & Rodriguez-Pose, 2018); the presence of well-developed institutions increase the efficiency of commercial institutions' operations (Lensink & Meesters, 2014). A different stream of research focuses on the effects of political institutions and social capital on firm performance, shaping the socioeconomic and business environments in which agents and organizations operate (Di Guilmi et al., 2008; Ganau & Rodriguez-Pose, 2023; Sabatini, 2008).

Finally, other scholars employing different measures of institutional quality found a positive correlation between institutional quality and firm efficiency (Aldieri, Kotsemir, et al., 2020; Aldieri, Makkonen, et al., 2020; Castiglione et al., 2018; Sun et al., 2019; Zallé, 2019). However, Sharma and Mitra (2015) and Aldieri et al. (2022) proved that increased corruption, as a standalone dimension of institutional quality, negatively affects firms' technical efficiency. Hence, this study fills this gap in the literature by suggesting that debauched institutions negatively affect firm performance.

The novelty of our contribution lies in controlling for endogeneity in the empirical assessment and keeping our estimates unbiased by applying the techniques developed by Karakaplan and Kutlu (2017a, 2017b) and Kutlu and Tran (2019). To the best of our knowledge, this is the first study to show that if endogeneity is not properly controlled, estimates of the effect of corruption on firm performance are systematically biased. This result calls for the careful consideration of anti-corruption policies.

3 | ENDOGENOUS PANEL STOCHASTIC PRODUCTION FRONTIER MODEL

Following much of the literature (e.g., Dal Bò & Rossi, 2007), this study utilizes SFA methods, which were first introduced by Aigner et al. (1977) and Meeusen and van den Broeck (1977). Unlike non-parametric techniques, SFA methods recognize both the technical inefficiency component, which includes deviations below the optimal output level, and random shocks, which may impact the production frontier beyond the producers' control. However, as Kumbhakar et al. (2014) pointed out, SFA estimates of technical efficiency often rely on model specifications, distributional assumptions, and the interpretation of inefficiency. Therefore, we considered several SFA panel data model specifications to check the robustness of our results and evaluate the implications of adopting different SFA approaches.

Furthermore, as previously mentioned, we focus on assessing the role of institutional factors and corruption control on firms' technical efficiency. In general, this involves assessing how environmental factors may impact a firm's efficiency. Environmental variables are external factors that influence the production process, without being an input or output. This affects the efficiency of converting the inputs into outputs.

In empirical applications, environmental variables are normally considered exogenous in the sense that they influence the production process but are not inputs or outputs. They influence the efficiency with which inputs are converted into outputs. The SFA framework occasionally incorporates a two-stage estimation approach. The first stage involves the specification and estimation of a stochastic frontier and the prediction of technical efficiency scores. The second stage is devoted to the specification of a regression model in which the technical efficiency is regressed on a set of explanatory variables. However, this approach yields inconsistent estimates. Indeed, as a first-stage assumption, it requires inefficiencies to be independent and identically distributed (Kumbhakar & Lovell, 2003; Wang & Schmidt, 2002).[1]

[1]Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) addressed this concern by introducing a single-stage maximum likelihood approach. Expanding on the work of Kumbhakar et al. (1991), Battese and Coelli (1995) presented a refined model that accommodates panel data.

Therefore, a large share of the literature applies a single-stage approach (Battese & Coelli, 1995) that assume that environmental factors directly affect technical inefficiency. Notwithstanding this, scholars, focusing on the relationship between institutional quality and firms' efficiency, employed a two-stage SFA framework, introducing potential endogeneity bias (Aldieri, Makkonen, et al., 2020; Aldieri, Kotsemir, et al., 2020; Castiglione et al., 2018; Dal Bò & Rossi, 2007; Méon & Weill, 2005; Sharma & Mitra, 2015). Using a one-stage estimation of technical efficiency resulting from SFA avoids the biases present in two-stage SFA procedures (Wang & Schmidt, 2002). Conversely, Aldieri et al. (2022) employ a two-stage approach with IV estimation in the second step to control for endogeneity between environmental variables and technical efficiency but at the cost of biased estimates of technical efficiency (Wang & Schmidt, 2002).

This study adopts a different approach, using a one-stage estimation method (panel SFA), which allows for consistent estimates of efficiency while controlling for endogeneity. This method, introduced by Karakaplan and Kutlu (2017a, 2017b), enables an unbiased analysis of environmental variables in an efficiency assessment.

SFA models assess the gap between the observed and optimal production outputs by identifying the most efficient production units. Specifically, a firm is considered technically inefficient if it cannot attain the highest attainable output under given input and technological conditions. Like in Battese and Coelli (1992) and Battese and Coelli (1995), conventional SFA assumes a composite error term that combines a two-sided error component, $v_{it} \sim N\left(0, \sigma_v^2\right)$, with the negative of a one-sided u_{it} (non-negative) random term representing inefficiency. The one-sided error term u_{it}, follows a half-normal distribution and is always non-negative. When a firm operates at full efficiency, the u_{it} term is zero, and higher values indicate lower levels of efficiency. This one-sided error term gauges the degree to which the observed output deviates from the optimal production levels.

Hence, the conventional panel data SFA production function takes the form[2]:

$$y_{it} = \boldsymbol{x'}_{it}\boldsymbol{\beta} + v_{it} - u_{it}, \quad i = 1, \ldots, n; 1.t = 1, \ldots, T, \tag{1}$$

where $y_{it} \in \mathbb{R}_+$ is the logarithm of output of firm i at time t, $\boldsymbol{x}_{it} \in \mathbb{R}_+^p$ are exogenous production inputs of firm i at time t. v_{it} is the standard two-sided error term and u_{it} is the one-sided non-negative error term that captures technical inefficiency. Moreover, the classical SFA model assumes normal distribution for the two-sided residual term: $v_{it} \sim N\left(0, \sigma_v^2\right)$, while u_{it} follows a half-normal distribution, $u_{it} \sim N^+\left(0, \sigma_u^2\right)$, where $N^+$is the half-normal distribution. Finally, and more important to our analysis, the standard literature on SFA postulates that the two-sided error term, v_{it}, is uncorrelated with $\boldsymbol{x}_{it}$ and that u_{it} and $v_{it}$are independent—in essence, the terms u_{it} and v_{it} are exogenous.[3]

Thus, in Equation (1), efficiency determinants such as environmental variables affect the distribution of the one-sided random variable (Kumbhakar et al., 2021; Wang & Ho, 2010). Nonetheless, a crucial assumption is that the two-sided error term is unrelated to the explanatory variables and inefficiency term. This implies that the frontier and environmental variables should not exert a mutual influence (Kutlu & Tran, 2019). Hence, a critical methodological challenge emerges when applying SFA to estimate technical efficiency, as in our study, which focuses on the determinants of

[2]For convenience, we assume a Cobb–Douglas-type production function in loglinear form. For a more detailed discussion, we refer the reader to Kumbhakar et al. (2021) and Kutlu and Tran (2019).

[3]More precisely, the classical SFA assumes that v_{it} and u_{it} are each identically and independently distributed (*iid*) and the covariates $\boldsymbol{x}_{it}$ are exogenous or independent of both u_{it} and v_{it}.

inefficiency. To the best of our knowledge, prior studies did not adequately address this concern. Notably, the literature largely overlooked the assumption that the two-sided error term must remain independent of both the explanatory variables in the production function (i.e., the production frontier) and the one-sided inefficiency term, leaving room for endogeneity. The presence of endogeneity in a stochastic frontier model can lead to a serious lack of consistency in the parameter estimates, calling for new ways to account for it (Kutlu & Tran, 2019).

However, the problem of endogeneity in SFAs is more complicated than in standard regression models. Kutlu (2010) introduced a maximum likelihood model to address the endogeneity arising from correlated regressors in the frontier and the two-sided error term found in Battese and Coelli's (1992) model. Notably, the model proposed by Kutlu (2010) lacks environmental variables and does not consider the endogeneity linked to the correlation between the one- and two-sided error terms. Karakaplan and Kutlu (2017b) extend the work of Kutlu (2010) to allow environmental variables in a cross-sectional data context to be employed in a one-stage model. A generalization of Greene's (2005) true fixed-effects model to the endogeneity case proposed by Karakaplan and Kutlu (2017b) overcomes such difficulties in a panel data setting. More specifically, Karakaplan and Kutlu (2017b) bypassed these limitations by proposing an endogenous panel SFA estimation framework that allows for instrumenting the inefficiency part and the shape of the frontier separately in a single stage. In addition, the full specification allows us to consider the endogeneity issue either in the frontier or in the inefficiency part (as in our case) by instrumenting the endogenous terms. More formally, to accommodate endogeneity both in the frontier and inefficiency parts, following Karakaplan and Kutlu (2017b), we rewrite Model (1) as follows:

$$y_{it} = x_{1it}\beta + v_{it} - u_{it}, \quad i = 1,...,n; 1.t = 1,...,T, \tag{2}$$

$$x_{it} = Z_{it}\gamma + \varepsilon_{it}, \tag{3}$$

where y_{it} is the logarithm of output of firm i at time t, $x_{1it}$is a vector of inputs of the firm i at time t, x_{2it} is a vector of environmental variables that effect the inefficiency term, $x_{it} = (x_{1it} + x_{2it})'$. Z_{it} is a matrix of exogeneous instruments and ε_{it} is a vector of reduced form errors. In Model (2), we assume a normal distribution for the two-sided residual term: $v_{it} \sim N(0, \sigma_v^2)$, while the one-sided non-negative error term u_{it}becomes $u_{it} = h_{it}u_i^*$where $h_{it} = \mathrm{f}(x_{it}, \varphi) > 0$ and u_i^*follows a half-normal distribution: $u_i^* \sim N^+(\mu, \sigma_u^2)$ and $v_{it}$and u_{it} are independent conditionally on x_{it}; and $h_{it}^2 = \exp(\mathrm{x}'_{uit}, \varphi_u)$. Hence, $v_{it}$and u_{it} are not necessarily independent, unconditional, or conditional on exogenous variables. Accordingly, we can address our empirical research questions.[4]

Finally, to specify the production frontier, we estimate both the Cobb–Douglas and translogarithmic (Translog) functional forms (Christensen et al., 1973). Although Translog is a

[4]The novel contribution of our study is the use of a new method introduced by Karakaplan and Kutlu (2017b) to explore the role of institutional quality and corruption using a large dataset of firms operating in the Italian construction sector as a case study. We use an endogenous stochastic frontier panel model to solve the problem of endogeneity, arising when analyzing the impact of environmental factors on firm performance. In fact, as in prior studies, employing SFAs to analyze the relationship between firm efficiency and environmental factors, inadequately addressed endogeneity in the stochastic frontier model leading to inconsistent estimates of production function parameters. However, one could argue that the production process may be a source of endogeneity. Indeed, Kutlu and Tran (2019) classify endogeneity in the production process as Type I endogeneity, the endogeneity of environmental variables and production process as Type II endogeneity, and the presence of both sources as Type III endogeneity. For a more formal discussion, we refer the reader to Kutlu and Tran (2019).

generalization of– the Douglas, the application of this functional form, in contrast to the latter, allows for higher flexibility (Kumbhakar et al., 2021). After comparing the two functional forms in terms of goodness of fit, we opted for the Translog model.[5] We present further details on the sample, empirical strategy, and estimates in the following sections.

4 | DATA SAMPLE AND EMPIRICAL STRATEGY

Our analysis relies on datasets from different sources. To estimate the technical (in)efficiency of firms, this study employs a balanced panel of Italian firms operating in the building sector from 2013 to 2019. The data were collected from various sources. Information on output, inputs, and other firm-level characteristics comes from the AIDA dataset, which contains balance sheet information from 2013 to 2019.[6] An important advantage of the AIDA dataset is that it includes all industries operating in the Italian economic system. We extracted information on several variables, including sales, number of workers, and total tangible fixed assets. We also retained information about the firms' geographic localization and industry. For our analysis, among the sectors in the AIDA database, we chose sector 4120: residential and non-residential building general contractors (roughly corresponding to codes 1520, 1530, and 1540 in the U.S. Standard Industrial Classification).[7] We opted for sector 4120 because it is a traditional industrial sector permeable to corruption in Italy (ANAC, 2019). Moreover, firms in the residential and nonresidential building sectors employ relatively homogeneous production technology and have similar characteristics across Italy (ANCE, 2022).[8]

The building sector[9] has been assessed by examining the relationship between public works and public procurement (e.g., Guccio et al., 2019) and the effects of institutional quality (e.g., Cavalieri et al., 2020) and corruption (Decarolis et al., 2020; Finocchiaro Castro et al., 2014, 2018) on the efficiency of public works execution.

Because sector 4120 consists mainly of very small firms characterized by missing or negligible turnover figures and a few years of survival, we excluded those with fewer than five employees. Furthermore, after removing firms with missing or incomplete information, we obtained a balanced panel of 5307 firms belonging to the residential and non-residential building sectors for of 2013–2019, yielding 37,149 observations.[10]

[5]Additional robustness checks using a Cobb–Douglas technology are available in Tables A.1–A.3 Appendix A.

[6]The AIDA database is compiled by the Bureau van Dijk and contains detailed accounts (following the scheme of the Fourth Directive of the EEC Council), indicators, and trade description of Italian companies, divided by economic sector and geographical area. Other information includes year of incorporation, ownership, and number of employees, and so on.

[7]The sector under scrutiny only partially overlaps with procurement in public works, which in Italy is significantly characterized by high levels of inefficiency and cost overruns (Cavalieri et al., 2019).

[8]The most recent estimates (ANCE, 2022) indicate that 108,000 units operate in the Italian residential and non-residential building sector, with almost 60% of firms with one employee only.

[9]Moreover, the building sector is affected by irregular work and the shadow economy, which are often associated with corruption. Indeed, the relationship between corruption and the shadow economy is still widely discussed in the literature (e.g., Dell'Anno & Teobaldelli, 2015; Dreher & Schneider, 2010). For a review, see (Dimant & Tosato, 2018).

[10]The correlation between the number of firms at the provincial level in our sample and the number of firms from official business statistics by ANCE is 0.87. Thus, the sample is representative of the actual population of province-level businesses in the residential and non-residential building sector in Italy in terms of geographical distribution.

TABLE 1 Firm size by number of employees in the sample.

Classes of employees	Freq.	%	% cumulate
5–9	2170	40.89	40.89
10–24	2410	45.41	86.3
25–49	510	9.61	95.91
50 or more	217	4.09	100
Total	5307	100	–

Note: This table reports the distribution of firms according to the number of employees taken from the AIDA database.
Source: Authors' elaborations on AIDA database.

Table 1 reports the distribution of firm size in our sample by number of employees. Most firms in our sample had no more than 24 employees (86.3%).[11]

Following many empirical efficiency studies, we employ financial accounting data as a proxy for production in the sector.[12] Specifically, we estimate the production frontier using value-added as the output variable (Y); labor input (L), measured as the total number of employees at the end of the year; and capital stock (K), proxied by the yearly nominal value of tangible and intangible assets after depreciation, as input variables. All monetary aggregates are in thousands of Euros and deflated in 2015. In our study, the Cobb–Douglas production function seems worth applying because it involves the estimation of relatively few parameters, thus allowing easy interpretation of the results. However, the Translog functional form may be preferred to the Cobb–Douglas form because of the restrictive elasticity of substitution and the scale properties of the latter. Therefore, we estimate the stochastic frontier model using both functions. The obtained estimates largely overlap. Therefore, because the deterministic part of the production function is usually better captured by a flexible input function, such as the Translog function, we report the estimates of the Translog production function.[13]

As noted above, the core discussion of our empirical exercise is to analyze the connection between business efficiency and environmental factors, considering the potential endogeneity of the latter. We assess the impact of environmental factors on firms' technical efficiency using a newly developed panel SFA (Karakaplan & Kutlu, 2017a, 2017b; Kutlu & Tran, 2019), enabling an unbiased assessment of environmental variables in the efficiency analysis. To apply this technique, we need to identify the environmental and instrumental variables to control for potential endogeneity.

We opted for the institutional quality index (IQI) sourced from the Nifo and Vecchione (2014) database. The IQI encompasses five groups of elementary indices: voice and accountability, government effectiveness, regulatory quality, rule of law, and control of corruption. Inspired by the World Governance Indicator proposed by Kaufmann et al. (2011), as part of the Knowledge for Change Program by the World Bank, the IQI data

[11]Below, we employed several empirical strategies to ensure that our results do not depend on firm size.
[12]In this industry, outputs are extremely heterogeneous and can be measured indirectly through proxies such as sales or value-added. Moreover, those proxies are consistent with the assumption that firms are output maximisers by the given level of inputs (Kumbhakar et al., 2021).
[13]The estimates using Cobb–Douglas technology are reported in the Appendix .

for its elementary indexes are taken from institutional sources, research institutes, and professional registers.

Our choice is based on two considerations. First, Nifo and Vecchione's (2014) database, unlike others, is available at a granular level (the provincial level) and over a wide time span. This allows us to better control environmental factors and their dynamics. Second, Nifo and Vecchione's (2014) database is the most widely used in the empirical literature on the impact of environmental factors on Italian companies' efficiency, allowing us to comparatively assess our findings.

Figure 1 reports the average value of the IQI for Italian provinces from 2013 to 2019 to. As expected, the IQI confirms the North–South Italian divide, reporting higher institutional quality in northern provinces than in southern provinces. However, it must be recalled that the IQI is based on five groups of elementary indexes, voice and accountability, government effectiveness, regulatory quality, rule of law, and control of corruption. Voice and accountability measure citizens' levels of participation in public elections, the number of associations and social cooperatives, and cultural liveliness, expressed in terms of the number of published and purchased books. Government effectiveness measures the endowment of social and economic structures in Italian provinces, together with the provincial and regional governments' ability to manage health, waste, and the environment. Regulatory quality refers to the level of economic openness, business environment, and startup lifecycle (mortality, registration, and cessation). The rule of law combines data on crimes against persons or property, magistrate productivity, trial times, tax evasion, and the shadow economy. Control over corruption measures the capacity of the public power to counteract corruption. It considers data on crimes against public administration, the number of local administrations overruled by central authorities, and the Golden and Picci (2005) index. Figure 2 depicts the average level of each IQI pillar in each Italian province. In addition, the results confirmed that in each pillar, the northern provinces obtained higher levels than the southern provinces.

As we pointed out, the empirical challenge in determining causality is the possible endogenous nature of institutional quality and its pillars, and the technical efficiency of firms. To address this issue, we use Karakaplan and Kutlu's approach (Karakaplan & Kutlu, 2017a), which requires an instrumental variable strategy. We chose two alternative instrumental variables available at the provincial level: current and historical. The former is the cheating index (Finocchiaro Castro & Guccio, 2020; Guiso et al., 2016), which measures the frequency of primary school teachers' cheating on a national mathematics exam taken by second- and fifth-grade pupils in Italy. The latter instrumental variable (IV) accounts for the kind of government rule at the beginning of the 14th century in Italy (De Blasio & Nuzzo, 2010). Section 4 investigates the role of history in local economic performance in Italy by assessing the levels of the most widely adopted example of informal rules: the concept of social capital namely (Putnam, 1993). From a historical perspective, the rationale is that the different levels of social capital today can be ascribed to the systems of government rule at the beginning of the 14th century (Acemoglu et al., 2001, 2008; Putnam, 1993).

Figure 3 shows the average cheating index values at the provincial level. The figure shows that the highest index values were observed in the Southern Italian provinces. In other words, most primary school teachers' cheating behavior occurred in southern Italy. Finally, Figure 4 illustrates the localization of different kinds of government rule in Italy at the beginning of the 14th century, as provided by De Blasio and Nuzzo (2010). According to some scholars, the

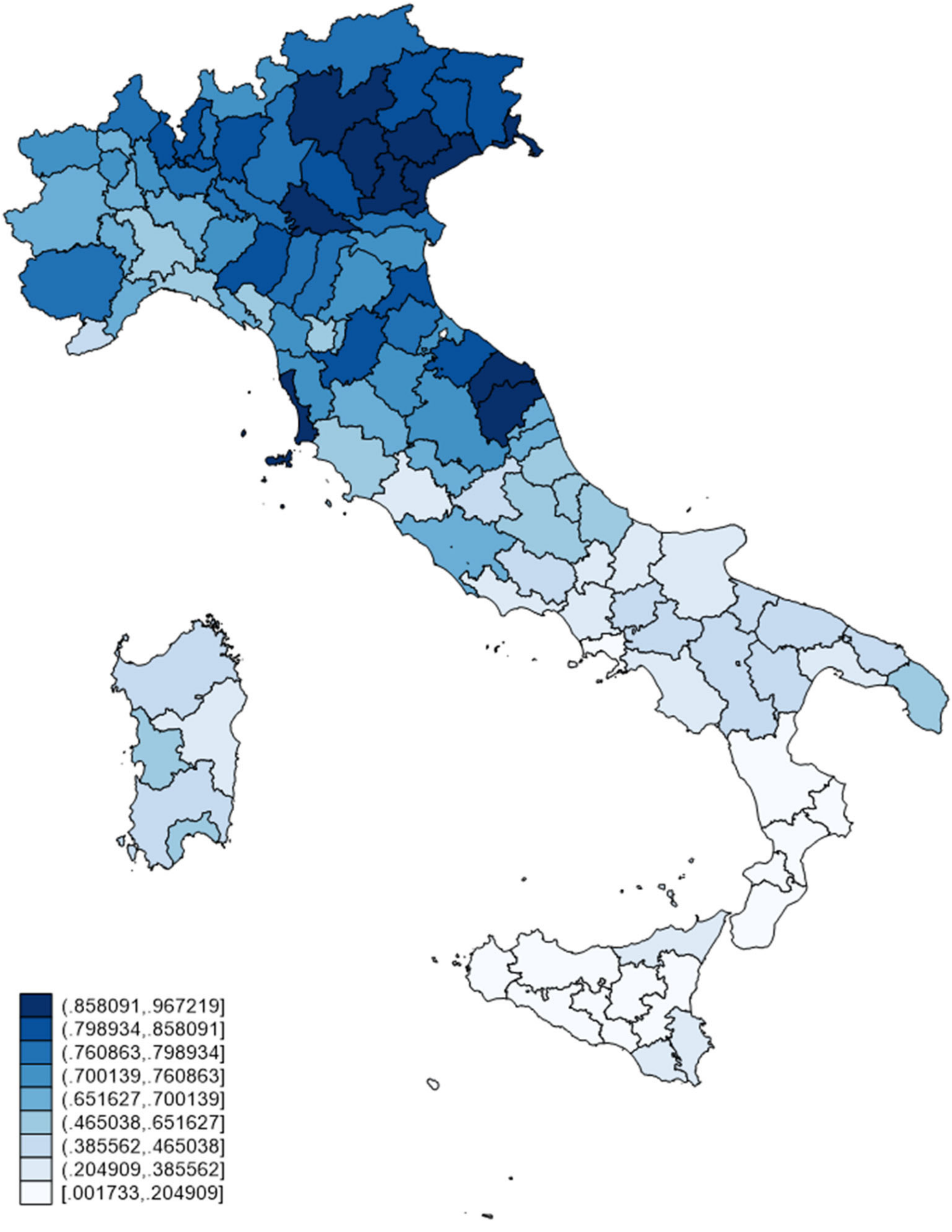

FIGURE 1 Average level of Institutional Quality Index (IQI) in the time span 2013–2019 at the provincial level. *Source:* our elaboration on data provided by Nifo and Vecchione (2014). This figure reports the average value of the institutional quality index (IQI) at provincial level, sourced from the Nifo and Vecchione (2014) database. The IQI is composed by five pillars, voice and accountability, government effectiveness, regulatory quality, rule of law, and control of corruption, namely. It reads as the darker the province, the higher the IQI level is, confirming the North–South divide in Italy. [Color figure can be viewed at wileyonlinelibrary.com]

historical presence of the Papal state and the Kingdom of Sicily in southern Italy can be considered the main cause of the low level of social capital in those areas (Acemoglu et al., 2001, 2008; Putnam, 1993).

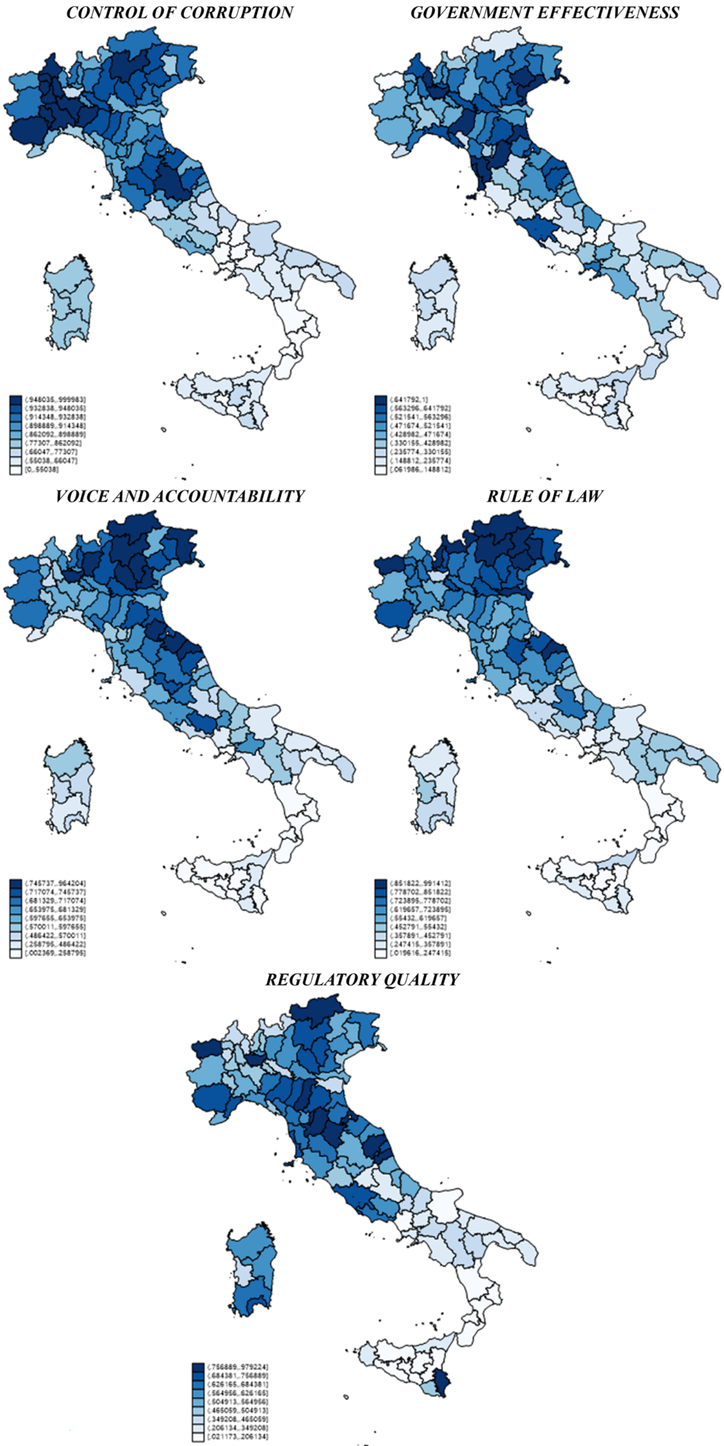

FIGURE 2 Average level of the pillars of IQI in the time span 2013–2019 at the provincial level. *Source:* Our elaboration on data provided by Nifo and Vecchione (2014). This figure reports the average value, at provincial level, of each of the five pillars that determine the IQI. As in Figure 1, it reads as the darker the province, the higher each pillar's level is. [Color figure can be viewed at wileyonlinelibrary.com]

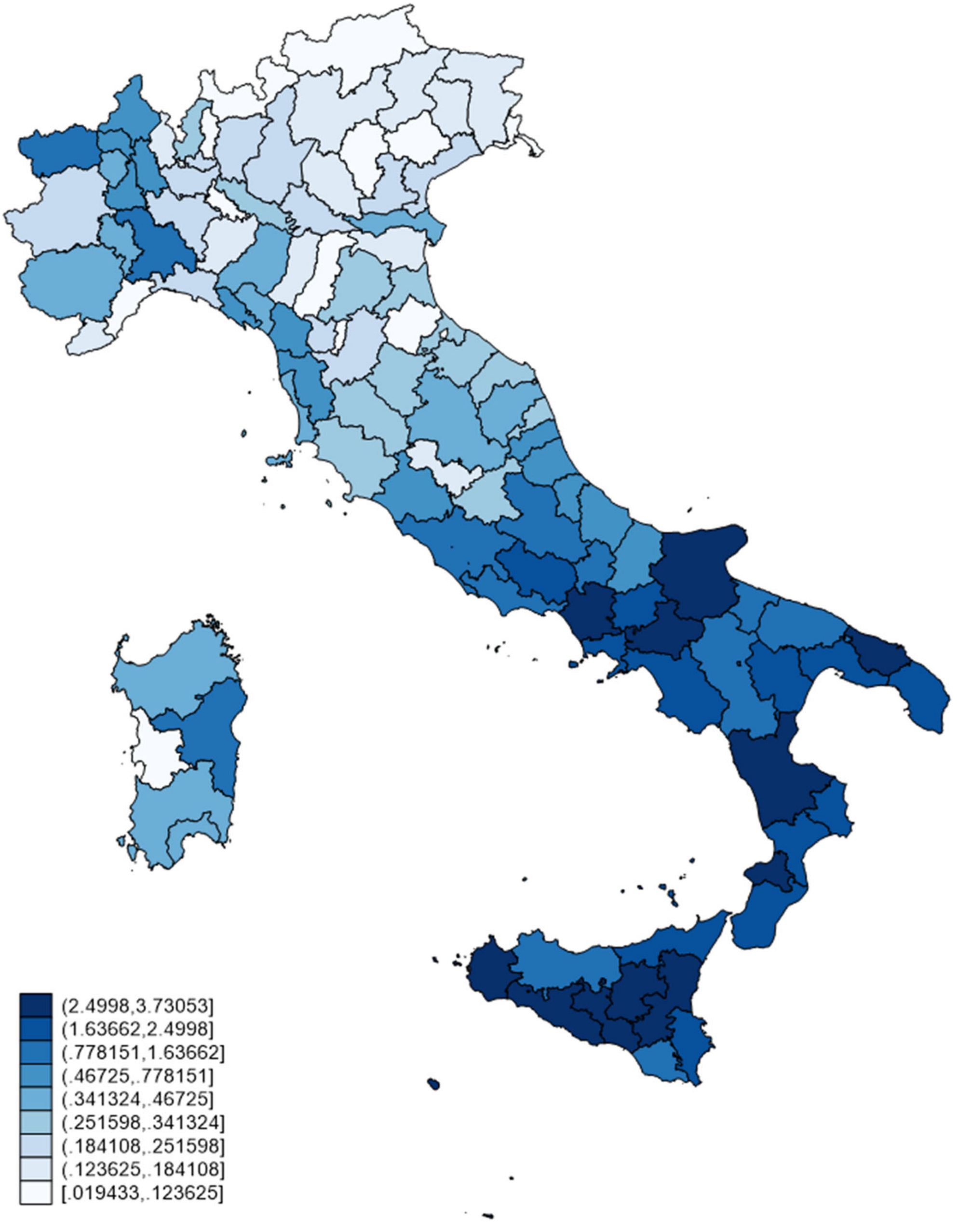

FIGURE 3 Average level of Cheating Index in the time span 2013–2019 at the provincial level. *Source:* Our elaboration on data provided by Finocchiaro Castro and Guccio (2020). The Cheating Index is built on objective data on Italian primary-school teachers' cheating behavior when administering a nationwide standardized test on mathematics, managed by the Italian institute for the assessment of educational system (INVALSI). As in the previous Figure, it reads as the darker the province, the higher the index's level is. [Color figure can be viewed at wileyonlinelibrary.com]

Table 2 summarizes the variables employed and their sources. In Table 3, we provide the descriptive statistics.

FIGURE 4 Fourteenth-century Local Policy Regimes. *Source:* De Blasio and Nuzzo (2010). This figure shows the kind of government ruling at the beginning of 14th century in Italy at the provincial level provided by De Blasio and Nuzzo (2010).

5 | RESULTS

5.1 | Main empirical findings

In this section, we provide the estimates of our empirical exercise.[14] As noted above, our core aim is to analyze the connection between firm efficiency and environmental factors, considering the potential endogeneity of the latter. We adopt a parsimonious approach to ensure the robustness of our findings. First, we report the SFA estimates, assuming environmental factors as exogenous factors influencing the distance between each firm's output and the efficient

[14]In our efficiency estimates, we used the "xtsfkk" Stata package developed by Karakaplan (2022).

TABLE 2 Variables and source.

Variable	Meaning	Source
Y	Value-added at firm level	AIDA
L	The total number of employees at firm level	AIDA
C	Capital stock at firm level	AIDA
Environmental variables		
IQI	Institutional quality index	Nifo and Vecchione (2014)
CONTROL OF CORRUPTION	IQI pilar for control of corruption at provincial level	Nifo and Vecchione (2014)
GOVERNMENT EFFECTIVENESS	IQI pilar for government effectiveness at provincial level	Nifo and Vecchione (2014)
VOICE AND ACCOUNTABILITY	IQI pilar for voice and accountability at provincial level	Nifo and Vecchione (2014)
RULE OF LAW	IQI pilar for rule of law at provincial level	Nifo and Vecchione (2014)
REGULATORY QUALITY	IQI pilar for regulatory quality at provincial level	Nifo and Vecchione (2014)
Instrumental variables		
CHEATING INDEX	Cheating in national mathematics exam at provincial level	Finocchiaro Castro and Guccio (2020)
COMMUNAL_REPUBLICS	Dummy for communal republic at provincial level	De Blasio and Nuzzo (2010)
SIGNORIE	Dummy for SIGNORIE provincial level	De Blasio and Nuzzo (2010)
PAPAL_STATE	Dummy for PAPAL_STATE at provincial level	De Blasio and Nuzzo (2010)
KINGDOM_SICILY	Dummy for Kingdom_Sicily at provincial level	De Blasio and Nuzzo (2010)
PERIPHERAL_AREAS	Dummy for Peripheral_areas at provincial level	De Blasio and Nuzzo (2010)
Other controls		
FIRM_DIMENSION	Categorical variable (1–4) based on the number of employees in the firm	AIDA
YEAR	Time dummies variables for the years from 2013 to 2019	AIDA

Note: This Table reports the variables employed to estimate the stochastic production frontier (Y, L, and C), the sets of environmental variables and IV employed in the empirical analysis.
Source: authors' elaborations.

frontier. We then assume that environmental factors may be endogenous, and for this purpose, we employ two different IV strategies.

To keep the model parsimonious, we begin with the baseline model and then add other factors to the regression model. Thus, time dummies are introduced into the model to capture exogenous factors in the economy that might affect the production set, whereas dummies for

TABLE 3 Summary statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
Y	37,149	7830.79	41,326.47	16.78	1,730,777.00
L	37,149	18.25	49.60	5.00	2788.00
C	37,149	2033.90	14,395.63	0.00	693,870.00
Environmental variables					
IQI	37,149	0.63	0.23	0.00	1.00
CONTROL OF CORRUPTION	37,149	0.78	0.20	0.24	0.98
GOVERNMENT EFFECTIVENESS	37,149	0.48	0.14	0.00	0.69
VOICE AND ACCOUNTABILITY	37,149	0.56	0.19	0.09	0.92
RULE OF LAW	37,149	0.56	0.21	0.07	1.00
REGULATORY QUALITY	37,149	0.61	0.21	0.17	0.98
Instrumental variables					
CHEATING INDEX	37,149	0.81	0.89	0.00	3.73
COMMUNAL_REPUBLICS	37,149	0.19	0.39	0.00	1.00
SIGNORIE	37,149	0.30	0.46	0.00	1.00
PAPAL_STATE	37,149	0.15	0.36	0.00	1.00
KINGDOM_SICILY	37,149	0.27	0.44	0.00	1.00
PERIPHERAL_AREAS	37,149	0.09	0.29	0.00	1.00

Note: This table reports the descriptive statistics of the variables employed to estimate the stochastic production frontier, the sets of environmental variables and IV employed in the empirical analysis.
Source: Authors' elaborations.

the class of firm dimensions are included to control for the heterogeneity of the firm sample. In Tables 4–6, Columns 1–6 report the estimates without fixed controls for time and firm dimensions, whereas Columns 7–12 show the estimates controlling for time and firm size fixed effects.

Table 4 reports the results of our baseline estimates, where the environmental factors are considered exogenous. We apply a single-stage approach (see Battese & Coelli, 1995), where environmental factors are assumed to directly affect technical inefficiency but are considered exogenous.

We estimated the endogenous model following Karakaplan's (Karakaplan & Kutlu, 2017a; Karakaplan & Kutlu, 2017b) methodology. The estimates are presented in Tables 5 and 6. More precisely, in Table 5, we consider the province-level cheating index (Finocchiaro Castro & Guccio, 2020; Guiso et al., 2016) as an instrument whereas in Table 6, we employ instrumental historical variables that account for the kind of government ruling at the beginning of the 14th century in Italy at the provincial level (De Blasio & Nuzzo, 2010). We use a Translog-production function for all estimates. Figure 5 shows the geographical distribution of average unconditional technical efficiency at regional (left) and provincial (right) level. The distribution of technical efficiency levels in Figure 5 confirms the regional gaps in the inefficiency of the entrepreneurial system even in the absence of environmental controls.

Overall, our results are consistent with those of prior studies. The coefficient estimates from the baseline models in Table 4 and the models that account for endogeneity in Tables 5 and 6 have the same sign for each variable and are significant at the 1% level. Furthermore, all environmental factors except *GOVERNMENT_EFFECTIVENESS* are significant at the 1% level and have the same signs. Moreover, the signs are robust to all the specifications adopted.

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TABLE 4 Baseline estimates with exogenous determinants of inefficiency—Translog production function.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Determinants in the variance of inefficiency												
IQI	−0.714***						−0.811***					
	(0.074)						(0.076)					
CONTROL_CORRUPTION		−0.503***						−0.692***				
		(0.083)						(0.087)				
GOVERNMENT EFFECTIVENESS			0.034						−0.175**			
			(0.069)						(0.074)			
VOICE & ACCOUNTABILITY				−0.227***						−0.338***		
				(0.055)						(0.056)		
RULE OF LAW					−0.764***						−0.724***	
					(0.072)						(0.074)	
REGULATORY QUALITY						−0.231***						−0.338***
						(0.051)						(0.056)
Production function (Translog)												
Constant (β_0)	6.049***	6.055***	6.076***	6.064***	6.058***	6.064***	0.664***	6.039***	6.061***	6.054***	6.043***	6.049***
	(0.062)	(0.062)	(0.062)	(0.062)	(0.062)	(0.062)	(0.043)	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)
L (ln)	0.655***	0.656***	0.649***	0.652***	0.659***	0.651***	0.670***	0.671***	0.665***	0.665***	0.674***	0.664***
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.043)	(0.042)	(0.043)	(0.043)	(0.043)	(0.043)
K (ln)	0.142***	0.143***	0.144***	0.144***	0.137***	0.144***	0.124***	0.125***	0.128***	0.128***	0.122***	0.127***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
L (ln) square	0.026**	0.025**	0.026**	0.025**	0.024*	0.026**	0.001	−0.001	0.001	0.001	−0.001	0.001
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
K (ln) square	0.026***	0.026***	0.025***	0.025***	0.026***	0.025***	0.025***	0.025***	0.024***	0.024***	0.025***	0.024***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
L (ln) * K(ln)	−0.012***	−0.013***	−0.012***	−0.012***	−0.012***	−0.012***	−0.007	−0.007	−0.007	−0.007	−0.007	−0.007
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Control for firm class dimension	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Mean efficiency	0.4113	0.4061	0.4075	0.4042	0.4067	0.4098	0.4097	0.4061	0.4039	0.4059	0.4082	0.4069
Observations	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149

Note: This table reports the estimates of the exogenous SFA applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). All estimates considering the environmental variable as endogenous. Standard errors in parentheses.
Source: Authors' elaborations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

TABLE 5 Endogenous SFA estimates—Translog production function using current IV.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Determinants in the variance of inefficiency												
IQI	−0.932***						−0.901***					
	(0.091)						(0.090)					
CONTROL_CORRUPTION		−1.221***						−1.243***				
		(0.080)						(0.102)				
GOVERNMENT EFFECTIVENESS			0.213*						0.151			
			(0.110)						(0.109)			
VOICE & ACCOUNTABILITY				−0.100						−0.171**		
				(0.078)						(0.079)		
RULE OF LAW					−1.384***						−1.326***	
					(0.090)						(0.089)	
REGULATORY QUALITY						−0.397***						−0.422***
						(0.078)						(0.080)
eta (endogenous variables)	*−0.319****	*−0.988****	*0.135***	*0.108***	*−0.655****	*−0.133****	*−0.147**	*−0.815****	*0.261****	*0.144****	*−0.705****	*0.014*
	(0.077)	*(0.081)*	*(0.064)*	*(0.047)*	*(0.056)*	*(0.047)*	*(0.080)*	*(0.084)*	*(0.064)*	*(0.048)*	*(0.058)*	*(0.050)*
IV (first stage estimates)												
CHEATING_INDEX	−0.221***	−0.181***	−0.095***	−0.173***	−0.192***	−0.185***	−0.221***	−0.181***	−0.094***	−0.173***	−0.192***	−0.185***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Eta endogeneity test												
$chi^2(1)$	3.57	147.99	4.44	5.24	135.34	7.93	3.41	94.90	16.68	9.07	149.41	0.08
p-value	*0.0591*	*0.0000*	*0.0351*	*0.0221*	*0.0000*	*0.0049*	*0.0647*	*0.0000*	*0.0000*	*0.0026*	*0.0000*	*0.7734*
Production function (Translog)												
Constant (β_0)	6.045***	6.037***	6.082***	6.061***	6.044***	6.064***	6.043***	5.996***	6.070***	6.052***	6.031***	6.049***
	(0.062)	(0.062)	(0.062)	(0.062)	(0.061)	(0.062)	(0.071)	(0.072)	(0.071)	(0.071)	(0.071)	(0.071)
L (ln)	0.663***	0.665***	0.644***	0.652***	0.670***	0.652***	0.673***	0.687***	0.657***	0.666***	0.684***	0.664***
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.043)	(−0.043)	(0.043)	(0.042)	(0.043)	(0.043)
K (ln)	0.142***	0.142***	0.144***	0.144***	0.136***	0.145***	0.124***	0.126***	0.128***	0.127***	0.121***	0.127***
	(−0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
L (ln) square	0.025**	0.028**	0.027**	0.026**	0.027**	0.026**	0.023	0.025*	0.025*	0.025*	0.026*	0.026*
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
K (ln) square	0.026***	0.028***	0.025***	0.025***	0.027***	0.025***	0.025***	0.027***	0.024***	0.024***	0.027***	0.024***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)

TABLE 5 (Continued)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
L (ln) * K(ln)	−0.013***	−0.016***	−0.012***	−0.012***	−0.015***	−0.012***	−0.008*	−0.010**	−0.007	−0.007	−0.010**	−0.007
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Control for firm class dimension	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Mean efficiency	0.4087	0.4113	0.4047	0.4073	0.4107	0.4064	0.4089	0.4098	0.4051	0.4068	0.4089	0.4070
Observations	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149

Note: This table reports the estimates of the endogenous SFA applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). To control for endogeneity issue, we use our current IV, the cheating index namely. All estimates considering the environmental variable as endogenous. Standard errors in parentheses.
Source: Authors' elaborations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

TABLE 6 Endogenous SFA estimates—Translog production function using historical IV.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Determinants in the variance of inefficiency												
IQI	−1.020***						−1.001***					
	(0.089)						(0.089)					
CONTROL_CORRUPTION		−1.081***						−1.091***				
		(0.105)						(0.107)				
GOVERNMENT EFFECTIVENESS			−0.993***						−0.967***			
			(0.138)						(0.138)			
VOICE & ACCOUNTABILITY				−0.719***						−0.829***		
				(0.097)						(0.099)		
RULE OF LAW					−1.462***						−1.426***	
					(0.101)						(0.101)	
REGULATORY QUALITY						−0.816***						−0.825***
						(0.090)						(0.091)
eta (endogenous variables)	*−0.426****	*−0.748****	*−0.834****	*−0.326****	*−0.452****	*−0.389****	*−0.293****	*−0.469****	*−0.543****	*−0.193****	*−0.483****	*−0.121**
	(0.070)	*(0.095)*	*(0.096)*	*(0.071)*	*(0.070)*	*(0.057)*	*(0.073)*	*(0.098)*	*(0.106)*	*(0.074)*	*(0.073)*	*(0.063)*
IV (first stage estimates)												
SIGNORIE	0.020***	−0.018***	0.006***	−0.039***	0.035***	0.097***	0.020***	−0.018***	0.006***	−0.039***	0.035***	0.097***
	(0.002)	(−0.002)	(−0.001)	(−0.001)	(−0.002)	(−0.002)	(−0.002)	(−0.002)	(−0.001)	(−0.001)	(−0.002)	(−0.002)
PAPAL_STATE	−0.137***	−0.065***	−0.073***	−0.016***	−0.180***	0.001	−0.136***	−0.064***	−0.073***	−0.016***	−0.179***	0.002
	(0.002)	(−0.002)	(−0.002)	(−0.002)	(−0.002)	(−0.002)	(−0.002)	(−0.002)	(−0.001)	(−0.002)	(−0.002)	(−0.002)
KINGDOM_SICILY	−0.444***	−0.394***	−0.228***	−0.394***	−0.342***	−0.327***	−0.444***	−0.394***	−0.228***	−0.394***	−0.342***	−0.327***
	(0.002)	(−0.002)	(−0.001)	(−0.001)	(−0.002)	(−0.002)	(−0.002)	(−0.002)	(−0.001)	(−0.001)	(−0.002)	(−0.002)
PERIPHERAL_AREAS	−0.085***	−0.031***	−0.225***	−0.050***	0.000	0.007***	−0.085***	−0.031***	−0.225***	−0.050***	0.000	0.007***
	(0.003)	(−0.003)	(−0.002)	(−0.002)	(−0.003)	(−0.002)	(−0.003)	(−0.002)	(−0.002)	(−0.002)	(−0.003)	(−0.002)
Eta endogeneity test												
$chi^2(1)$	36.82	52.86	62.39	76.01	21.14	42.26	16.05	22.71	26.08	26.08	44.32	3.65
p-Value	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0001*	*0.0000*	*0.0000*	*0.0093*	*0.0000*	*0.0562*
Production function (Translog)												
Constant (β_0)	6.048***	6.074***	6.056***	6.060***	6.057***	6.070***	6.048***	6.045***	6.048***	6.047***	6.046***	6.048***
	(0.062)	(0.062)	(0.062)	(0.062)	(0.061)	(0.062)	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)
L (ln)	0.664***	0.660***	0.666***	0.657***	0.664***	0.653***	0.673***	0.671***	0.673***	0.670***	0.675***	0.666***
	(0.034)	(0.034)	(0.034)	(0.034)	(0.033)	(0.033)	(0.043)	(0.043)	(0.043)	(0.042)	(0.042)	(0.042)

TABLE 6 (Continued)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
K (ln)	0.141***	0.137***	0.144***	0.144***	0.137***	0.142***	0.124***	0.121***	0.128***	0.126***	0.121***	0.125***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
L (ln) square	0.025**	0.023*	0.024*	0.024*	0.025*	0.026**	0.001	−0.001	0.001	−0.001	0.000	0.001
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
K (ln) square	0.026***	0.026***	0.026***	0.025***	0.026***	0.025***	0.025***	0.025***	0.025***	0.024***	0.025***	0.025***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
L (ln) * K(ln)	−0.013***	−0.012**	−0.014***	−0.012***	−0.012***	−0.012***	−0.008*	−0.007	−0.008*	−0.007	−0.008*	−0.007
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Control for firm class dimension	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Mean efficiency	0.4263	4113	0.4121	0.4202	0.4115	0.4187	0.4255	0.4101	0.4134	0.4201	0.4089	0.4040
Observations	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149

Note: This table reports the estimates of the endogenous SFA applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). To control for endogeneity issue, we use our historical IV, the kind of government ruling in Italy at the beginning of 14th century at the provincial level and provided by De Blasio and Nuzzo (2010). All estimates considering the environmental variable as endogenous. Standard errors in parentheses.

Source: Authors' elaborations.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

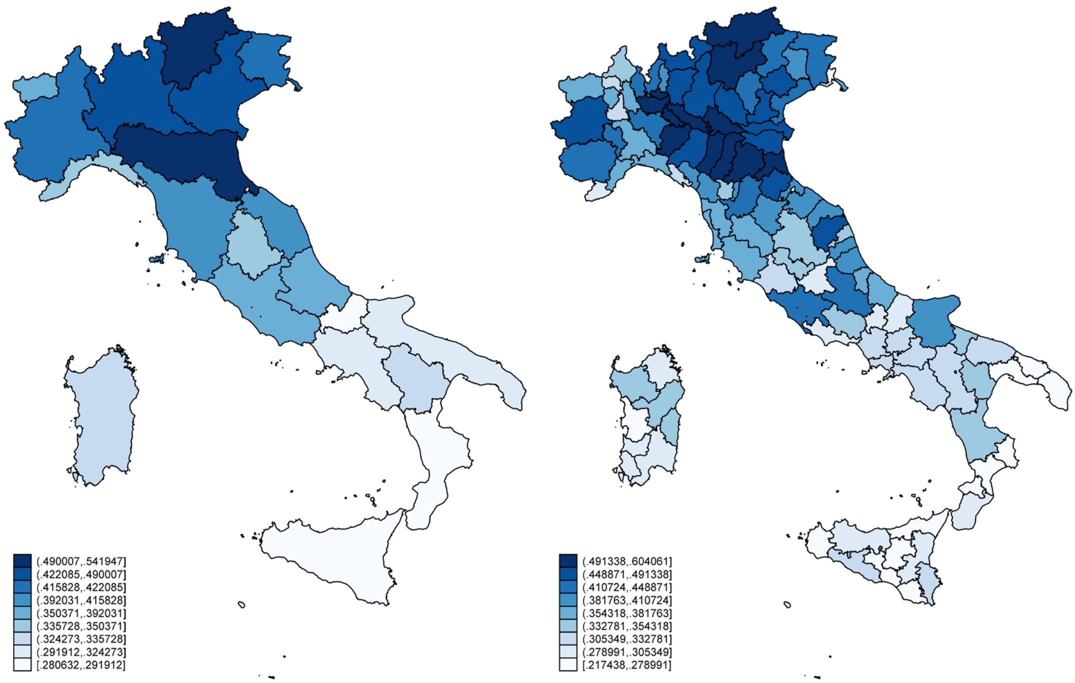

FIGURE 5 Estimate of average technical efficiency of the firms in building sector in Italy. *Source*: authors' elaborations. This figure report the mean unconditional technical efficiency at regional (left) and provincial (right) level. [Color figure can be viewed at wileyonlinelibrary.com]

The average firm efficiency estimates in our sample are around 40%, indicating a low level of efficiency in Italy's building sector. This is not surprising given the characteristics of this sector (ANCE, 2022) (Figure 5).

Because our main interest is the impact of the exogenous assumption of environmental factors on firm inefficiency, we begin the discussion here. Tables 5 and 6 report the first-stage results for the two different IVs (namely current and historical), which are all highly significant. Furthermore, Tables 5 and 6 show the endogeneity tests that generally support the endogenous models, and consequently, the instruments employed. In particular, the reported chi-square statistical test ensured that we solved the endogeneity problem using the selected instruments. Indeed, except for the estimates of *REGULATORY_QUALITY* in Column 12, Tables 5 and 6 show that the individual eta terms for the environmental factors are statistically significant, and the eta endogeneity tests reject the null hypothesis at any conventional level of significance. This result indicates that a correction for endogeneity in the estimated models, as well as in the inefficiency estimates, is necessary.

Regarding the institutional factors, the results differ significantly between the endogenous and exogenous models. Indeed, the coefficients of the IQI and some pillars were greater and more significant when endogeneity was considered, confirming the importance of correctly handling potential endogeneity issues. Based on endogeneity tests, we used endogenous models to interpret the empirical results.

The sign of the IQI variable is negative for all estimates. On average, firms operating in a more favorable institutional environment achieve higher performance. This finding confirms

TABLE 7 Testing for U-shaped relation—Translog production function using current IV.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Determinants in the variance of inefficiency						
IQI	−1.518***					
	(0.428)					
IQI_SQ	0.559					
	(0.390)					
CONTROL_CORRUPTION		0.992***				
		(0.276)				
CONTROL_CORRUPTION_SQ		−1.704***				
		(0.243)				
GOVERNMENT EFFECTIVENESS			0.797*			
			(0.432)			
GOVERNMENT EFFECTIVENESS_SQ			−1.082**			
			(0.474)			
VOICE & ACCOUNTABILITY				−3.570***		
				(0.270)		
VOICE & ACCOUNTABILITY_SQ				0.085		
				(0.238)		
RULE OF LAW					−2.008***	
					(0.382)	
RULE OF LAW_SQ					1.068***	
					(0.340)	
REGULATORY QUALITY						−2.823***
						(0.275)
REGULATORY QUALITY_SQ						0.105
						(0.236)
eta (endogenous variables)	−0.672**	0.630**	0.548**	−1.695***	−1.433***	−1.861***
	(0.299)	(0.237)	(0.264)	(0.143)	(0.279)	(0.190)
IV (first stage estimates)						
CHEATING_INDEX	−0.233***	−0.009***	−0.046***	0.025***	−0.042***	−0.073***
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Eta endogeneity test						
$chi^2(1)$	6.66	12.17	4.32	26.37	141.03	95.69
p-value	0.0358	0.0005	0.0377	0.0000	0.0000	0.0000
Production function (Translog)						
Constant (β_0)	6.039***	6.027***	6.063***	6.003***	6.019***	5.986***
	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)	(0.072)
L (ln)	0.674***	0.671***	0.662***	0.676***	0.684***	0.684***
	(0.043)	(0.042)	(0.043)	(0.043)	(0.043)	(0.043)

(Continues)

TABLE 7 (Continued)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
K (ln)	0.125***	0.124***	0.128***	0.130***	0.122***	0.128***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
L (ln) square	0.001	0.000	0.001	0.001	−0.001	0.004
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
K (ln) square	0.025***	0.025***	0.024***	0.025***	0.026***	0.027***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
L (ln) * K(ln)	−0.008*	−0.007	−0.007	−0.009**	−0.008*	−0.011**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Control for firm class dimension	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	Yes	Yes	Yes	Yes	Yes	Yes
Mean efficiency	0.4098	0.4101	0.4088	0.4067	0.4099	0.4073
Observations	37,149	37,149	37,149	37,149	37,149	37,149

Note: This table reports the estimates of the endogenous SFA applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). To control for endogeneity issue, we use our current IV, the cheating index namely. If the endogeneity ETA test is not satisfied at 5% level, the table shows the estimates considering the environmental variable as exogenous. Standard errors in parentheses.
Source: Authors' elaborations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

the role of the local institutional setup, or, more broadly, of governments, in creating advantageous conditions for firms to operate efficiently.

Tables 5 and 6 show that other institutional quality factors, such as the control of corruption and the rule of law, have a substantial effect on firm performance. Thus, having a more favorable environment in terms of the efficiency of the judiciary system (rule of law) and lower levels of corruption and offenses against public administration moves firms closer to the production frontier (control of corruption). In other words, firms operating in provinces with higher institutional quality are more efficient, being in a favorable environment, regardless of adopting an exogenous or endogenous model and the chosen IV.[15]

Columns 7–12 of Tables 5 and 6 show that the inclusion of other controls that may influence firm inefficiency, such as time and firm-size fixed effects, do not significantly change the overall picture.

5.2 | Robustness checks

The results reported in the previous section are robust and generally in line with the related literature. The results support the "sand the wheels" versus the "grease the wheels" hypothesis on the effects of corruption (Méon & Weill, 2010).

[15]In assessing the impact of determinants on efficiency in the estimated SFA models, a negative (positive) coefficient has a positive (negative) effect on technical efficiency (Battese & Coelli, 1995).

TABLE 8 Testing for U-shaped relation—Translog production function using historical IV.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Determinants in the variance of inefficiency						
IQI	−0.864***					
	(0.249)					
IQI_SQ	0.050					
	(0.223)					
CONTROL_CORRUPTION		1.973***				
		(0.374)				
CONTROL_CORRUPTION_SQ		−3.249***				
		(0.326)				
GOVERNMENT EFFECTIVENESS			0.638			
			(0.427)			
GOVERNMENT EFFECTIVENESS_SQ			−0.913*			
			(0.470)			
VOICE & ACCOUNTABILITY				−0.580		
				(0.404)		
VOICE & ACCOUNTABILITY_SQ				−0.163		
				(0.362)		
RULE OF LAW					−2.970***	
					(0.266)	
RULE OF LAW_SQ					2.365***	
					(0.236)	
REGULATORY QUALITY						−2.306***
						(0.269)
REGULATORY QUALITY_SQ						0.053
						(0.230)
eta (endogenous variables)	−0.407	1.313***	1.281***	0.182	−0.108**	−1.463***
	(0.286)	(0.179)	(0.136)	(0.270)	(0.047)	(0.188)
IV (first stage estimates)						
SIGNORIE	0.004***	0.002**	0.020***	−0.011***	−0.009***	0.041***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
PAPAL_STATE	0.017***	0.039***	0.002***	0.002*	−0.006***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
KINGDOM_SICILY	−0.053***	0.079***	0.002**	−0.105***	−0.065***	0.049***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
PERIPHERAL_AREAS	0.002***	−0.013***	0.002**	−0.013***	−0.031***	0.030***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Eta endogeneity test						
$chi^2(1)$	2.03	53.78	2.78	3.06	60.30	88.13

(Continues)

TABLE 8 (Continued)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
p-Value	*0.154*	*0.0000*	*0.0955*	*0.0892*	*0.0000*	*0.0000*
Production function (Translog)						
Constant (β_0)	6.046***	6.028***	6.062***	6.026***	6.044***	6.010***
	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)
L (ln)	0.670***	0.673***	0.663***	0.672***	0.674***	0.680***
	(0.043)	(0.042)	(0.043)	(0.043)	(0.043)	(0.043)
K (ln)	0.123***	0.120***	0.128***	0.128***	0.121***	0.126***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
L (ln) square	0.000	−0.000	0.001	−0.000	−0.001	0.003
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
K (ln) square	0.025***	0.026***	0.024***	0.025***	0.026***	0.027***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
L (ln) * K(ln)	−0.007	−0.008*	−0.007	−0.008*	−0.007	−0.010**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Control for firm class dimension	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	Yes	Yes	Yes	Yes	Yes	Yes
Mean efficiency	0.4097	0.4093	0.4081	0.4112	0.4066	0.4070
Observations	37,149	37,149	37,149	37,149	37,149	37,149

Note: This table reports the estimates of the endogenous SFA applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). To control for endogeneity issue, we use our historical IV, the kind of government ruling in Italy at the beginning of 14th century at the provincial level and provided by De Blasio and Nuzzo (2010). If the endogeneity ETA test is not satisfied at 5% level, the table shows the estimates considering the environmental variable as exogenous. Standard errors in parentheses.
Source: Authors' elaborations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Here we run further robustness checks to test whether the relationship between institutional quality and its pillars and firm efficiency is linear or U-shaped. We add a quadratic term to each of the indices to capture the non-linearities of the effect of institutional quality on performance. Tables 7 and 8 report the estimates obtained using the cheating index at provincial level (Finocchiaro Castro & Guccio, 2020; Guiso et al., 2016) and the type of government that ruled in Italy at the beginning of the 14th century at provincial level (De Blasio & Nuzzo, 2010) as IVs, respectively. In both tables we use time and firm size fixed effects. Finally, if the endogeneity test fails at the 5% level, the tables display the estimates obtained assuming the environmental variable as exogenous.[16]

The results show no evidence of non-linear relationship between firm efficiency and institutional quality, strongly confirming previous findings. However, the picture changes significantly when we repeat the exercise for each IQI pillars separately.

[16]Full estimates are available from the authors on request.

TABLE 9 Estimates for the subsample of firms in the Centre-South of the country.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Determinants in the variance of inefficiency						
IQI	−0.493***					
	(0.176)					
CONTROL_CORRUPTION		−2.705***				
		(0.457)				
GOVERNMENT EFFECTIVENESS			−0.980***			
			(0.176)			
VOICE & ACCOUNTABILITY				−0.441***		
				(0.149)		
RULE OF LAW					−1.945***	
					(0.181)	
REGULATORY QUALITY						−1.035***
						(0.137)
eta (endogenous variables)	*−0.214*	*−2.096****	*−0.748****	*−0.796****	*−1.165****	*−0.415****
	(0.200)	(0.232)	(0.094)	(0.077)	(0.097)	(0.089)
IV (first stage estimates)						
CHEATING_INDEX	−0.205***	−0.234***	−0.222***	−0.284***	−0.262***	−0.301***
	(0.005)	(0.004)	(0.007)	(0.009)	(0.006)	(0.008)
Eta endogeneity test						
$chi^2(1)$	1.14	81.79	63.75	21.70	143.75	107.42
p-value	*0.2855*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
Production function (Translog)						
Constant (β_0)	6.449***	6.456***	6.515***	6.404***	6.481***	6.435***
	(0.108)	(0.109)	(0.109)	(0.108)	(0.109)	(0.108)
L (ln)	0.487***	0.480***	0.458***	0.488***	0.471***	0.496***
	(0.067)	(0.068)	(0.068)	(0.068)	(0.069)	(0.067)
K (ln)	0.132***	0.116***	0.126***	0.127***	0.116***	0.131***
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
L (ln) square	0.077***	0.086***	0.082***	0.094***	0.099***	0.079***
	(0.024)	(0.024)	(0.024)	(0.024)	(0.025)	(0.024)
K (ln) square	0.022***	0.028***	0.021***	0.028***	0.030***	0.024***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
L (ln) * K(ln)	−0.006	−0.011*	−0.003	−0.013**	−0.015**	−0.008
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Control for firm class dimension	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	Yes	Yes	Yes	Yes	Yes	Yes

(Continues)

TABLE 9 (Continued)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Mean efficiency	0.3892	0.3886	0.3936	0.3888	0.4001	0.3971
Observations	19,315	19,315	19,315	19,315	19,315	19,315

Note: This table reports the estimates of the endogenous SFA for the subsample of firms located in the Centre-South part of the country applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). To control for endogeneity issue, we use the cheating index at the provincial level. If the endogeneity ETA test is not satisfied at 5% level, the table shows the estimates considering the environmental variable as exogenous. Standard errors in parentheses.
Source: Authors' elaborations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Estimates show evidence that corruption control and rule of law have a nonlinear impact on the efficiency of firms. Indeed, the coefficient of the corruption control index turns positive while the square is negative, and both are highly significant. Thus, very low level of corruption tolerance can have a positive effect on firm efficiency but excessive laxity in corruption control has a strongly negative impact on efficiency. In the case of rule of law index, the result is reversed. The explanation could be that very high levels of compliance to the rule of law leads to an increase in bureaucratic costs, lowering firm efficiency. Looking at the other pillars, our results do not provide clear evidence of U-shaped effects on firm efficiency.

Finally, it could be argued that given that our results may be due to the well-known productivity gaps between the North and the Centre-South of Italy.

Figure 2 shows the estimates of the average (unconditional) technical efficiency of the firms in our sample at both the regional and provincial levels.

As a further robustness check, we re-run our estimates on two sub-samples of firms in the building sector that are located respectively in the North and in the Centre-South of the country. However, the historical IV considering the type of government at the beginning of the 14th century in Italy by De Blasio and Nuzzo (2010) has a very limited variability in the two macro-areas (in particular in the Centre-South). Hence, it cannot be used in the sub-samples. In these estimates, we employ as IV the cheating index only (Finocchiaro Castro & Guccio, 2020; Guiso et al., 2016). The results are shown in Tables 9 and 10 for the Central South sub-sample and the North sub-sample of firms, respectively.[17]

As might be expected, the two subsamples show quite different average efficiency levels. The sample of firms in the North has an efficiency level of around 0.45, whereas those in the Centre-South shows an average efficiency of 0.39, confirming the assumption that the productivity gap between firms in different areas in Italy is relevant. Overall, the sign of the impact of institutional quality and its pillars identified by previous estimates is confirmed. However, the impact is significantly different in the two macro areas. In general terms, the sign of the impact of institutional quality and its pillars on the performance of firms in the building sector reported by previous estimates is confirmed. However, the magnitude of the impact appears significantly different in the two macro areas. It is confirmed that the rule of law and control of corruption are the most relevant factors in determining firm efficiency. However, the effect of those factors is noticeably more relevant for firms located in the South-Central part of the country. In particular, the impact of the control of corruption index is more than five times for firms in the South

[17]The descriptive statistics of the two subsamples of firms are presented in Table A.4 in the Appendix .

TABLE 10 Robustness checks for the subsample of firms in the North of the country.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Determinants in the variance of inefficiency						
IQI	−0.513***					
	(0.119)					
CONTROL_CORRUPTION		−0.622***				
		(0.130)				
GOVERNMENT EFFECTIVENESS			−0.547***			
			(0.163)			
VOICE & ACCOUNTABILITY				−0.530***		
				(0.128)		
RULE OF LAW					−1.012***	
					(0.161)	
REGULATORY QUALITY						−0.330***
						(0.089)
eta (endogenous variables)	*−0.023*	*−0.315****	*−0.373****	*−0.162***	*−0.471****	*−0.118*
	(0.091)	(0.075)	(0.076)	(0.064)	(0.090)	(0.076)
IV (first stage estimates)						
CHEATING_INDEX	−0.189***	−0.177***	−0.085***	−0.190***	−0.142***	−0.158***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Eta endogeneity test						
$chi^2(1)$	0.06	17.62	24.40	6.33	27.11	3.23
p-Value	*0.7993*	0.0000	0.0000	0.0119	0.0000	0.0723
Production function (Translog)						
Constant (β_0)	5.599***	5.571***	5.625***	5.590***	5.575***	5.590***
	(0.100)	(0.100)	(0.100)	(0.100)	(0.100)	(0.100)
L (ln)	0.800***	0.806***	0.781***	0.796***	0.810***	0.801***
	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)
K (ln)	0.129***	0.136***	0.129***	0.131***	0.132***	0.133***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
L (ln) square	−0.048**	−0.047**	−0.045**	−0.048**	−0.049**	−0.047**
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
K (ln) square	0.021***	0.020***	0.020***	0.020***	0.020***	0.021***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
L (ln) * K(ln)	−0.009	−0.010	−0.008	−0.009	−0.010	−0.010
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Control for firm class dimension	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	Yes	Yes	Yes	Yes	Yes	Yes

(Continues)

TABLE 10 (Continued)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Mean efficiency	0.4595	0.4572	0.4587	0.4577	0.4570	0.4584
Observations	17,834	17,834	17,834	17,834	17,834	17,834

Note: This table reports the estimates of the endogenous SFA for the subsample of firms located in the North part of the country applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). To control for endogeneity issue, we use the cheating index at the provincial level. If the endogeneity ETA test is not satisfied at 5% level, the table shows the estimates considering the environmental variable as exogenous. Standard errors in parentheses.
Source: Authors' elaborations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Central than for those located in the North of Italy. Confirming that weak anti-corruption efforts can have a serious impact on business efficiency, especially in the construction sector. Effective anti-corruption measures in this sector are crucial to the creation of a fair and efficient business environment, especially where economic systems are weak.

6 | CONCLUSIONS

Although institutions shape individual incentives and are crucial for economic growth and development, few studies investigated the impact of institutional quality on firm efficiency, with special emphasis on the role of corruption as a major driver of firms' activities. Indeed, corruption can significantly disrupt the level playing field of businesses, favoring those engaging in corrupt practices over innovative, productive, and quality-driven competitors. Despite extensive research on the impact of corruption on entrepreneurship, growth, and innovation (e.g., Anokhin & Schulze, 2009; De Waldemar, 2012; Dincer, 2019; Paunov, 2016), limited empirical investigations on the relationship between corruption and firm efficiency exist.

Our work contributes to the literature on the role of local institutional quality, with a special focus on corruption control (Aldieri, Makkonen, et al., 2020; Aldieri, Kotsemir, et al., 2020; Castiglione et al., 2018; Lasagni et al., 2015; Sun et al., 2019; Zallé, 2019). The relationship between institutional quality and corruption is intricate and multifaceted. Higher institutional quality is often associated with lower levels of corruption. Strong institutions, characterized by transparency, accountability, and the rule of law, create an environment that discourages corrupt practices. When institutions are robust, mechanisms are in place to detect, prevent, and punish corrupt behavior, thereby reducing the incentives for individuals to engage in corruption. Conversely, poor institutional quality can foster corruption. However, the relationship between institutional quality and corruption is nonunidirectional. Corruption can undermine institutional quality by eroding public trust, distorting decision-making processes, and diverting resources from public services to development initiatives. This can perpetuate a cycle of poor institutional quality and corruption.

Hence, we assessed the causal relationship between institutional quality of Italian provinces, with special attention paid to the role of corruption control, one of its pillars, and the technical efficiency of firms in the building sector. Our results indicate that local institutional quality factors significantly affect firm performance. As pointed out by an anonymous reviewer, we acknowledge that it would have been worth to run the same empirical analysis on a sector which is not permeable corruptive factors in Italy, hoping for null effects. Doing so, it would have increased the robustness of our findings. Unfortunately, it is very unlikely to find a sector with that characteristic. As pointed out, the empirical challenge to be addressed in determining causality in this line of inquiry is the possible endogenous nature of institutional quality and firms' technical efficiency. To the best of our knowledge, this is the first study to assess endogeneity issues in determining the role of institutional quality pillars in firm performance. However, improper endogeneity controls cause a downward estimation of the role of local institutional quality in firm performance. Finally, among the five pillars on which the institutional quality index is based, the rule of law and control of corruption are the most relevant in determining firm efficiency.

Our findings provide relevant insights for policymakers. First, there is a need to invest in more advanced tools to increase corruption control to create and maintain a favorable environment for firms' growth and innovation. Our findings provide evidence that the impact of these factors is higher in the case of firms located in the South-Central part of Italy than in the case of firms located in the North of the country. Second, as the rule of law (together with the control of corruption), the most relevant pillar of the institutional quality index to affect firm performance, it is urgent to increase the efficiency of the judiciary system, reduce the time to resolve lawsuits, and increase the number and staff of special sections devoted to firms' issues.

Although our empirical findings are robust to several checks, some points may be interesting to assess. The most relevant being that whereas the main objective of this study is to assess the impact of environmental factors on firm performance assuming the presence of potential endogeneity, one could argue that the production process itself can also be a source of endogeneity. Thus, further research should robustly identify the overall effects of environmental factors on firm performance while also considering other sources of endogeneity in stochastic frontier estimates. Finally, further efforts should be devoted to the comparative analyses of other production sectors or countries and to extend the empirical analysis including spatial interaction effects (Kutlu et al., 2020).

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APPENDIX A

TABLE A.1 Baseline estimates with exogenous determinants of inefficiency—Cobb–Douglas production function.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Determinants in the variance of inefficiency												
IQI	−0.7004***						−0.7967***					
	(0.0737)						(0.0756)					
CONTROL_CORRUPTION		−0.4893***						−0.6765***				
		(0.0834)						(0.0872)				
GOVERNMENT EFFECTIVENESS			0.0368						−0.1724**			
			(0.0694)						(0.0739)			
VOICE & ACCOUNTABILITY				−0.2305***						−0.3416***		
				(0.0553)						(0.0562)		
RULE OF LAW					−0.7446***						−0.7013***	
					(0.0715)						(0.0742)	
REGULATORY QUALITY						−0.2274***						−0.4354***
						(0.0513)						(0.0559)
Production function (Cobb-Douglas)												
Constant (β_0)	5.8632***	5.8780***	5.8942***	5.8831***	5.8700***	5.8817***	5.9053***	5.9077***	5.9271***	5.9200***	5.9057***	5.9117***
	(0.0284)	(0.0285)	(0.0286)	(0.0285)	(0.0284)	(0.0285)	(0.0364)	(0.0365)	(0.0365)	(0.0364)	(0.0364)	(0.0365)
L (ln)	0.6889***	0.6858***	0.6826***	0.6848***	0.6885***	0.6847***	0.6522***	0.6491***	0.6469***	0.6482***	0.6516***	0.6488***
	(0.0084)	(0.0084)	(0.0084)	(0.0084)	(0.0084)	(0.0084)	(0.0143)	(0.0143)	(0.0143)	(0.0143)	(0.0143)	(0.0143)
K (ln)	0.2171***	0.2180***	0.2183***	0.2178***	0.2167***	0.2180***	0.2114***	0.2124***	0.2128***	0.2120***	0.2116***	0.2122***
	(0.0045)	(0.0045)	(0.0046)	(0.0045)	(0.0045)	(0.0045)	(0.0045)	(0.0046)	(0.0046)	(0.0046)	(0.0046)	(0.0046)
Control for firm class dimension	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Mean efficiency	0.4201	0.4109	0.4192	0.4202	0.4190	0.4200	0.4173	0.4201	0.4177	0.4199	0.4182	0.4209
Observations	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149

Note: This table reports the estimates of the exogenous SFA applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). All estimates considering the environmental variable as endogenous. Standard errors in parentheses.
Source: Authors' elaborations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

TABLE A.2 Endogenous SFA estimates—Cobb–Douglas production function using current IV.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Determinants in the variance of inefficiency												
IQI	*−0.9278****						*−0.8935****					
	(0.0909)						*(0.0905)*					
CONTROL_CORRUPTION		*−1.2113****						*−1.2311****				
		(0.0994)						*(0.1013)*				
GOVERNMENT EFFECTIVENESS			*0.2361***						*0.1790*			
			(0.1105)						*(0.1095)*			
VOICE & ACCOUNTABILITY				*−0.1001*						*0.0911*		
				(0.0784)						*(0.1003)*		
RULE OF LAW					*−1.3817****						*−1.3201****	
					(0.0898)						*(0.0899)*	
REGULATORY QUALITY						*−0.3965****						*−0.4239****
						(0.0782)						*(0.0801)*
eta (endogenous variables)	*−0.3320****	*−0.9905****	*0.1493***	*0.1106***	*−0.6701****	*−0.1358****	*−0.1572***	*−0.8177****	*0.2817****	*0.2817****	*−0.7200****	*−0.3320****
	(0.0769)	*(0.0807)*	*(0.0639)*	*(0.0471)*	*(0.0564)*	*(0.0371)*	*(0.0801)*	*(0.0827)*	*(0.0639)*	*(0.0639)*	*(0.0577)*	*(0.0769)*
IV (first stage estimates)												
CHEATING_INDEX	−0.2211***	−0.1812***	−0.0944***	−0.1729***	−0.1920***	−0.1848***	−0.2210***	−0.1811***	−0.0941***	−0.0941***	−0.1921***	−0.1845***
	(0.0007)	(0.0009)	(0.0009)	(0.0010)	(0.0009)	(0.0009)	(0.0007)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Eta endogeneity test												
$chi^2(1)$	5.45	18.65	5.50	3.85	141.11	150.72	3.85	22.83	7.13	0.04	155.59	8.93
p-Value	*0.0195*	*0.0000*	*0.0190*	*0.0497*	*0.0000*	*0.0000*	*0.0497*	*0.0000*	*0.0076*	*0.8417*	*0.0000*	*0.0028*
Production function (Cobb-Douglas)												
Constant (β_0)	5.8696***	5.8612***	5.8943***	5.8800***	5.8676***	5.8854***	5.9074***	5.8723***	5.9289***	5.9289***	5.9116***	5.9116***
	(0.0284)	(0.0282)	(0.0286)	(0.0285)	(0.0282)	(0.0286)	(0.0364)	(0.0366)	(0.0366)	(0.0366)	(0.0365)	(0.0365)
L (ln)	0.6906***	0.6913***	0.6821***	0.6851***	0.6975***	0.6848***	0.6531***	0.6585***	0.6463***	0.6463***	0.6488***	0.6488***
	(0.0084)	(0.0085)	(0.0084)	(0.0084)	(0.0085)	(0.0084)	(0.0143)	(0.0145)	(0.0143)	(0.0143)	(0.0143)	(0.0143)
K (ln)	0.2162***	0.2174***	0.2180***	0.2178***	0.2117***	0.2177***	0.2111***	0.2123***	0.2120***	0.2120***	0.2122***	0.2122***
	(0.0045)	(0.0046)	(0.0046)	(0.0046)	(0.0046)	(0.0045)	(0.0046)	(0.0046)	(0.0046)	(0.0046)	(0.0046)	(0.0046)
Control for firm class dimension	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Control for year	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Mean efficiency	0.4072	0.4075	0.4101	0.4028	0.4055	0.4093	0.4031	0.4098	0.4051	0.4053	0.4089	0.4070
Observations	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149

Note: This table reports the estimates of the endogenous SFA applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). To control for endogeneity issue, we use our current IV, the cheating index namely. All estimates considering the environmental variable as endogenous. Standard errors in parentheses.
Source: Authors' elaborations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

TABLE A.3 Endogenous SFA estimates—Cobb–Douglas production function using historical IVa.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Determinants in the variance of inefficiency												
IQI	−1.0288***						−1.0068***					
	(0.0891)						(0.0892)					
CONTROL_CORRUPTION		−1.2075***						−1.2106***				
		(0.0981)						(0.0994)				
GOVERNMENT EFFECTIVENESS			−0.0261						−0.0573			
			(0.1107)						(0.1106)			
VOICE & ACCOUNTABILITY				−0.0670						−0.0601		
				(0.0768)						(0.1091)		
RULE OF LAW					−1.3942***						−1.3354***	
					(0.0878)						(0.0881)	
REGULATORY QUALITY						−0.4404***						−0.4610***
						(0.0786)						(0.0799)
eta (endogenous variables)	*−0.4556****	*−1.0523****	*−0.0496*	*0.0440*	*−0.6471****	−0.1717***	*−0.3227****	*−0.8538****	*0.0911*	0.0975	*−0.6882****	−0.4225***
	(0.0704)	*(0.0852)*	*(0.0681)*	*(0.0469)*	*(0.0523)*	(0.0371)	*(0.0733)*	*(0.0867)*	*(0.0690)*	(0.0693)	*(0.0533)*	(0.0769)
IV (first stage estimates)												
SIGNORIE	0.0196***	−0.0069***	−0.0479***	−0.0234***	0.0526***	0.0964***	0.0196***	−0.0070***	−0.0479***	−0.0479***	0.0526***	0.0963***
	(0.0019)	(0.0022)	(0.0022)	(0.0023)	(0.0025)	(0.0024)	(0.0019)	(0.0022)	(0.0022)	(0.0022)	(0.0025)	(0.0023)
PAPAL_STATE	−0.1370***	−0.0624***	−0.1041***	0.0014	−0.1718***	0.0040	−0.1367***	−0.0621***	−0.1037***	−0.1037***	−0.1718***	0.0045*
	(0.0023)	(0.0026)	(0.0026)	(0.0027)	(0.0030)	(0.0028)	(0.0023)	(0.0026)	(0.0026)	(0.0026)	(0.0030)	(0.0027)
KINGDOM_SICILY	−0.4444***	−0.3852***	−0.2556***	−0.3768***	−0.3297***	−0.3182***	−0.4440***	−0.3850***	−0.2550***	−0.2550***	−0.3298***	−0.3176***
	(0.0020)	(0.0023)	(0.0023)	(0.0024)	(0.0026)	(0.0024)	(0.0020)	(0.0022)	(0.0022)	(0.0022)	(0.0026)	(0.0023)
PERIPHERAL_AREAS	−0.0855***	0.0139***	−0.2405***	0.0195***	0.0229***	0.0580***	−0.0854***	0.0140***	−0.2403***	−0.2403***	0.0229***	0.0582***
	(0.0027)	(0.0030)	(0.0030)	(0.0032)	(0.0035)	(0.0032)	(0.0026)	(0.0030)	(0.0030)	(0.0030)	(0.0034)	(0.0031)
Eta endogeneity test												
$chi^2(1)$	41.84	152.54	0.53	9.41	152.79	12.82	19.38	97.00	1.98	0.20	166.59	2.98
p-Value	*0.0000*	*0.0000*	*0.4665*	*0.0022*	*0.0000*	*0.0003*	*0.0000*	*0.0000*	*0.1595*	0.6544	*0.0000*	*0.1005*
Production function (Cobb-Douglas)												
Constant (β_0)	5.8743***	5.8637***	5.8948***	5.8778***	5.8680***	5.8858***	5.9136***	5.8806***	5.9262***	5.9262***	5.9099***	5.9120***
	(0.0285)	(0.0284)	(0.0286)	(0.0285)	(0.0283)	(0.0286)	(0.0365)	(0.0366)	(0.0365)	(0.0365)	(0.0367)	(0.0365)

(Continues)

TABLE A.3 (Continued)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
L (ln)	0.6918***	0.6928***	0.6826***	0.6851***	0.6988***	0.6851***	0.6536***	0.6570***	0.6469***	0.6469***	0.6587***	0.6489***
	(0.0084)	(0.0085)	(0.0084)	(0.0084)	(0.0085)	(0.0084)	(0.0143)	(0.0145)	(0.0143)	(0.0143)	(0.0145)	(0.0143)
K (ln)	0.2150***	0.2162***	0.2183***	0.2179***	0.2110***	0.2176***	0.2101***	0.2113***	0.2127***	0.2127***	0.2055***	0.2122***
	(0.0045)	(0.0046)	(0.0046)	(0.0046)	(0.0046)	(0.0045)	(0.0046)	(0.0046)	(0.0046)	(0.0046)	(0.0046)	(0.0046)
Control for firm class dimension	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
Control for year	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
Mean efficiency	0.4086	0.4069	0.4095	0.4020	0.4061	0.4093	0.4044	0.4065	0.4083	0.4027	0.4075	0.4051
Observations	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149	37,149

Note: This table reports the estimates of the endogenous SFA applying the approach of Karakaplan and Kutlu (2017b) and using the Stata package "xtsfkk" developed by Karakaplan (2022). To control for endogeneity issue, we use our historical IV, the kind of government ruling in Italy at the beginning of 14th century at the provincial level and provided by De Blasio and Nuzzo (2010). All estimates considering the environmental variable as endogenous. Standard errors in parentheses.

Source: Authors' elaborations.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

TABLE A.4 Summary statistics for the subsample of firms in the building sector in different macro areas.

Variable	Obs.	Mean	Std. dev.	Min	Max
North of the country					
Y	17,834	9708.50	54,122.83	35.89	1,730,777.00
L	17,834	19.10	59.82	5.00	2759.00
C	17,834	2594.45	19,439.80	0.00	693,870.00
Centre-South of the country					
Y	19,315	6133.23	24,095.14	16.78	708,432.00
L	19,315	17.59	38.37	5.00	2788.00
C	19,315	1533.88	7077.58	0.00	232,282.00

Note: This table reports the descriptive statistics of the firms in the two subsample in the macro areas of the North and of the Centre-South of the country.
Source: Authors' elaborations.