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Working Paper

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Suggested Citation: Finocchiaro Castro ,Massimo; Guccio, Calogero (2023) : New wine in old bottle: Exploring the Corruption-inefficiency nexus using endogenous stochastic frontier approach, ZBW - Leibniz Information Centre for Economics, Kiel, Hamburg

This Version is available at:

<https://hdl.handle.net/10419/275730>

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New wine in old bottle: Exploring the Corruption-inefficiency nexus using endogenous stochastic frontier approach

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Abstract

A large body of literature has analyzed the relationship between factors affecting institutional quality at local level and the efficiency of firms with a particular focus on the role of corruption. However, due to reverse causality, the endogeneity problem makes it difficult to identify the real effect of institutional factors at local level on firms' efficiency. This paper adopts a novel stochastic frontier methodology to examine the relationship between the quality of local institutions and production efficiency, under the arrangement that endogeneity is well addressed. Specifically, we use a panel stochastic frontier analysis that endogenizes production efficiency and allows us to robustly assess the effect of corruption at local level on firms' technical efficiency. For this purpose, the paper employs a large panel of Italian firms operating in the building sector from 2013 to 2019. The empirical findings reported in the paper indicate that the factor affecting the quality of local institutions affect firms' performance, with a preeminent role played by the rule of law and the control of corruption. Moreover, when controlling for endogeneity, the magnitude of the effects of institutional quality factors at local level increase significantly. Our findings are robust to alternative IV strategies, alternative specifications of the production function, and inclusion of other factors that may affect firms' efficiency.

Keywords: Corruption; Firms; Production efficiency; Stochastic frontier analysis; Endogeneity

JEL: D24; D73; L25; C23; C26.

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1. Introduction

Corruption is a pervasive problem in many countries, and it has been linked to numerous negative economic outcomes, including decreased investment, reduced economic growth (Mauro, 1995; Lambsdorff, 2003; Pellegrini and Gerlagh, 2004), low level of international and domestic trade (Wei, 2000; Wanchek, 2009, Emenalo et al., 2018), and increased income inequality (Gupta et al, 2002; Dincer and Gunalp, 2012). At the same time, other scholars have supported 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; Zergawu et al., 2020; Saha and Sen, 2021). These mixed insights have originated a large body of empirical literature supporting the two opposite views. Whereas Méon and Sekkat (2005), Johnson et al. (2011) and, Zelekha and Sharabi (2012) support the “sand the wheels” hypothesis, other papers such Méndez and Sepúlveda (2006) and Méon and Weil (2010) find evidence in favor of the “grease the wheels” hypothesis.

Within this literature, one area that has surprisingly received less attention from researchers is the relationship between corruption and the efficiency of firms. Indeed, corruption can have a significant impact on the efficiency of firms by creating an uneven playing field for businesses. When corruption is rampant, businesses that engage in corrupt practices can gain an unfair advantage over their competitors. This creates a situation where inefficient and unproductive firms are more likely to succeed than those that invest in innovation, productivity, and quality. Corruption can also increase the transaction costs of doing business. Bribery, for instance, can lead to inflated costs of raw materials, permits, and licenses, which ultimately increase the cost of production. This, in turn, can reduce the profitability of firms 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 the efficient functioning of markets (Zergawu et al., 2020). When businesses cannot rely on the legal system to enforce contracts and protect their property rights, they may be less likely to invest in innovation and expansion. This is because they are uncertain

about the security of their investments and may lack the confidence to take risks. On the other hand, some scholars argue that corruption can have positive effects on the efficiency of firms. For instance, in some countries, bribery can be used to expedite bureaucratic processes and reduce red tape (De Rosa et al., 2010; Goedhuys et al., 2016; Pluskota, 2020). This can help firms to operate more efficiently and effectively. However, the overall impact of corruption on the efficiency of firms seems to be negative.

Empirical research has provided support for the relationship between corruption and the efficiency of firms. For example, a pioneer study by Fisman and Svensson (2007) found that firms in countries with higher levels of corruption faced more significant delays in obtaining necessary permits, leading to reduced efficiency of the firms. Another study by Aidt and Dutta (2008) found that corruption was associated with reduced investment and lower productivity in the manufacturing sector. Similarly, Tanzi and Davoodi (1998) found that corruption had a negative impact on the efficiency of public firms in developing countries.

While the impact of corruption on entrepreneurship, growth and innovation of the firms has been extensively studied (e.g., Anokhin & Schulze, 2009; De Waldemar, 2012; Paunov, 2016; Dincer, 2019), less attention has been devoted to assessing the relationship between corruption and firms' efficiency. The economic literature suggests that corruption hampers firms' efficiency by changing management incentives towards factor coordination and by acting like an extortionary tax on firms.

Our work also relates to the analysis of the relationship between firms' inefficiency and institutional quality. Since the seminal work by North (1990), the impact of institutions on economic development at macro level has been widely investigated. Institutions can indeed matter for business, and the interest in the institutional perspective on firms' efficiency assessment has increased over time (Lasagni et al., 2015). Although some studies have shown that higher institutional quality leads to higher firm efficiency (Castiglione et al., 2018; Sun et al., 2019; Zallé, 2019; Aldieri et al., 2020a; Aldieri et al., 2020b), little is known about the impact of corruption on firm efficiency. Only a few studies, such as those by Dal Bó and Rossi (2007),

Sharma and Mitra (2015) and Aldieri et al. (2022) have demonstrated that increased corruption is detrimental to firms' technical efficiency.

The above-mentioned stream of research poses a big challenge to researchers when they attempt at determining causality because of the possible endogenous nature of corruption and firms' technical efficiency. Endogeneity may arise because government's ability in curbing corruption and firm efficiency can be determined simultaneously. More specifically, the main concern in assessing the relationship between measures of control of corruption and firm efficiency stems from the potential endogeneity inherent in the relationship, determined by reverse causality dynamics. Indeed, a reasonable hypothesis is that higher levels of control of corruption have an impact on firm efficiency. However, variations in firm efficiency may affect the government's ability to reduce corruption. Under the same logic, the challenge of reverse causality arises from the mutual influence between the quality of institutions and economic growth (Mauro, 1995). Consequently, this justifies the adoption of an econometric methodology that can address endogeneity issues (Aldieri et al., 2022).

Several cited 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 the issue of endogenous explanatory variables (e.g., control of corruption), and could lead to considerable bias in both parameter and efficiency estimates (Kutlu and Tran, 2019).

In this paper, we contribute to this strand of literature by using a newly developed SFA approach (Karakaplan and Kutlu, 2017a) to evaluate the impact of institutional quality and environmental corruption on firms' technical efficiency. More relevantly, the proposed novel approach allows to address endogeneity in a single-stage estimation process for stochastic frontier models, thereby enabling an unbiased appraisal of environmental variables in efficiency analysis (Kutlu and Tran, 2019). Due to the historical socioeconomic gap between northern and southern areas, Italy is an ideal case study to explore the potential link between institutional quality, corruption, and the performance of the firms. For this purpose, the paper employs a large panel of Italian firms operating in the building sector

during the period from 2013 to 2019. To empirically assess the effects of institutional quality on firms' inefficiency we rely on data on the institutional quality index (IQI) at provincial level, sourced from the Nifo and Vecchione (2014) database. The IQI encompasses five pillars of institutional quality, namely control of corruption, government effectiveness, rule of law, regulatory quality and voice and accountability.

Our results, which are robust to alternative specifications of the production function and different IV strategies suggest that increased institutional quality significantly reduces firms' inefficiency, with a preeminent role played by the rule of law and the control of corruption. However, not properly controlling for endogeneity cause a downward estimation of the role of local institutional quality on the performance of the firms.

Our research contributes to the literature in several ways. First, a key contribution of this paper is to 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. Indeed, to the best of our knowledge, our paper is the first one to examine, in a robust way, that relationship providing a sounding econometric lens to re-examine the impact of institutional quality, and in particular the control of corruption, at local level on firms' performance.

Second, to assess firms' performance, we have investigated a remarkably large sample of Italian firms in the building sector over the time span from 2013 to 2019. Firms in this sector have been little investigated in the literature, and our work is one of the first to assess their performance. Indeed, the building sector in Italy has features that make it particularly useful for our purposes.

Finally, we use different IV strategies and a particularly conservative approach to evaluate the impact of institutional factors that allows us to develop a more comprehensive understanding of the determinants of inefficiency compared to standard SFA studies that overlook the role of these factors.

The remainder of the paper is organized as follows. Section 2 introduces the literature review. Section 3 presents the dataset, encompasses the methodology and the empirical approach used to evaluate technical efficiency. Section 4 focuses on the results and some conclusions are presented in Section 5.

2. Literature review

As already mentioned, overall, both theoretical and empirical evidence on the effect 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) has shown that the level of bribes represents the different opportunity costs of economic agents. In fact, more efficient firms can buy lower efficient red tape. As suggested by Leys (1965), in such context, bribes may represent a highly desired incentive for bureaucrats to speed up both decision-making phase and its realization. Bailey (1966) suggests that, especially in transition economies, the low average wage of civil servants in comparison with the private sector may make bribes look like monetary bonus to them. Under certain circumstances, economic agents may engage in a competitive auction to gain civil servants’ favor (Beck and Maher, 1986). More recently, Dzhumashev (2014) shows that the positive effects of corruption take place only if the government’s size exceeds the optimal level. Empirically, Méndez and Sepúlveda (2006) and Méon and Weil (2010) support 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). Also, bureaucrats have the incentives to create distortions in the economy to maintain the demand for their illegal services (Kurer, 1993). Trade (Wanchek, 2009), financial system (Emenalo et al., 2018) and growth (Pellegrini and Gerlagh, 2004) are negatively affected by corruption. Although corruption may resemble a competitive auction, it is very unlikely that the winner

is the most efficient one, rather the one ready to decrease goods quality once he receives the license (Méon and Sekkat, 2005). In such context, efficiency and growth decrease due to the negative effects of corruption on productivity and innovation (Salinas-Jiménez and Salinas-Jiménez, 2007) and on 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 firms’ performance is negatively affected by the level of corruption measured in the area where firms operate.

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

From an empirical perspective, some studies have investigated whether institutions being virtuous or debauched can affect firms’ performance (Soroush et al., 2021). For instance, the effects of institutions on investments paths in human and physical capitals (Ketterer and Rodriguez-Pose, 2011); the presence of well-developed institutions increase the efficiency of operation of commercial institutions (Lensing and Meesters, 2014). A different stream of research focuses on the effects of political institutions and social capital on firms’ performance, shaping the socioeconomic and business environments where agents and organizations operate (Di Guilmi et al., 2008; Sabatini 2008, Ganau and Rodriguez-Pose, 2023).

Finally, other scholars, employing different measures of institutional quality, have shown that institutional quality and efficiency of firms are positively correlated (Castiglione et al., 2018; Sun et al., 2019; Zallé, 2019; Aldieri et al., 2020a; Aldieri et al., 2020b). However, only Sharma and Mitra (2015) and Aldieri et al. (2022) have proved that increased corruption, as a stand-alone dimension of institutional quality, negatively affects technical efficiency of firms. Hence, this paper contributes to fill this gap in the literature suggesting that debauched institutions negatively affect firms’ performances.

The novelty of our contribution lays in controlling for endogeneity in the empirical assessment, keeping our estimates unbiased through the application of the technique developed by Karakaplan and Kutlu (2017a, 2017b) and Kutlu and Tran (2019). To the best of our knowledge, this is the first paper showing that, if endogeneity is not properly controlled for, the estimates of the effect of corruption on firms' performances are systematically biased. This result calls for a carefully consideration of anti-corruption policies.

3. Data and Methods

3.1 Data sample

To estimate the technical (in)efficiency, this paper employs a balanced panel of Italian firms operating in the building sector from 2013 to 2019. The data were collected from different sources. Information on output, inputs and other firm-level characteristics come from the AIDA dataset, which contains balance sheet information over the period 2013- 2019¹. An important advantage of the AIDA dataset is that it includes all industries operating in the legal market in Italy. We have extracted information on several variables including sales, the number of workers, and total tangible fixed assets. Also, we have retained information about firms' geographic localization and industry. For our analysis, among the sectors in AIDA database, we have chosen sector 4120: Residential and non-residential buildings general contractors (roughly corresponding to 1520, 1530, and 1540 code in US Standard Industrial Classification)². We have opted for sector 4120 because it is a traditional industrial sector that is quite permeable to corruptive factors in Italy (ANAC, 2019)³. Moreover, firms in residential and non-residential buildings sector employ a relative homogeneous production technology and have similar

¹ 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 among the other: year of incorporation, ownership, and number of employees.

² 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).

³ For the effects of corruption on the building sector in Italy, see among others: Finocchiaro Castro et al., (2014); Finocchiaro Castro et al., (2018); Guccio et al., (2019); Cavalieri et al., (2020).

characteristics across Italy (ANCE, 2022)⁴. Since sector 4120 is mainly formed by very small firms that often survive just few years and particularly prone to corruption and bankruptcy, we have decided to exclude those with less than 5 employees. Our approach is therefore deliberately conservative given that our sample relates to firms that have been present in the legal market for a relatively long time and whose size is not extremely small.⁵

After excluding firms with missing or incomplete information, we have obtained a balanced panel of 5,307 firms belonging to the residential and non-residential buildings sector over the period 2013 – 2019, counting of a total of 37,149 observations.⁶

Table 1 reports the distribution of firms' size in our sample by number of employees. It appears that most firms in our sample does not have more than 24 employees (86.3%)⁷.

<<Table 1 about here>>

As common in many empirical efficiency studies, we employ financial accounting data as a proxy for production in the sector⁸. More specifically, the variables employed to estimate the production frontier are the 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

⁴ The most recent estimates (ANCE, 2022) show that the whole set of firms operating in the Italian residential and non-residential buildings sector amounts to 108,000 units, with almost 60% of firms with one employee only.

⁵ In general terms, firms in our sample should be relatively less prone to the phenomena of irregular employment and shadow economy, which are often associated with corrupt phenomena. Indeed, the relationship between corruption and the shadow economy is still widely discussed in the literature (e.g., Dreher and Schneider, 2010; Dell'Anno and Teobaldelli, 2015). For a review, see (Dimant and Tosato, 2018)

⁶ 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 equal to 0.87. Thus, the sample turns out to be representative of the actual population of businesses in residential and non-residential buildings sector in Italy in terms of the geographical distribution of firms at the provincial level.

⁷ In the following analysis, we will employ several empirical strategies to ensure that our results do not depend on the different size of firms.

⁸ In the 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.

and intangible assets after depreciation, as input variables. All monetary aggregates are in thousands and deflated at 2015 Euros.

The environmental variables are normally considered exogenous in the sense that they influence the production process, but they are not either inputs or outputs. They, in fact, influence the efficiency with which inputs are turned into outputs. In the specific framework of SFA, a two-stage estimation approach is sometimes used. In 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, where the technical efficiency is regressed on a set of explanatory variables. This approach will, however, lead to inconsistent estimates. Indeed, it requires a first-stage assumption that the inefficiencies are independent and identically distributed (Wang and Schmidt, 2002; Kumbhakar and Lovell 2003)⁹.

Therefore, a large share of literature applies a single stage approach (Battese and Coelli 1995) where environmental factors are assumed to directly affect technical inefficiency. Notwithstanding this, several scholars focusing on the relationship between institutional quality and firms' efficiency have employed a two-stage SFA framework, introducing potential endogeneity bias (Méon and Weill, 2005; Dal Bó and Rossi, 2007; Sharma and Mitra, 2015; Castiglione et al., 2018; Aldieri et al., 2020a, 2020b). In fact, using a one-stage estimation of technical efficiency resulting from SFA avoids the biases present in two-stage SFA procedures (Wang and 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 and Schmidt, 2002).

Our paper takes a different approach, allowing for consistent estimates of efficiency scores in one stage SFA and, at the same time, controlling for potential endogeneity between environmental variables and technical efficiency. To do so, we assess the

⁹ Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) tackle this concern by introducing a single-stage Maximum Likelihood approach. Expanding on the work of Kumbhakar et al. (1991), Battese and Coelli (1995) present a refined model that accommodates for panel data.

impact of environmental factors on firms' technical efficiency using a newly developed panel SFA (Karakaplan and Kutlu, 2017a; Kutlu and Tran, 2019). Karakaplan and Kutlu (2017a) have introduced a novel method of handling endogeneity in a one-stage estimation approach for panel stochastic frontier models, enabling an unbiased assessment of environmental variables in the efficiency analysis.

To apply the above-mentioned technique, we need to identify the environmental variables and the instrumental variables to control for potential endogeneity.

As environmental variables, we have opted for the institutional quality index (IQI), sourced from the Nifo and Vecchione (2014) database. The IQI encompasses five groups of elementary indexes, voice and accountability, government effectiveness, regulatory quality, rule of law, and control of corruption, namely. 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 for its elementary indexes are taken from institutional sources, research institutes, and professional registers.

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

Thus, Figure 1 reports the average value of the IQI index for Italian provinces in 2013-2019. As expected, the IQI index confirms the North-South Italian divide, reporting higher levels of institutional quality in Northern provinces than in Southern ones. However, it must be recalled that the IQI index 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' participation level 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 economy openness, business environment, start-ups' lifecycle (mortality, registration, cessation). Rule of law mixes data on crime against persons or property, magistrate productivity, trial times, tax evasion, and shadow economy. Control over corruption measures public power's capacity to contrast corruption. It considers data on crime against the public administrations, the number of local administrations overruled by the central authorities, and the Golden and Picci (2005)'s index. Figure 2 shows the average levels of each IQI pillar in each Italian province. Also in this case, the results confirm that, in each pillar, the Northern provinces obtained higher levels than the Southern ones.

<<Figure 1 about here>>

<<Figure 2 about here>>

As we have pointed out, the empirical challenge to be addressed in determining causality is the possible endogenous nature of institutional quality - and its pillars - and technical efficiency of the firms. To address this issue, we use the approach proposed by Karakaplan and Kutlu, (2017a) that requires an instrumental variable strategy. Regarding the choice of instrumental variables, we have opted for two alternative variables, available at provincial level: one current and one historical. The former is the cheating index (Guiso et al., 2016; Finocchiaro Castro and Guccio, 2020), measuring the frequency of primary school teachers' cheating in a national mathematics exam taken by second and fifth grades pupils in Italy. The latter instrumental variable accounts for the kind of government ruling at the beginning of 14th century in Italy (De Blasio and Nuzzo, 2010). The historical IV investigates the role of history on 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). The rationale, from an historical perspective,

is that different levels of social capital today are ascribable to the systems of government ruling at the beginning of 14th century (Putnam, 1993; Acemoglu et al. 2001, 2008).

Figure 3 reports the average value of Cheating Index at provincial level. The figure shows that the highest index values can be observed in Southern Italian provinces. In other words, most of the primary school teachers' cheating behavior took place in the South of Italy. Finally, Figure 4 illustrates the localization of the different kind of government ruling in Italy at the beginning of 14th century provided by De Blasio and Nuzzo (2010). The historical presence of the Papal state and the Kingdom of Sicily in the South of Italy, according to some scholars, can be considered as the main cause of low level of social capital in those areas (Putnam, 1993; Acemoglu et al. 2001, 2008).

<<Figure 3 about here>>

<<Figure 4 about here>>

Table 2 reports the variables employed and their sources, whereas Table 3 reports variables descriptive statistics.

<<Table 2 about here>>

<<Table 3 about here>>

3.2 Methods

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 the random shocks that may impact the production frontier beyond producers' control. However, as Kumbhakar et al. (2014) point out, the SFA estimates of technical efficiency are often reliant on model specification, distributional assumptions, and the interpretation of inefficiency. Therefore, we consider several SFA panel data

models' specification to check the robustness of our results and to evaluate the implications due to the adoption of different SFA approaches.

Furthermore, as previously mentioned, we are particularly interested in the assessment of the role of corruption on technical efficiency. In general terms, this involves assessing how environmental factors may impact on firms' efficiency. Environmental variables are considered external factors that influence the production process without being inputs or outputs themselves. They affect the efficiency of converting inputs into outputs. In the context of SFA, a two-stage estimation approach is sometimes used, but it leads to inconsistent estimates. To address this, a single-stage approach is commonly applied, if environmental factors directly impact technical inefficiency. However, this introduces potential endogeneity issues between institutional quality and firm efficiency. This paper takes a different approach by using a one-stage estimation method, specifically panel SFA, which allows for consistent estimates of efficiency while controlling for endogeneity. This method, introduced by Karakaplan and Kutlu (2017a), enables an unbiased analysis of environmental variables in efficiency assessment.

More formally, in the context of production analysis, SFA models aim to quantify the gap between 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 for given inputs and technological conditions. Conventional SFA, as exemplified by works like Battese and Coelli (1992) and Battese (1995), assumes a composite error term that combines a two-sided error component, $v_{it} \sim N(0, \sigma_v^2)$, with the negative of a one-sided u_{it} (nonnegative) 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; higher values indicate lower levels of efficiency. Essentially, this one-sided error term gauges the degree to which observed output deviates from the optimal production levels.

Formally, the conventional panel data SFA production function takes the form¹⁰:

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

where $y_{it} \in \mathbb{R}_+$ is the logarithm of output of firm i at time t , $\mathbf{x}_{it} \in \mathbb{R}_+^p$ 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: $v_{it} \sim N(0, \sigma_v^2)$, while u_{it} follows to a half-normal distribution: $u_{it} \sim N^+(0, \sigma_u^2)$, 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 \mathbf{x}_{it} and that u_{it} and v_{it} are independent – in essence, the terms u_{it} and v_{it} are exogenous¹¹.

In practice, in model (1) efficiency determinants, such as environmental variables, are employed to model the distribution of the one-sided random variable (Wang and Ho, 2010; Kumbhakar et al., 2021). Nonetheless, a crucial assumption of these models is that the two-sided error term is unrelated to the explanatory variables and the inefficiency term. This implies that the frontier and environmental variables should not exert mutual influence on each other (Kutlu and Tran, 2019). Hence, a critical methodological challenge emerges when applying SFA to estimate technical efficiency, as is the case in our study, with a specific focus on the determinants of inefficiency, like the control of corruption. Indeed, to the best of our knowledge, existing research fails to adequately address this concern. Notably, the literature has largely overlooked the assumption that the two-sided error term must remain independent from both the explanatory variables in the production function (*i.e.*, the production frontier) and the one-sided inefficiency term. In essence, previous applications have insufficiently considered that the relationship between the frontier and the environmental variables (*e.g.*, control of corruption) should not be endogenous. In practical terms, this assumption may be unrealistic. The presence

¹⁰ In what follows, for convenience, we assume a production function of the Cobb-Douglas type in loglinear form. For a more detailed discussion we refer the reader to Kumbhakar et al., (2021) and Kutlu and Tran, (2019).

¹¹ More precisely, classical SFA assumes that v_{it} and u_{it} are each identically independently distributed (*iid*) and the covariates \mathbf{x}_{it} in the model are exogenous or independent of both u_{it} and v_{it} .

of endogeneity in a stochastic frontier model can lead to parameter estimates lacking consistency, necessitating proper handling. As a result, in the empirical literature, concerns about endogeneity issues in stochastic frontier models are increasing (Kutlu and Tran, 2019).

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

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

$$x_{it} = Z_{it}\gamma + \varepsilon_{it} \quad (3)$$

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. Moreover, 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} become $u_{it} = h_{it}u_i^*$ where $h_{it} = f(x_{it}, \varphi)$ and

u_i^* follows to a half-normal distribution: $u_i^* \sim N^+(\mu, \sigma_u^2)$ and v_{it} and u_{it} are independent conditionally on x_{it} . Hence, v_{it} and u_{it} are not necessarily independent unconditionally or conditional on exogenous variables and it enables us to explore empirical questions that previously were not possible to address properly¹².

As for the specification of the production frontier, we estimate both the Cobb-Douglas and (a more flexible) translogarithmic (Translog) functional forms (Christensen et al., 1973). Although the Translog is a generalization of the Cobb-Douglas, the application of this functional form, differently from the latter, allows for higher flexibility (Kumbhakar et al., 2021). After comparing the two functional forms considering the goodness of fit, the Translog model is selected to include the inefficiency determinants¹³. Further details on the estimates are in the next Section.

4. Results

In this Section, we provide the estimates of our empirical exercise. To ensure the robustness of our findings, we adopt a parsimonious approach. More precisely, we report the stochastic production frontier for both the exogenous and endogenous estimations, considering Z variables (i.e., institutional factors) as affecting the distance between the production of each firm and the frontier.

To keep the model parsimonious, we first consider the estimates without considering other factors that may affect firms' efficiency and, only afterwards, we start adding other factors to the baseline regression model. Thus, time dummies are introduced in the model to capture exogenous factors in the economy that might affect the production set, whereas dummies for class of firms' dimension are included to control for the heterogeneity of firms' sample.

Table 4 reports the results of our baseline estimates, where the determinants are considered exogenous. To do so, we apply a single stage approach (see Battese and Coelli, 1995) where environmental factors are assumed to directly affect technical

¹² For a more formal discussion, we refer the reader to Kutlu and Tran (2019).

¹³ Additional robustness checks using a Cobb-Douglas technology are available from the authors upon request.

inefficiency but are considered exogenous. In turn, we estimate the endogenous model following Karakaplan's (2017b) methodology. Estimates that consider environmental variables as endogenous are shown in Tables 5 and 6. In Table 5, we consider the Cheating Index at provincial level as an instrument, whereas, in Table 6, we employ as IV the historical variables that accounts for the kind of government ruling at the beginning of 14th century in Italy at the provincial level (De Blasio and Nuzzo, 2010). In all estimates we use a Translog function.

In Tables 4, 5 and 6, columns 1-6 report the estimates without the fixed control for time firms' dimension, whereas columns 7-12 show the estimates controlling for time and firm size fixed effects.

We note that the coefficient estimates from the baseline models in Table 4 and models that account for endogeneity in Tables 5 and 6 have the same sign for any variable, significant at the 1 percent level. Furthermore, we observe that all the explanatory variables (except GOVERNMENT EFFECTIVENESS) are significant (at the 1% level) and consistently have the same sign. Moreover, the signs are robust to all specifications adopted. The average firms' efficiency estimates in our sample ranges around 40 percent, indicating a low level of efficiency in the building sector in Italy. This is not surprising given the characteristics of that sector (ANCE, 2022). Since the main interest of this paper is to assess the impact of the exogenous assumption of Z variables (i.e., institutional factors) on firm inefficiency, we start the discussion from here. With the only exception of the estimates of REGULATORY_QUALITY in column 12, Tables 5 and 6 show that individual eta terms for Z variables are statistically significant, and the eta endogeneity tests reject the null hypothesis at any conventional level of significance. It indicates that a correction for endogeneity in the estimated models is necessary, as well as in the inefficiency estimates.

Regarding institutional factors, results significantly differ between the endogenous and exogenous models. Indeed, the coefficients of IQI and some pillars are greater and significant when endogeneity is considered, highlighting the importance of handling potential endogeneity issues in the assessment of the role of institutional quality on the performance of the firms. As the endogeneity tests support the

endogenous models instead of exogenous ones, in the rest of the discussions, we will use the former to interpret the results coming from the efficiency estimates and the role of institutional factors on the performance of Italian firms in the building sectors.

The sign of the IQI variable is negative for all estimates. Hence, it appears that on average as the firms operate in a more favorable institutional environment, they can achieve higher performance, indicating that the role of the local institutional set-up, or, more broadly, of governments, on creating advantageous conditions for firms to operate and use their resources efficiently.

Tables 5 and 6 report that other institutional quality factors, such as control of corruption and rule of law, have a substantial effect on firms' performance. Thus, having a more propitious environment, in terms of efficiency of judiciary system and lower levels of corruption and offences against the public administration, moves firms closer to the production frontier, indicating that firms operating in provinces with better institutions are more efficient and benefit from a more favorable environment regardless of adopting an exogenous or endogenous model and of the chosen IV ¹⁴. Columns 7 through 12 of Tables 5 and 6 show that, even the inclusion of other controls that may influence firm inefficiency, such as time and firm size fixed effects, do not change the picture significantly.

<<Table 4 about here>>

<<Table 5 about here>>

<<Table 6 about here>>

While we exercise caution in extrapolating regression results across sectors, our findings suggest that the direction of these relationships may potentially agree for other sectors with similar characteristics in Italy.

¹⁴ 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 and Coelli, 1995).

5. Conclusions

Although it is widely recognized that institutions shape individual incentives and are crucial for economic growth and development, little is known about the impact of institutional quality on firm efficiency, with special emphasis on the role of corruption as major drivers of firms' activities. Corruption has long been associated with detrimental economic consequences in numerous countries. Surprisingly, the relationship between corruption and firms' efficiency has received less scholarly attention. Indeed, corruption can significantly disrupt the level playing field for businesses, favoring those engaging in corrupt practices over innovative, productive, and quality-driven competitors. Despite extensive research on corruption's impact on entrepreneurship, growth, and innovation (e.g., Anokhin & Schulze, 2009; De Waldemar, 2012; Paunov, 2016; Dincer, 2019), limited empirical investigation has been conducted on the relationship between corruption and firm efficiency.

Our work contributes to the assessment of the role of the different components of local levels of institutional quality with a special focus on the control of corruption (Lasagni et al., 2015; Castiglione et al., 2018; Sun et al., 2019; Zallé, 2019; Aldieri et al., 2020a; Aldieri et al., 2020b). Indeed, 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, there are mechanisms in place to detect, prevent, and punish corrupt behavior, thereby reducing the incentives for individuals to engage in corruption. Conversely, weak institutional quality can foster corruption. The relationship between institutional quality and corruption is not solely unidirectional. Corruption can also undermine institutional quality by eroding public trust, distorting decision-making processes, and diverting resources away from public services and development initiatives. This, in turn, can perpetuate a cycle of poor institutional quality and further corruption.

Hence, we aim at assessing the causal relationship between institutional quality of Italian provinces and technical efficiency of firms in the building sector. The focus

of our analysis is the role of environmental corruption control, which is one of the pillars of institutional quality at the local level. As we have 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 technical efficiency of enterprises. To the best of our knowledge, we are the first one to soundly assess endogeneity issues in determining the role of institutional quality pillars on firms' performance. Our results show that local institutional quality factors significantly affect firms' performance. However, not properly controlling for endogeneity cause a downward estimation the role of local institutional quality in the performance of the firms. Finally, among the five pillars on which the institutional quality index is based, the most relevant to determine firms' efficiency are the rule of law and the control of corruption. Our findings bear relevant policy insights for the policymakers. First, the need to invest in more advanced tools to increase the control of corruption to create and maintain a favorable environment for firms' growth and innovation. Second, being the rule of law (together with the control of corruption) the most relevant pillar of institutional quality index to affect firms' performance, it becomes urgent to increase the efficiency of judiciary system reducing the judgement time of lawsuits and increasing the number and the staff of special section devoted to firms' issues.

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TABLES AND FIGURES

Table 1 - Firm size by number of employees in the sample

Classes of employees	Freq.	%	% Cumulate
5-9	2,170	40.89	40.89
10-24	2,410	45.41	86.3
25-49	510	9.61	95.91
50 or more	217	4.09	100
Total	5,307	100	-

Source: authors' elaborations on AIDA database.

Note: Table 1 reports the distribution of firms according to the number of employees taken from the AIDA database.

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)
<i>CONTROL OF CORRUPTION</i>	IQI pillar for control of corruption at provincial level	Nifo and Vecchione (2014)
<i>GOVERNMENT EFFECTIVENESS</i>	IQI pillar for government effectiveness at provincial level	Nifo and Vecchione (2014)
<i>VOICE AND ACCOUNTABILITY</i>	IQI pillar for voice and accountability at provincial level	Nifo and Vecchione (2014)
<i>RULE OF LAW</i>	IQI pillar for rule of law at provincial level	Nifo and Vecchione (2014)
<i>REGULATORY QUALITY</i>	IQI pillar 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)

Source: authors' elaborations

Note: Table 2 reports the variables employed to estimate the stochastic production frontier (Y, L, C) and the sets of environmental variables and IV employed in the approach proposed by Karakaplan and Kutlu (2017b).

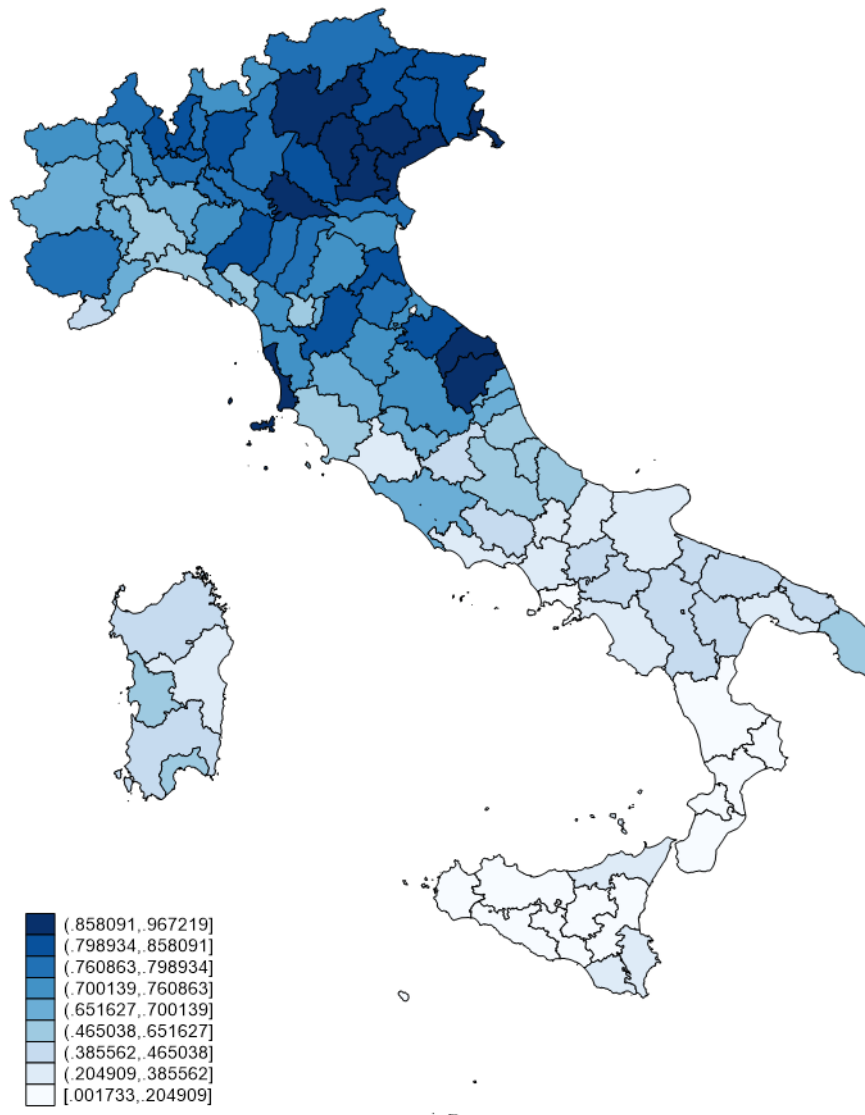
Table 3 – Summary statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Y	37,149	7,830.79	41,326.47	16.78	1,730,777.00
L	37,149	18.25	49.60	5.00	2,788.00
C	37,149	2,033.90	14,395.63	0.00	693,870.00
Environmental variables					
IQI	37,149	0.63	0.23	0.00	1.00
<i>CONTROL OF CORRUPTION</i>	37,149	0.78	0.20	0.24	0.98
<i>GOVERNMENT EFFECTIVENESS</i>	37,149	0.48	0.14	0.00	0.69
<i>VOICE AND ACCOUNTABILITY</i>	37,149	0.56	0.19	0.09	0.92
<i>RULE OF LAW</i>	37,149	0.56	0.21	0.07	1.00
<i>REGULATORY QUALITY</i>	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

Source: authors' elaborations

Note: Table 3 reports the descriptive statistics of the variables employed to estimate the stochastic production frontier and of the sets of environmental variables and IV employed in the approach proposed by Karakaplan and Kutlu (2017a).

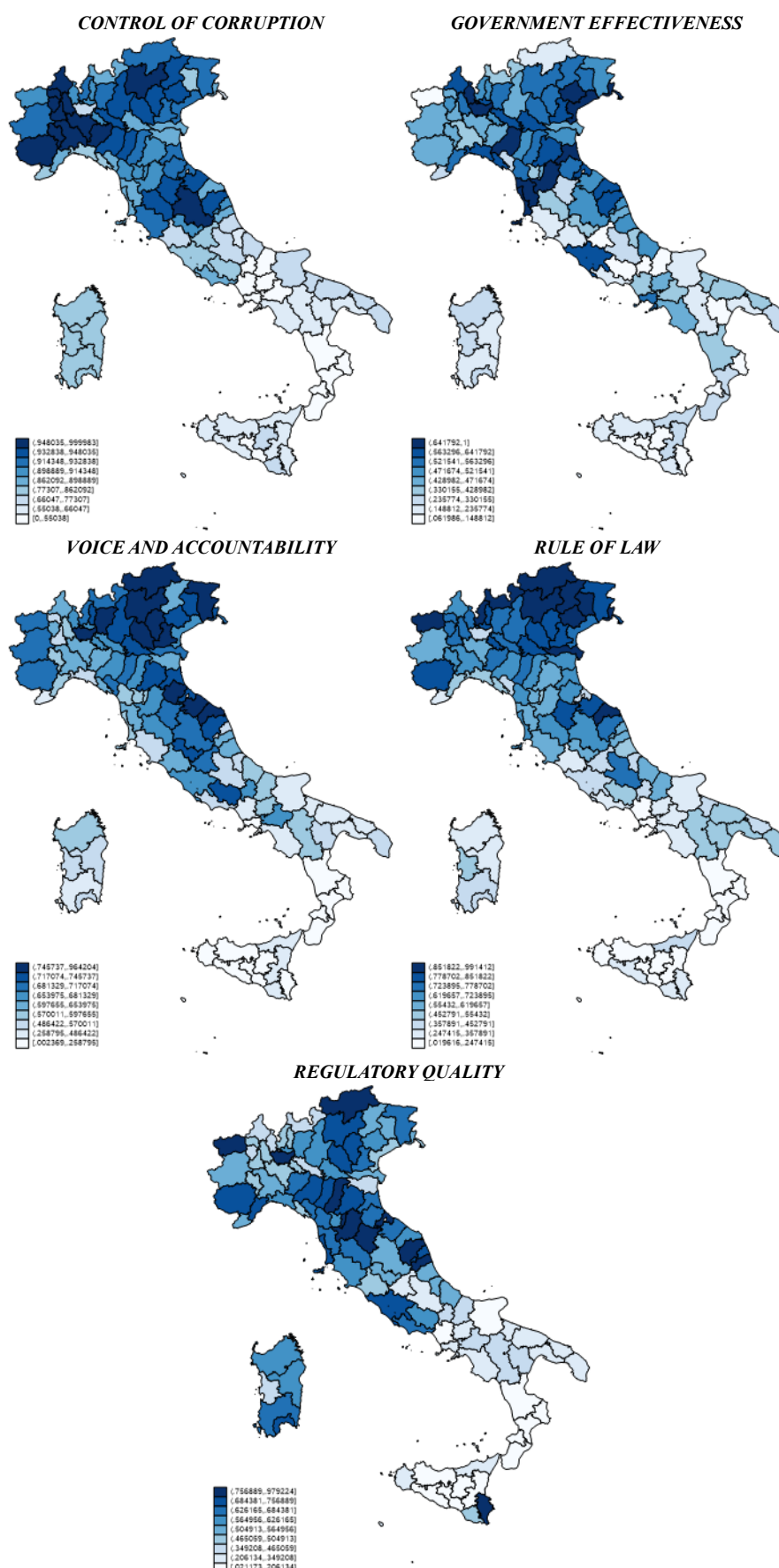
Figure 1 – Average level of Institutional Quality Index (IQI) in the time span 2013-2019 at the provincial level



Source: our elaboration on data provided by Nifo and Vecchione (2014)

Note: Figure 1 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.

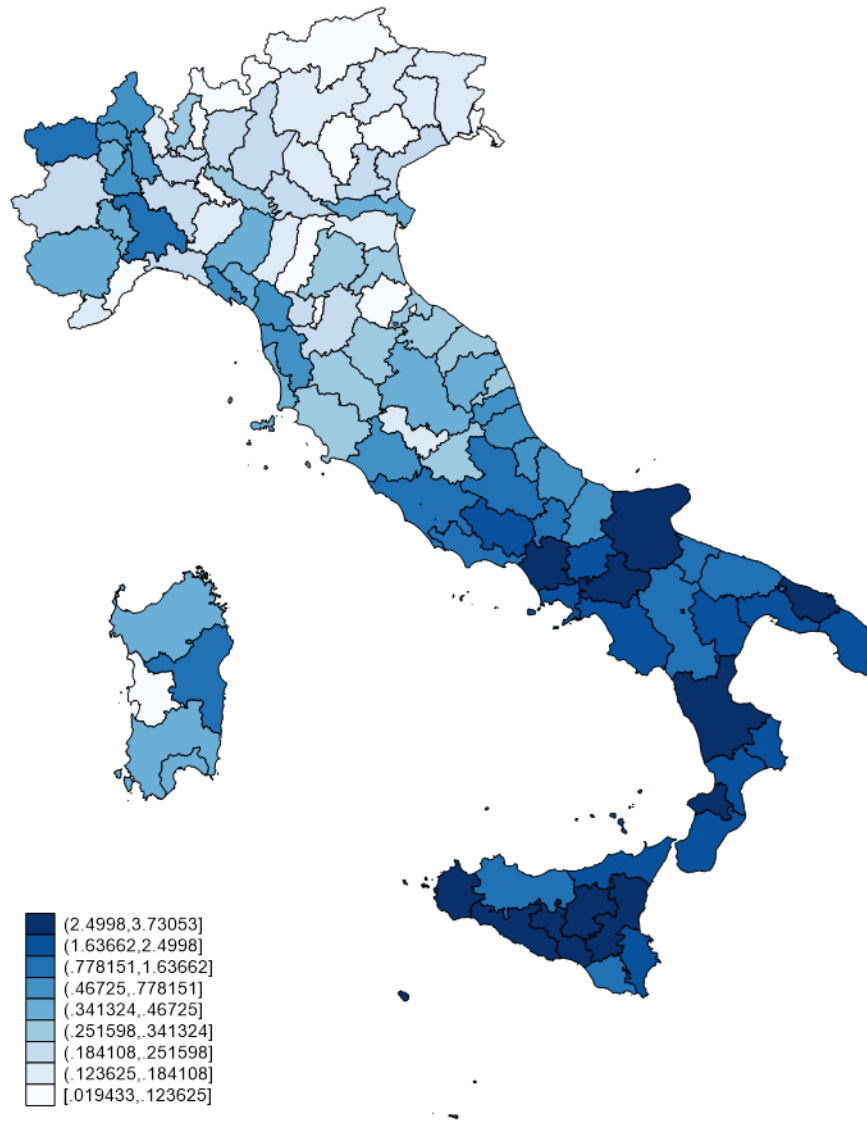
Figure 2 – Average level of the pillars of IQI in the time span 2013-2019 at the provincial level



Source: our elaboration on data provided by Nifo and Vecchione (2014)

Note: Figure 2 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.

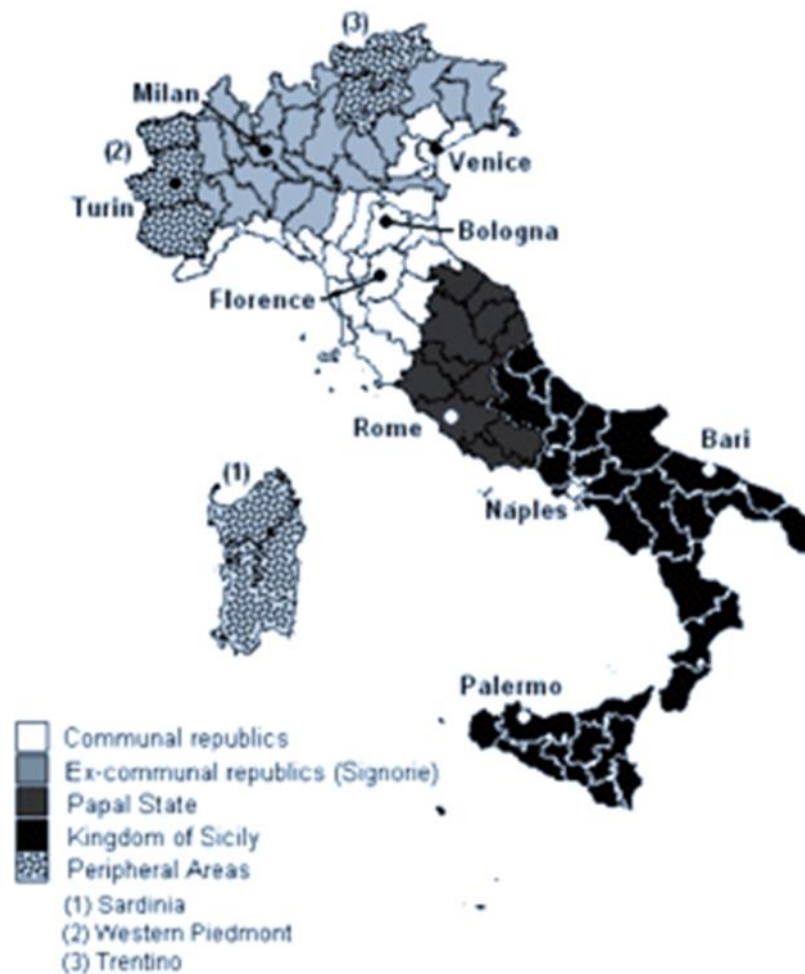
Figure 3 – Average level of Cheating Index in the time span 2013-2019 at the provincial level



Source: our elaboration on data provided by Finocchiaro Castro and Guccio (2020)

Note: 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.

Figure 4 - Fourteenth-century Local Policy Regimes



Source: De Blasio and Nuzzo (2010)

Note: Figure 4 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).

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*** (0.074)											
CONTROL_CORRUPTION		-0.503*** (0.083)										
GOVERNMENT EFFECTIVENESS			0.034 (0.069)							-0.175** (0.074)		
VOICE & ACCOUNTABILITY				-0.227*** (0.055)							-0.338*** (0.056)	
RULE OF LAW					-0.764*** (0.072)							-0.724*** (0.074)
REGULATORY QUALITY						-0.231*** (0.051)						-0.338*** (0.056)
Production function (Translog)												
Constant (β_0)	6.049*** (0.062)	6.055*** (0.062)	6.076*** (0.062)	6.064*** (0.062)	6.058*** (0.062)	6.064*** (0.062)	0.664*** (0.043)	6.039*** (0.071)	6.061*** (0.071)	6.054*** (0.071)	6.043*** (0.071)	6.049*** (0.071)
	v2	v8	v11	v14	v17	v20		v5	v8	v8	v14	v17
L (ln)	0.655*** (0.034)	0.656*** (0.034)	0.649*** (0.034)	0.652*** (0.034)	0.659*** (0.034)	0.651*** (0.034)	0.670*** (0.043)	0.671*** (0.042)	0.665*** (0.043)	0.665*** (0.043)	0.674*** (0.043)	0.664*** (0.043)
K (ln)	0.142*** (0.017)	0.143*** (0.017)	0.144*** (0.017)	0.144*** (0.017)	0.137*** (0.017)	0.144*** (0.017)	0.124*** (0.017)	0.125*** (0.017)	0.128*** (0.017)	0.128*** (0.017)	0.122*** (0.017)	0.127*** (0.017)
L (ln) square	0.026** (0.013)	0.025** (0.013)	0.026** (0.013)	0.025** (0.013)	0.024* (0.013)	0.026** (0.013)	0.001 (0.015)	-0.001 (0.015)	0.001 (0.015)	0.001 (0.015)	-0.001 (0.015)	0.001 (0.015)
K (ln) square	0.026*** (0.004)	0.026*** (0.004)	0.025*** (0.004)	0.025*** (0.004)	0.026*** (0.004)	0.025*** (0.004)	0.025*** (0.004)	0.025*** (0.004)	0.024*** (0.004)	0.024*** (0.004)	0.025*** (0.004)	0.024*** (0.004)
L (ln) * K(ln)	-0.012*** (0.005)	-0.013*** (0.005)	-0.012*** (0.005)	-0.012*** (0.005)	-0.012*** (0.005)	-0.012*** (0.005)	-0.007 (0.005)	-0.007 (0.005)	-0.007 (0.005)	-0.007 (0.005)	-0.007 (0.005)	-0.007 (0.005)
Control for firm dimension	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
Control for time	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

Source: authors' elaborations

Notes: the Table reports the estimates of the endogenous SFA applying the approach of Karataklan and Kutlu (2017b). *** 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*** -0.091						-0.901*** -0.090					
CONTROL_CORRUPTION		-1.221*** -0.080						-1.243*** -0.102				
GOVERNMENT EFFECTIVENESS			0.213* -0.110						0.151 -0.109			
VOICE & ACCOUNTABILITY				-0.100 -0.078						-0.171** -0.079		
RULE OF LAW					-1.384*** -0.090						-1.326*** -0.089	
REGULATORY QUALITY						-0.397*** -0.078						-0.422*** -0.080
IV												
CHEATING_INDEX	-0.221*** -0.001	-0.181*** -0.001	-0.095*** -0.001	-0.173*** -0.001	-0.192*** -0.001	-0.185*** -0.001	-0.221*** -0.001	-0.181*** -0.001	-0.094*** -0.001	-0.173*** -0.001	-0.192*** -0.001	-0.185*** -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*** -0.062	6.037*** -0.062	6.082*** -0.062	6.061*** -0.062	6.044*** -0.061	6.064*** -0.062	6.043*** -0.071	5.996*** -0.072	6.070*** -0.071	6.052*** -0.071	6.031*** -0.071	6.049*** -0.071
L (ln)	0.663*** -0.034	0.665*** -0.034	0.644*** -0.034	0.652*** -0.034	0.670*** -0.034	0.652*** -0.034	0.673*** -0.043	0.687*** -0.043	0.657*** -0.043	0.666*** -0.042	0.684*** -0.043	0.664*** -0.043
K (ln)	0.142*** -0.017	0.142*** -0.017	0.144*** -0.017	0.144*** -0.017	0.136*** -0.017	0.145*** -0.017	0.124*** -0.017	0.126*** -0.017	0.128*** -0.017	0.127*** -0.017	0.121*** -0.017	0.127*** -0.017
L (ln) square	0.025** -0.013	0.028** -0.013	0.027** -0.013	0.026** -0.013	0.027** -0.013	0.026** -0.013	0 -0.015	0.002 -0.015	0.002 -0.015	0 -0.015	0.001 -0.015	0.001 -0.015
K (ln) square	0.026*** -0.004	0.028*** -0.004	0.025*** -0.004	0.025*** -0.004	0.027*** -0.004	0.025*** -0.004	0.025*** -0.004	0.027*** -0.004	0.024*** -0.004	0.024*** -0.004	0.027*** -0.004	0.024*** -0.004
L (ln) * K(ln)	-0.013*** -0.005	-0.016*** -0.005	-0.012*** -0.005	-0.012*** -0.005	-0.015*** -0.005	-0.012*** -0.005	-0.008* -0.005	-0.010** -0.005	-0.007 -0.005	-0.007 -0.005	-0.010** -0.005	-0.007 -0.005
Control for firm dimension	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
Control for time	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
eta (endogenous variables)	-0.319*** -0.077	-0.988*** -0.081	0.135** -0.064	0.108** -0.047	-0.655*** -0.056	-0.133*** -0.047	-0.147* -0.08	-0.815*** -0.084	0.261*** -0.064	0.144*** -0.048	-0.705*** -0.058	0.014 -0.05
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

Source: authors' elaborations

Note: the Table reports the estimates of the endogenous SFA applying the approach of Karataklan and Kutlu (2017b). To control for endogeneity issue, we use our current IV, the cheating index namely. *** 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*** -0.089						-1.001*** -0.089					
CONTROL_CORRUPTION		-1.081*** -0.105						-1.091*** -0.107				
GOVERNMENT_EFFECTIVENESS			-0.993*** -0.138						-0.967*** -0.138			
VOICE & ACCOUNTABILITY				-0.719*** -0.097						-0.829*** -0.099		
RULE OF LAW					-1.462*** -0.101						-1.426*** -0.101	
REGULATORY_QUALITY						-0.816*** -0.090						-0.825*** -0.091
IV												
SIGNORIE	0.020*** -0.002	-0.018*** -0.002	0.006*** -0.001	-0.039*** -0.001	0.035*** -0.002	0.097*** -0.002	0.020*** -0.002	-0.018*** -0.002	0.006*** -0.001	-0.039*** -0.001	0.035*** -0.002	0.097*** -0.002
PAPAL_STATE	-0.137*** -0.002	-0.065*** -0.002	-0.073*** -0.002	-0.016*** -0.002	-0.180*** -0.002	0.001 -0.002	-0.136*** -0.002	-0.064*** -0.002	-0.073*** -0.001	-0.016*** -0.002	-0.179*** -0.002	0.002 -0.002
KINGDOM_SICILY	-0.444*** -0.002	-0.394*** -0.002	-0.228*** -0.001	-0.394*** -0.001	-0.342*** -0.002	-0.327*** -0.002	-0.444*** -0.002	-0.394*** -0.002	-0.228*** -0.001	-0.394*** -0.001	-0.342*** -0.002	-0.327*** -0.002
PERIPHERAL_AREAS	-0.085*** -0.003	-0.031*** -0.003	-0.225*** -0.002	-0.050*** -0.002	0.000 -0.003	0.007*** -0.002	-0.085*** -0.003	-0.031*** -0.002	-0.225*** -0.002	-0.050*** -0.002	0.000 -0.003	0.007*** -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*** -0.062	6.074*** -0.062	6.056*** -0.062	6.060*** -0.062	6.057*** -0.061	6.070*** -0.062	6.048*** -0.071	6.045*** -0.071	6.048*** -0.071	6.047*** -0.071	6.046*** -0.071	6.048*** -0.071
L (ln)	0.664*** -0.034	0.660*** -0.034	0.666*** -0.034	0.657*** -0.034	0.664*** -0.033	0.653*** -0.033	0.673*** -0.043	0.671*** -0.043	0.673*** -0.043	0.670*** -0.042	0.675*** -0.042	0.666*** -0.042
K (ln)	0.141*** -0.017	0.137*** -0.017	0.144*** -0.017	0.144*** -0.017	0.137*** -0.017	0.142*** -0.017	0.124*** -0.017	0.121*** -0.017	0.128*** -0.017	0.126*** -0.017	0.121*** -0.017	0.125*** -0.017
L (ln) square	0.025** -0.013	0.023* -0.013	0.024* -0.013	0.024* -0.013	0.025* -0.013	0.026** -0.013	0.001 -0.015	-0.001 -0.015	0.001 -0.015	-0.001 -0.015	0.000 -0.015	0.001 -0.015
K (ln) square	0.026*** -0.004	0.026*** -0.004	0.026*** -0.004	0.025*** -0.004	0.026*** -0.004	0.025*** -0.004	0.025*** -0.004	0.025*** -0.004	0.025*** -0.004	0.024*** -0.004	0.025*** -0.004	0.025*** -0.004
L (ln) * K(ln)	-0.013*** -0.005	-0.012** -0.005	-0.014*** -0.005	-0.012*** -0.005	-0.012*** -0.005	-0.012*** -0.005	-0.008* -0.005	-0.007 -0.005	-0.008* -0.005	-0.007 -0.005	-0.008* -0.005	-0.007 -0.005
Control for firm dimension	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
Control for time	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
eta (endogenous variables)	-0.426*** -0.070	-0.748*** -0.095	-0.834*** -0.096	-0.326*** -0.071	-0.452*** -0.070	-0.389*** -0.057	-0.293*** -0.073	-0.469*** -0.098	-0.543*** -0.106	-0.193*** -0.074	-0.483*** -0.073	-0.121* -0.063
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

Source: authors' elaborations.

Note: the Table reports the estimates of the endogenous SFA applying the approach of Karataklan and Kutlu (2017b). 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). *** p<0.01, ** p<0.05, * p<0.1.