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# What Happens in Criminal Firms after Godfather Management Removal? Judicial Administration and Firms Performance\*

Francesca M. Calamunci<sup>†</sup>

## Abstract

In this paper, I assess the causal effects of judicial administration on a sample of Italian criminal firms in the period 2004–2016, to shed light on the dynamic path of the firm's performance from pre-seizure to the post-entry judicial administration phase. By using exogenous enforcement law decisions imposed by authorities for each case, I estimate their impact, highlighting the economic consequences of having new legal governance aiming to establish legality and the perpetuation of activities. The results show that there are adverse effects on profitability and efficiency with an increase in the leverage level. The empirical evidence shows how organised crime firms are intrinsically managed by their dark criminal side; removing the criminal ties makes it challenging to maintain profitability and efficiency. Overall, the negative results are due to difficulty in establishing a new economic framework for (ex-criminal) firms in which they are able to operate efficiently and according to market rules.

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Keywords: Organised crime; Enforcement Law; Firm level data; Panel data analysis.

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# 1 Introduction

Organised crime (OC hereafter) is a widespread phenomenon across the globe. Criminal organisations have expanded across a range of activities both in illicit markets and legal businesses. In particular, OC infiltration through companies has played a predominant role in the Italian economy. Specifically, 8.7% of the Italian mafia's investments consist of companies and stocks in the period of analysis, 1983–2011 (Transcrime, 2013). Through firms, criminal organisations invest an enormous amount of capital, widen their influence, and strengthen business relationships. There are several reasons why criminal organisations might use their power to control competition and take competitive advantage of those firms operating lawfully (UNICRI, 2016). For example, a criminal firm<sup>1</sup> might exploit its coercive power to gain access to certain markets acting as a barrier to market entry or to fix more favourable trade conditions. Moreover, criminal groups may be involved in the allocation of investment funds and public procurement contracts. Finally, criminal firms might have access to massive financial resources that are available at no or very low interest rates.

Several interventions have been adopted by legal jurisdictions in order to both fight the burden that these activities pose on the economy and to guarantee the legality of market competition (Atkinson et al., 2017). With the confiscation and seizure of productive criminal assets, Italian law aims to prevent the penetration of OC into the legal economy and tackle the patrimonial aspects of criminal organisations. As of July 2019, the Italian government has seized more than 3,000 companies and over 17,000 properties (ANBSC, *Agenzia Nazionale dei Beni Sequestrati e Confiscati*). The law governing the confiscation process was introduced in 1982, defining the *Mafia-type association* in Article 416-bis and introducing clear measures aimed at the confiscation of assets. The law implements preventive measures against firms connected to criminal organisations through an administrator, appointed by a judge, who has to manage the assets and search for a new legal organisation that is able to operate efficiently. Given the nature of these productive assets, the law aims to guarantee the conservation and continuity of the productive processes while breaking all previous links with the criminal network.

While previous studies focus on the relationship between regional entrepreneurship (Operti, 2018) and the degree of competition in local entrepreneurship (Ferrante et al., 2019), little is known about the direct effects on the firms targeted by the interventions, despite their widespread

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<sup>1</sup>For the purpose of this study I use the expression *criminal firm* to indicate those companies that have been confiscated due to the connection with members of criminal organisations.

implementation and powerful socioeconomic effects. For example, in a recent contribution, Calamunci and Drago (2020) estimate the spillover effects of the judicial administration of OC firms on legal firms, i.e., those firms that were neither infiltrated by nor colluded with criminal organisations operating in the same market. The authors analyse the economic consequences of interventions on firm profitability, performance, and investment aspects. However, only a few papers (i.e., Cabras and Meli (2017) and Dalla Chiesa (2017)), using a qualitative approach, have investigated the changes that occur when criminal corporate organisations have to re-define their operations. The present analysis is an attempt to fill this gap. As *Godfathers* on company boards continue to own and manage firms without respecting legal constraints and rules, providing advantages, it seems legitimate to question the effectiveness of the current legal framework, and to what extent the restoration of firms' legal status could improve or worsen the business.

In this paper, I depart from the analysis of the Italian institutional setting to study aspects related to the creation of a new business organisation for confiscated firms. I investigate how the performance of such firms is impacted when they are transformed into legal entities and led by externally-appointed administrators. More specifically, I ask the following question: *What are the corporate consequences in terms of financial performance after removing the Godfather from management and implementing judicial administration (JA hereafter)?* To answer this question, I estimate the causal effect of judicial administration on the firms in question, highlighting changes in their performances between the pre-seizure and post-judicial administration phases. I expect to see a change in the performance of criminal firms, given they also incorporate criminal characteristics which confer competitive advantage in comparison to their legal counterparts (Arlacchi, 1983, 2010).

Since criminal company management is different from running a 'legitimate' business, when the business is placed under preventive measures, the new governance has to re-define its economic relationships in terms that adhere to the law. Therefore, changes in the firm's management, under the control of judicial administrators inspired by legislative objectives, could lead to very different economic outcomes. The management issue and the ensuing financial results of firms under preventive measures are of particular importance when the crucial role played by firms in the circular flow of income within an economy is considered, since such firms have already appropriated resources and development opportunities in the territory in which they operate.

To investigate the research question, I use financial data on Italian criminal firms for the period 2004–2016 provided by AIDA (*Analisi Informatizzata delle Aziende*— Computerised Analysis of

Firms), the Italian Bureau Van Dijk database<sup>2</sup>. Over the analysed period, I found 413 firms under preventive measures. As primary sources to identify criminal companies, I used AIDA which contains a section of information about legal procedures affecting firms. However, information about JA status has not been collected systematically and the relevant section does not include all criminal firms that are subject to judicial proceedings. For this reason, I automated the recovery of information from online newspapers, matched with other legal sources and cross-referenced with the financial statements available in AIDA.

The empirical design exploits changes in the performance of firms, controlling for firm time-invariant characteristics (firm-fixed effects) and common shocks affecting all firms (year-fixed effects). In particular, I estimate the causal effect of judicial administration across three different profiles: profitability (ROA and ROI), debt (total debt on total assets) and efficiency (technical and cost efficiency)<sup>3</sup>. The identification strategy rests on the assumption that the year of entry into JA is exogenous to a firm's performance, conditional on the large set of fixed effects. After several years of investigations, collegiate court rules on the seizure decree and the forfeiture by evaluating the specific case based on the penal code.

The main results indicate that when firms are removed from OC ownership and put under legal control, they experience a loss in profitability. In the firms analysed, ROA and ROI decreased by 4.42% and 2.42%, respectively. Furthermore, criminal firms lose out at both technical and cost efficiency levels; the impact of JA on efficiency is always significant and negative. In contrast, judicial administration results in a significant leveraging of companies to a level of 7.21%. These effects increase when firms are in more capital-intensive sectors and it is larger in non-tradable sectors. Overall, I provide evidence that criminal firms undergo negative consequences from this administrative process. Thus, the deterioration of firm performance highlights how criminal firms benefit from being managed by criminal groups, and severing these ties makes it challenging to maintain profitability and efficiency.

To corroborate the interpretation of the baseline results and support the assumption of the identification strategy used, I also ran a set of robustness checks. I implemented a placebo test in the spirit of Belloc et al. (2016) in order to check whether the effect is causal or due to random chance. The exercise demonstrated considerable robustness of the variables considered, according

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<sup>2</sup>Financial information was not available before 2004 and 2016 is the latest available period.

<sup>3</sup>The literature (Athanasopoulos and Ballantine, 1995; Clementi and Maruotti, 2007) emphasises that efficient frontier approaches seem to appear superior compared to the use of traditional financial ratios from accounting statements in terms of measuring performance. Both approaches contribute to obtaining a complete analysis of the performance profiles.

to which the evaluation of the true JA is not artificial, and the year of entry of a treated firm is exogenous to its performance. Moreover, I checked the identifying assumption by firstly estimating a dynamic model including leads and lags and secondly, introducing year-specific dummies for the years before JA to have a more flexible modelling strategy. All the findings suggest that there are no differential pre-trends invalidating the identification assumption in my empirical design.

Finally, as firms experience a deterioration in performance, they might also alter their probability of survival. Therefore, I also analysed the impact of JA corporate governance restructuring on firms by calculating a (nonparametric) Kaplan-Meier survival function (1958). I thus provide evidence of how the probability of firm survival changes before and after judicial administration.

This paper connects several pieces of literature. First, it is one of only a handful of studies providing causal evidence about the direct effect of confiscation, which has received little attention so far. This evidence rests on unique firm-level data and contrasts with the approach in Ferrante et al. (2019) and Operti (2018), which uses aggregate-level data (provincial and municipal units). Indeed, to the best of my knowledge, the current analysis is the first attempt to evaluate, through an econometric approach, what happens to businesses when JA is implemented. This is achieved by quantifying the effect of law enforcement, also focusing on the profiles through which the effect unfolds. While not directly comparable, the research of Cabras and Meli (2017), who analysed, using a qualitative approach, the effects of seizure measures on a limited sample of companies, is relevant to this study, as explained in detail below.

Second, the paper contributes to recent literature (Acconcia et al., 2014; Garoupa, 2007; Paterson et al., 2019) on the implications of policies aiming to tackle criminal organisations (Ryder, 2013) by focussing on the effects of a particular area of legislation. This paper thus seeks to extend the empirical evidence regarding studies of organised crime infiltration and, more specifically, to draw the attention of other researchers to the importance of criminal firms and enforcement policies in markets and communities in which criminal organisations have stolen resources and development opportunities.

Third, by studying what happens to a business when JA is implemented by authorities, changing the ecosystem in which the firm operates and, consequently, its governance and ownership mechanisms, the paper contributes to the literature on the governance structure of criminal firms. In particular, it adds to emerging literature on this topic that identifies specific organisational features of criminal firms, including differences in governance structure, performance and control mechanisms (Bianchi et al., 2017; Duplat et al., 2012; Fabrizi et al., 2017; Mirenda et al., 2019;

Transcrime, 2013).

Finally, the work also relates to recent literature studying the effects of organized crime infiltration on the economy. Most of these studies attempt to quantify the effects of the infiltration of criminal organisations in terms of economic growth (Detotto and Otranto, 2010; Melnikov et al., 2019; Pinotti, 2015b), the institutional environment (Bandiera, 2003; Buonanno et al., 2015), public transfers (Barone, Narciso, et al., 2012; Daniele and Dipoppa, 2018; Galletta, 2017), the productivity of firms (Albanese and Marinelli, 2013) and investment (Le Moglie and Sorrenti, 2020). Indeed, given the economic and social importance of productive criminal assets, this study provides evidence of the economic impacts of OC arising from the difficult criminal firms' value preservation and the dispersion of produced wealth.

The paper is organized as follows. The following sections briefly discuss the legal and institutional setting of the analysis and the conceptual framework. Then, I present the data and the empirical strategy employed. The results are outlined in section 6. In section 7, I provide some robustness checks. Conclusions are provided in the final section.

## **2 Legal Background and Institutional Setting**

Many instruments of legal prosecution, including freezing, seizure and confiscation of assets linked with organized crime activities, have been adopted by jurisdictions across the world (UNODC, 2017). The Italian framework is among the most sophisticated such frameworks. In this section, I briefly describe the evolution of the Italian legal system as it faced the severe and growing threat of criminal infiltration of legal businesses.

### **2.1 The Italian Criminal Law: from Rognoni-La Torre to the Anti-Mafia Package**

The first legislative change to fight organised criminal groups in Italy took place with the Rognoni-La Torre Law (13th September 1982, No. 646), substantially modifying the physiognomy of the law on the basis of preventive measures. The establishment of this law involved the introduction of article 416-bis into the Italian criminal code, which, for the first time in the national legal experience, sanctioned the mafia as an organisation. Another significant change provided by this law was the introduction, alongside personal prevention measures, of those aimed to fight ex-ante criminals' profits and properties.

Another change arrived with Law 356 in 1992, with which legislators introduced a new type of

confiscation for criminals and preventive confiscation in case of conviction and ‘plea agreements.’ The ‘Security Package’ (Law 125/2008) overcame the ‘ancillary’ principle introduced by Rognoni-La Torre law, with the possibility of the separate application of financial measures from those of personal nature. Afterwards, Law 50/2010 established the *National Agency* for the management and use of the *assets seized and confiscated* from OC (ANBSC). The fragmentation and lack of systematic harmonisation led legislators to implement a complete reorganisation of the regulation with the Anti-Mafia Code (Legislative Decree 159) in 2011.

The Anti-Mafia Code provides that, in the case of belonging to Mafia association, both the procedure for ascertaining the associated crime and the process for the application of the preventive measure must be activated simultaneously (article 2-ter l. 575/65—now articles 20–22 Codice Antimafia). A preventive proceeding has a distinct function and nature in comparison to a criminal one. The criminal measure requires a conviction and a relation to the crime the person is accused of; the preventive one does not imply a crime and aims to prevent the actions of subjects deemed dangerous. In addition, patrimonial preventive measures are the main tool to fight against the connections between infiltrated assets and criminal organizations.

## 2.2 Patrimonial Preventive Measure: Judicial Administration

Rognoni La-Torre law, along with Anti-Mafia Code, regulates JA that is a long-term management structure with two distinct phases: judicial, which goes from the issuing of the seizure decree to the confiscation decree of the first degree; and administrative, that goes from the confiscation of the first degree to the definitive confiscation decree (D’Orsi, 2013). The seizure decree and forfeiture are decided by the collegiate court, which establishes the details of the measures and appoints the delegated judge and the judicial administrator who must be a professional enrolled in a special register with expertise in business management<sup>4</sup>. The judge has to supervise the management administrator who, in turn, must perform his duties using the outmost diligence (*diligence of the good father of the family*). The legislation, along with the conservation and custody of the seized asset, hopes for an increase in the profitability of these assets (art. 35, paragraph 5 Antimafia code). Administrator asset management has to guarantee the achievement of the same benefits as if the real owner had kept administration.

However, it should be pointed out that with JA the objective of the company changes: it is not the maximisation of profits and the accumulation of mafia clans or the other criminal stake-

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<sup>4</sup>The register is online recently and the total official number of judicial administrators is not available (UNODC, 2014).



holders wealth, but a search for a new organisational structure that is able to operate efficiently and in line with the law (Di Maria et al., 2014). According to the legislative provision, it has to be functional and efficient management of the company and, therefore, directed to guarantee the firms valorization, management and survival over time, preserving economic interests and the social welfare; so that, the market is corrected by possible distortions and the economic wealth, stolen by criminals, is preserved for the entire society. JA, thus, must sever all the relationships and advantages that the previous mafia management had given to the entrepreneurial activity.

The first task of the administrator is to check whether there are positive margins to renew the management of the asset, detecting and cutting all the connections firms have with criminal groups<sup>5</sup>. He submits a detailed report to the judge, indicating the status of the assets, their possible market value, the rights of the third parties and an indication of the most profitable forms of management. Once the situation has been ascertained, the court approves the project and issues guidelines for the control of the company. At the end of the administrative procedure and, in any case, after the confiscation of first instance, the judicial administrator shows to the appointed judge the management report, which sets out the modalities of the management itself, as well as the evidence of the sums paid and collected, the analytical description of the assets and the final balance. The judge conducts the appropriate checks and, if there are no objections, approves the report.

After the first-level confiscation decree (second phase), the whole administration of the asset goes from the judicial authority to the National Agency. Like the judicial administrator, the Agency has to provide the custody, the preservation and the administration of the assets seized during the entire proceeding, and also to increase, if possible, the profitability of the assets. Following the ‘definitive’ confiscation of prevention, assets are acquired as state property, free of charges and burdens. The definitive confiscation consists of the attribution of assets to the community. In this case, the National Agency administers the confiscated assets and their allocation for institutional and social purposes, according to specific procedures indicated in the Code.

Overall, JA has a double goal. The law points to the establishment of legality in the corporate governance of the criminal firms, keeping economic interests. Together, it aims to prevent crimes and to preserve the correct functioning of the market, removing possible distortions.

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<sup>5</sup>For example, it is required not to undertake relations with suppliers in the case of suspicious connections, or to nullify agreements incurred with organized crime affiliates.

### 3 Conceptual Framework and Hypotheses

Since the administrator must proceed with an institutional restyling of the firm’s organisation, according to which the previous illegal relationships are scrapped and replaced with new ones based on a need for transparency, legality and freedom, it is intuitive to hypothesize that the implementation of JA may have an impact on a firm’s performance, its investment choices and the way in which inputs and output are coordinated. Case studies conducted by Cabras and Meli (2017) investigate ten Italian companies to understand factors influencing the survival of these firms under judicial administration (Dalla Chiesa, 2017). The research indicates the extreme diversity of the situations in which seizure and confiscation are carried out, classifying cases of success, failure and uncertain outcome. However, considering the multiple possible outcomes of JA, the mechanisms underlying its overall effects cannot be determined from the qualitative analysis of a limited number of cases, that do not properly evaluate the causal effect of interest. Therefore, from a theoretical perspective, the relation between JA involvement and firm performance is ambiguous.

#### 3.1 Judicial Administration and Positive Effects

The implementation of JA could lead to a successful outcome; the reasons are varied and refer to the context as well as the merit of the subjects involved. The argument supporting a positive effect can be view along with three profiles: managerial, relational and contextual factors.

As a professional with expertise in business, the administrator can shape the management of the firm according to different logics, from the entrepreneurial one to conservative or marginal (Dalla Chiesa, 2017) to make a decisive contribution to the survival and development of businesses in a long-term perspective. Moreover, as Cabras and Meli (2017) pointed out, also the timing is a crucial factor to implement a governance model that supports the management and/or company workers in acquiring the know-how and resources necessary to ensure the survival, profitability and development of the company (Nelson and Winter, 1982).

Furthermore, undertaking in the surrounding environment a process of radical change in culture, objectives, operational practices, control mechanisms, and criteria represents a source of success. For example, JA and anti-mafia policies could improve the firms’ reputation within the market through campaigns dedicated to legal issues, strengthening ties with suppliers and potential customers easily<sup>6</sup>. Moreover, even the competitive and contextual position in the business

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<sup>6</sup>In January 2020, the ANSBC presented a case study on the Immobiliare Strasbourg company with the aim of “recognising reliability”, using digitalized reputational rating as a tool to evaluate the entire production chain and

(intended as the market share held, network with social partners, etc.) represents a crucial factor for the success of the operation. In this regard, the initiatives launched at the local level such as "the memorandum of understanding for the management of seized and confiscated assets"<sup>7</sup> are very meaningful to activate a constant and timely connection between the various actors involved and to guarantee the business continuity.

Overall, such novel ethical behaviour (adherence to the law in the management, business environment and relationships with workers, etc.) may lead to efficiency gains and improve the firm's ability to earn a higher return on resources and meet its financial obligations.

### **3.2 Organized Crime Entrepreneurship, Lawful Management and Negative Effects**

Implementing the institutional restyling is not easy, since all criminal advantages could complicate the management of firms brought into judicial administration, possibly leading to a deterioration of the results.

Following the general framework by Barney (1991), I consider criminal management a resource inaccessible to some firms that provides considerable competitive advantages and offers some lucrative opportunities. Within this framework, the main hypothesis is that OC has the distinctive attribute of deploying criminal methods to manage companies, creating a favourable business climate through the exploitation of informal social rules and criminal network interactions (Mastrobuoni, 2015).

There are several arguments that support this hypothesis. Arlacchi (1983, 2010) and Transcrime (2013) stress certain competitive advantages for OC-infiltrated firms in comparison to their legal counterparts. These are operationalized via measures such as pressures on suppliers, input-cost minimisation achieved via pressure on workers, low-cost and poor-quality materials and services, easy access to capital derived both from illegal sources and favourable relationships with financial institutions, network effects (facilitations in permits, authorisations and other favourable administrative measures). Cumulatively, these measures are highly indicative of the 'dark side' which such businesses strive to conceal. Similarly, Albanese and Marinelli (2013) argues that criminal companies often coercively coordinate production factors such as capital and labour. Moreover, criminal connections strengthen these firms' ability to manage transaction, agency and

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distributional network of the firm.

<sup>7</sup>Known as Protocollo d'intesa per la gestione dei beni sequestrati e confiscati, it is signed between courts– preventive measure section– and various local authorities (prosecutors, ANBSC, municipalities, council of accountants and accounting experts, trade unions, anti-mafia associations,etc).

organisational costs. Thus, they determine the production and cost function of firms, implying different sets of production possibilities and shaping their efficiency (Fama and Jensen, 1983; Jensen and Meckling, 1976, 1979).

More generally, given the OC firm’s stronger contractual power in the market, *modus operandi*, it can make its operations more profitable, and consequently influence its level of efficiency, increasing its market power and reducing the uncertainty of investments. These findings are confirmed by Miranda et al. (2019) using accounting data<sup>8</sup>. This analysis demonstrates how firms controlled by organized crime are able to increase their revenues. Such improved performance is also associated with an increase in the number of employees, while it tends not to be coupled with an increase in investments.

Additionally, as suggested by prior studies (e.g. Duplat et al. (2012) referring to principal-agent theory) the governance mechanisms used in OC firms may differ significantly from the mechanisms used in lawful firms: they operate using four typical aspects such as violence and intimidation, corruption, affiliates’ turnover, and firm turnover. Furthermore, the potential misalignment of interests and goals between involved agents is also reduced thanks values of “loyalty”, “trust” and “respect” towards the OC owner/manager. For example, in criminal firms, the managerial selection process is largely driven by allegiance to the OC owner, even if this person lacks managerial skills<sup>9</sup> meaning that employees are motivated by loyalty and a sense of belonging to the criminal network.

Overall, the disappearance of these criminal values could harm firms performance. The implementation of JA and the resulting loss of the criminal approach to coordinating inputs and outputs could possibly lead to a period of uncertainty, in which a firm loses market share or advantageous concessions and face higher costs and prices. This would potentially depress business, ruining relations with suppliers and all involved parties (employees can change their behaviour; customers could divert orders elsewhere), as many studies highlight (ANBSC, 2012; Bivona, 2012; Garofali, 2013). As a result, administered companies could struggle to access the network needed

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<sup>8</sup>Even if the reliability of accounting data can be questioned, it can help to understand its role in the mechanism of the criminal economy. In this respect, accounting contributes to the concealment of crime by conferring the impression of rationality and credibility (Compin, 2008). This understanding of accounting data derives from recent research in which financial statement information is used to understand the characteristics and the mechanisms of criminal companies (Bianchi et al., 2017; Fabrizi et al., 2017; Ravenda et al., 2015a; Transcrime, 2013).

<sup>9</sup>Although this aspect deserves more research attention, empirical investigation is problematised by difficulties in obtaining adequate data, since 1) it is difficult to compare pre-JA and JA management qualities, given that such firms are usually managed by an OC owner, replaced by a figurehead in official documentation, meaning that the observed change in management quality would not be real; and 2) the profile of the appointed judicial administrator is not always available. Ideally, surveys could provide detailed information on various aspects of entrepreneurs and firms (e.g., Carbonara et al. (2019)).

to re-establish profitability, worsening their financial results and shaping other output-input combinations.

### 3.3 Hypothesis Development

To sum up, on the one hand, there are several reasons to believe that judicial administration might confer substantial advantages on the firm. On the other hand, theories supporting the view that OC may create a favourable business environment for its firms suggests that JA may foster substantial disadvantages, potentially harming firms.

Overall, it is an empirical question whether the definition of a new legal business model increases or decreases profitability and leverage. Admittedly, the analysis may suffer from the issue of under-reporting/over-reporting. The criminal method could be characterized by particular aspects such as tax evasion and concealment. Therefore, firms may downward-manage earnings for tax-avoidance purposes and applying accounting fraud schemes like any other legal business (Ravenda et al., 2015a) or may report fictitious business transactions injecting dirty money in order to avoid suspicions arising from regular contributions of capital from shareholders (Transcrime, 2013) increasing the level of debt. Consequently, if it is assumed that criminal firms may implement policies of pushing up debt and restricting earnings, the effect of JA on leverage and profitability appear more remarkable (because the reduction in profitability would be more significant and the increase in leverage too). Depending on how these schemes are configured, judicial administration could lead to the increase, maintenance or decline of business. Thus, in line with the conceptual framework and the above-discussion, I frame Hypothesis 1(a,b):

H1a: *Firms entering JA management show levels of profitability and leverage that are higher than the pre-JA phase.*

H1b: *Firms entering JA management show levels of profitability and leverage that are lower than the pre-JA phase.*

Given that business activity is also evaluated by how performance outcomes fulfil efficiency, I also examine how the implementation of JA affects firm efficiency, if at all, framing Hypothesis 2(a,b) as follow:

H2a: *Firms entering JA management show levels of efficiency that are higher than the pre-JA phase.*

H2b: *Firms entering JA management show levels of efficiency that are lower than the pre-JA*

*phase.*

Currently, JA affects companies operating in a range of sectors, including construction, manufacturing, agriculture, professional activities, health care, etc. Conceptually, accounting for the specificity and heterogeneity of sectors should improve understanding of how JA impacts criminal advantages. Levels of sectoral sensitivity to the advantages of criminal management are likely to vary. For example, companies operating in sectors characterized by lower technical specialisation (such as labour-intensive sectors like the hospitality sector) could have a greater chance of success under JA, since these are not complex activities (Cabras and Meli, 2017). Instead, some sectors could benefit more from the OC management, and hence suffer a greater loss resulting from the lack of OC benefits. For instance, in non-tradable sectors, the OC network might be helpful in imposing economic market power and protecting firms from competition, making JA management difficult. Therefore, it is an empirical question whether and how JA affects firm performance, taking into account the different structural characteristics of the sectors. Accordingly, I frame Hypothesis 3(a,b), as follows:

H3a: *The particular operational sector will influence whether firms entering JA management show levels of performance that are higher than the pre-JA phase.*

H3b: *The particular operational sector will influence whether firms entering JA management show levels of performance that are lower than the pre-JA phase.*

## **4 Data**

### **4.1 Data Analysis**

To empirically investigate the research question, I assembled a new panel dataset regarding criminal firms that entered the status of JA from 2004 to 2016. The Italian legal framework offers the possibility of univocal identification of criminal firms connected with OC groups. Each preventive measure is distinctively and autonomously decided by authorities after investigations proving the belonging of the assets to an illegal plan. The higher concentration of mafia-type organisations, combined with the OC infiltration in the legal business, provides a favourable setting for the collection of a significant sample. The results could have global implications regarding other organisations, considering that the Italian mafia represents the ‘prototype’ for other criminal or-

ganisations in different countries (Pinotti, 2015a).

Data released by ANBSC do not allow a univocal identification of companies and do not present information on their personal profile. Further investigations with DIA (the Anti-Mafia Investigative Directive) and the national anti-Mafia prosecutors confirm that this information is not systematically collected in any database.

The identification of criminal firms is made ex-post-preventive measures since it is not possible to identify them prior to legal procedures. AIDA (*Analisi Informatizzata delle Aziende*—Computerised Analysis of Firms), the Italian Bureau Van Dijk database, contains full information on all the Italian companies that are required to deposit balance sheets. It covers financial statements and also a section about the legal procedures that affect the companies, including indications of confiscation dates and status. Notwithstanding this, not all firms present in the AIDA and effectively under legal measures have this information indicated in the database. This comes from the difficulties of the Italian Chamber of Commerce (AIDA source) in systematically collecting registration from the tribunals, as it is often in a text field which is difficult to read.

To increase the availability of data about companies linked with OC and subjected to preventive measures, I used Python programming language and text-analysis, through which I automated the recovery of information in online newspapers. Also, taking advantage of some Python libraries, I made sure that the data were saved and updated several times. To reduce proxy noise, the information collected was checked with other official legal data. Finally, I crossed this list of data with the financial information available in AIDA for a total of 185 companies. Some companies were deleted from the sample because of lack of data available or discrepancies in terms of the years analysed. Additionally, the number of observations was reduced because of some missing data in AIDA, which was necessary for the computation of the variables. Overall, the analysed sample of criminal companies consists of 413 firms under preventive measures.

Table 1 shows the geographical distribution of criminal companies and data sources. The legal procedures are spread across every region, although it is possible to observe that the southern region experienced a higher number of measures. In particular, the areas of Calabria and Sicilia are overrepresented. This distribution is not surprising given that the South represents the original stronghold of OC groups and sees the most intense efforts by the anti-mafia authority against criminal organisations in these regions, which have lasted for over twenty years (Arlacchi, 2010). The geographical distribution of the collected sample confirms the results of Transcrime (2013) and Ravenda et al. (2015b). The heterogeneity in infiltration area suggests several organised

groups are involved.

Table 1 also presents descriptive statistics for each variable considered in the regression models, which comparing pre- and post -preventive measures. To weaken outlier influence, all variables are winsorised at 1 percentile. Applying this method, it is possible to limit the effect of outliers and abnormal extreme values on the estimation. The status of JA reduces firm performance and increases debt level. As can be seen, JA status decreases the profitability and efficiency of the treated firms. Indeed, on average, sample firms are statistically more profitable ( $p < .01$ ) before the treatment: the differences in mean are 2.57 and 1.95, for ROA and ROI respectively. Conversely, after the treatment, companies are more leveraged. Also, in terms of efficiency, there is a significant ( $p < .01$ ) reduction in mean in both profit and cost.

Figure 1 summarises criminal companies by the confiscation year. It can be seen that 2014 and 2015 are the years with the most significant number of companies under JA.

Finally, Figure 2 presents the industry distribution by two-digit ATECO2007 code for the sample of criminal companies considered in the analysis. The distribution gives an overview of the sector and of the markets infiltrated by OC. Mostly, infiltration occurs in sectors characterised by low level of technology, presence of public funds or public administration management, moderate entrepreneurial risk. Indeed, mainly, they are construction, wholesale and retail, manufacturing, transportation, utilities supply (e.g. waste trade), public and service activities (including health care), but they also infiltrate professional ones. This finding is supported by Savona and Berlusconi (2015) and Savona and Riccardi (2011, 2015).

## 4.2 Graphical Evidence

To provide graphical evidence about the effect of JA on firms' performance, I have reported firms' performance for the 13 years around the year in which a firm is subjected to preventive measures. I used the five variables (ROA, ROI, leverage, technical and cost efficiency) to investigate the three profiles. Graph 3 reports the firm's performance effects before and after JA comparing the mean of the variables for each year around the event. As is clear from the graphs, the firms' aspects systematically change with the event, showing a difference before and during the JA.

Analysing the firm's profitability, ROA and ROI, there is a change in proximity to 0 in the event year. For example, ROA declines from 0.68 in t-1 to -2.09 in year t with a slight improvement only after eight years of treatment. The same result can be seen for ROI, indeed the ratio declines from 0.77 to -0.91 and remains under the pre-phase level. After the intervention of the



administrator, the level of return is always lower than in the pre-phase. The result for leverage is slightly different. There is a slight increase (from 0.83 to 0.85 only in that period) in leverage, i.e., on the debt level, as a result of the change in the management. This is because, in addition to the company having previous liability, it will be able to access new finance thanks to the possibility established by the law. With regards to technical efficiency, near the year event, the level of efficiency suffers a decline. Similarly, cost efficiency shows a marked decrease after the treatment showing a loss of efficiency in cost management.

Overall the graphs, in line with the literature, show preliminary evidence that when firms undergo governance change by reducing their criminal aspects, their businesses post weaker results. The economic results after the treatment are always below the horizontal line that indicates the mean of ratio average. Conversely, for leverage, the ratio is often above the horizontal line.

## 5 Empirical Strategy

### 5.1 Profitability and Leverage

Let  $y$  be the outcome variable considered across two different profiles,  $i$  the firm, and  $t$  the year. The following regression model was used to estimate the causal effect of preventive measures on criminal firms' aspects:

$$y_{it} = \alpha_i + \lambda_t + \beta JA_{it} + \varepsilon_{it} \quad (1)$$

Where  $\alpha_i$  are firm-fixed effects,  $\lambda_t$  year-fixed effects, and  $\varepsilon_{it}$  is an error term. In all estimations, errors are clustered at the firm level. The estimated coefficient  $\beta$  measures the causal effect of interest.  $JA_{it}$  is a dummy variable that has value 1 from the year of judicial administration. According to hypothesis 1, I have no prediction for  $JA_{it}$ . The identification strategy rested on the assumption that the entry year of treated firms is exogenous to their performance. Indeed, the judicial administrator enters in the firms after several years of investigation, and the JA decision depends on the involvement of the firm in a criminal plan. The status of JA is decided by a committee of judges on the basis of the penal code and the evaluation of the specific case. The year effects are coefficients on time dummies while the unobserved specific effects are coefficients on dummies for each firm. The main point is that FE estimation does not infer a causal effect from a comparison of different firms, but by comparing within-firm change that is induced by a plausibly random (with respect to the year of implementation) treatment event. The inclusion of time dummies in addition to the firm dummy contributes to the FE estimation by providing an

estimate of the time trend. Then, the time trend is differentiated from the within comparison of the treatment group.

In addition to model 1, I estimated regressions that include firm-level time-varying control. The selection of profile and explanatory variables was carried out by following the traditional ratio measures and taking into account criminal firms' characteristics, highlighted by accounting criminal literature (footnote 6). The first profile captures the profitability aspect computed in two ways: ROA, which takes into account firms' amount of debt; and ROI, which expresses the profitability of the invested capital. I choose these two ratios because they are not affected by firms' accounting policies (Sostero et al., 2014), particularly for the kind of companies investigated. The regression model includes a vector of control variables: Sales/TA (that is the turnover rate of capital) expresses the speed with which these cycles are repeated during the year, i.e., how many times the invested capital has turned into financial resources through the sale of the products; Debt controls for the firm's capital structure (only for the ROA case) and Size is the log transformation of the firm's annual revenues, to control for differences in size that might drive operating performances:

$$ROA_{it} = \alpha_i + \lambda_t + \beta_1 JA_{it} + \beta_2 SalesTA_{it} + \beta_3 Debt_{it} + \beta_4 Size_{it} + \varepsilon_{it}$$

and

$$ROI_{it} = \alpha_i + \lambda_t + \beta_1 JA_{it} + \beta_2 SalesTA_{it} + \beta_3 Size_{it} + \varepsilon_{it}$$

The second profile captures debt aspects through the leverage:

$$Leverage_{it} = \alpha_i + \lambda_t + \beta_1 JA_{it} + \beta_2 Profit_{it} + \beta_3 Size_{it} + \beta_4 FixedAsset_{it} + \varepsilon_{it}$$

Leverage can be measured by using different financial ratios and can be defined as either the ratio of total debt to total equity or the ratio of total debt to total assets, which is the variable used in the current study. As control variables, I selected determinants, namely: profitability, determined by the earnings before interest and tax (EBIT) to total assets ratio; and firm size, using the difference of logarithm of sales and fixed assets which is generally accepted as an indicator of capital structure composition (Lemmon et al., 2008; Rajan and Zingales, 1995).

## 5.2 Efficiency-Stochastic Frontier Analysis

To obtain a complete picture of how firm performance changes under JA, I lastly evaluate performance by considering technical and cost efficiency. The stochastic production frontier approach provided by Greene (2005)(see Appendix for further details of the methodology applied) was used to measure technical efficiency. To account for non-standard characteristics in the firms considered, I used a flexible translog production function. The translog function is non-homogeneous and belongs to the class of flexible functional forms that provide a second-order local approximation to any functional form. Considering that firms produce output using inputs, in natural log value, the translog function can be written as:

$$\begin{aligned} \ln Y_{it} = & \alpha_i + \lambda_t + \beta_k \ln K_{it} + \beta_L \ln L_{it} + \frac{1}{2} [\beta_{kk} (\ln K_{it})^2 + \\ & \beta_{LL} (\ln L_{it})^2] + \frac{1}{2} \beta_{KL} \ln K_{it} \ln L_{it} + v_{it} - u_{it} \end{aligned} \quad (2)$$

where  $Y_{it}$  is the added value (output),  $K_{it}$  and  $L_{it}$  are the capital (total assets) and labour (number of employees) inputs used in the production,  $\lambda_t$  includes year-fixed effects,  $v_{it}$  is the statistical noise term and  $u_{it}$  is a nonnegative one-sided inefficiency term for the firm. If the firm is fully efficient, then  $u_{it} = 0$ . The inefficiency component of the model ( $u_{it}$ ) is not directly observable and has to be calculated according to classical assumptions where  $v_{it}$  has zero mean and constant variance and  $u_{it} \geq 0$  follows a half-normal distribution so that  $u_{it} \sim iidN^+(0, \sigma_u^2)$ .

Unlike technical efficiency, cost efficiency requires the use of input prices and following Greene (2005), it is computed using this equation:

$$\begin{aligned} \ln CT_{it} = & \alpha_i + \lambda_t + \beta_k \ln PK_{it} + \beta_L \ln PL_{it} + \beta_Y \ln Y_{it} + \frac{1}{2} [\beta_{kk} (\ln PK_{it})^2 + \\ & \beta_{LL} (\ln PL_{it})^2 + \beta_{YY} (\ln Y_{it})^2] + \frac{1}{2} \beta_{KL} \ln PK_{it} \ln PL_{it} + \frac{1}{2} \beta_{KY} \ln PK_{it} \ln Y_{it} + \\ & \frac{1}{2} \beta_{LY} \ln PL_{it} \ln Y_{it} + v_{it} - u_{it} \end{aligned} \quad (3)$$

Where  $CT_{it}$  represents the total production cost,  $PL_{it}$  and  $PK_{it}$  are input prices, and  $Y_{it}$  is the output expressed in added value. In particular, according to Pilar et al. (2018), labour price ( $PL_{it}$ ) is computed as personal expenses divided by the total number of employees and capital price ( $PK_{it}$ ) is the sum of depreciation and financial charges divided for the total asset.  $\lambda_t$  represents year-fixed effects,  $v_{it}$  is the statistical noise term with zero mean and constant variance and  $u_{it} \geq 0$  is a nonnegative one-sided inefficiency term which follows a half-normal distribution

so that  $u_{it} \sim iidN^+(0, \sigma_u^2)$ .

The analysis of technical efficiency allows a better evaluation of company performance than cost efficiency because it captures the wrong choice of both inputs and outputs (Berger and Mester, 1997). More specifically, technical efficiency constitutes a more comprehensive source of information than the partial insight provided by analysing cost efficiency. If firms are efficient on the profit side, their costs and scales of production will also be efficient (Fitzpatrick and McQuinn, 2008). Consequently, technical efficiency is viewed as overall efficiency.

Technical efficiency, taking into account the efficiency of the use of the input variables, can be outlined as the ratio of observed production over the maximum technical output possible for the firm when inefficiency is not present. Consequently, the efficiency index (TE) of the firm  $i$  in year  $t$  could be written as:

$$TE_{it} = \frac{y_{it}}{\exp(x_{it}\beta + v_{it})} = \frac{\exp(x_{it}\beta + v_{it} - u_{it})}{\exp(x_{it}\beta + v_{it})} = \exp(-u_{it})$$

It is delimited by zero and one. A near-zero score means that the firm is inefficient in its use of the given technology and could thus increase its output level without a concomitant increase in the input level, while a score of one equates to full technical efficiency. In other words, if  $TE_{it} = 1$  then a company uses its inputs efficiently and thus achieves its maximum feasible outcome, while  $TE_{it} < 1$  denotes some kind of inefficiency.

Similarly, cost-efficiency is the ratio of the potentially sustainable minimum cost and the cost effectively supported by firms, so that:

$$CE_{it} = \frac{C^{min}}{C} = \frac{C(y_{it}, w_{it})\exp(v_{it})}{C(y_{it}, w_{it})\exp(u_{it} + v_{it})} = \exp(-u_{it})$$

It is bounded by zero when the actual cost is more significant than the minimum estimated cost and one when the firm system is characterised by full efficiency.

### 5.2.1 Firm Efficiency Determinants

I model firm efficiency as a function of environmental variables in order to analyse the differences in efficiency from the most efficient companies. Therefore, I use the distance from the efficiency frontier (estimated from Eq. 2-3) and analyse it as a function of the factors that influence firms. I am particularly interested in the impact of JA in facilitating or hindering the technical and cost

efficiency of firms, estimating the following inefficiency equation:

$$u_{it} = f(JA_{it}, \text{controlvariables}, Z_{it}) \quad (4)$$

Where  $u_{it}$  can be defined as the distance from the efficiency frontier for a firm  $i$  at period  $t$ ; JA is the dummy variable that takes value 1 from the year in which companies are placed under preventive measures. The JA event is considered as an environmental factor that affects firm efficiency and is not under managerial control<sup>10</sup>, as used by Castiglione et al. (2018). According to hypothesis 2, I have no predictions for  $JA_{it}$ .

To summarise, technical inefficiency and cost efficiency are estimated by stochastic frontier analysis and simultaneously explained by a set of institutional and environmental variables affecting efficiency. This one-step method avoids the inconsistencies of the two-stage approach, where the first stage requires the estimation of a conventional frontier model with environmental variables omitted and the second stage implicates the regression of these predicted technical efficiencies on the environmental variables (Wang and Schmidt, 2002).

## 6 Results

### 6.1 Basic Results

Table 2 presents the results using ROA and ROI as measures of performance. I examined the impact on profitability when firms are removed from OC ownership and placed under JA, only absorbing year-fixed effects, and then absorbing for firm-fixed effects, and progressively adding control variables.

As previously stated, the variable of interest for this research is the dummy variable JA in order to determine how companies' performance changes once criminal characters are eliminated and legality is implemented. When controlling only for year-fixed effects in columns (1) and (4), JA seems to play an important role. Indeed, as expected from graphical evidence, the treatment is negatively correlated with the firm's profitability. Following this line, once controlled for firm-fixed effects in columns (2), (3), (5) and (6), the results remain unchanged. Columns (3) and (6) introduce a set of variables to control for size and capital structure. Following the literature, I used winsorisation at 1% to eliminate outliers that characterise accounting variables. In line with the analysis presented above,  $\beta_1$  is negative and significant at (5%) in columns 3 and 6 for

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<sup>10</sup>This aspect will be taken up in section 7.

both ratios after controlling for size, and capital structure and including the year-fixed effect. The coefficient  $\beta_1$  is always statistically significant and negative (at 1% for ROA and 10% for ROI, considering the regression without any control). These measures support the interpretation that the profitability of companies decreases after legal measures are implemented. In particular, ROA and ROI fall by 4.42 and 2.42 respectively, rejecting H1a and supporting H1b.

Next, the policy impact in terms of debt relations was analysed using the leverage ratio (Table 3). Column (1) indicates that when controlling only for the year-fixed effect, there is no statistically significant impact on the leverage level. However, when a control for the firm-fixed effect was added in column (2), the treatment effect shows a statically significant impact on the leverage level ( $p < .05$ ). In column (3), including control variables, the causal effect of the judicial measure is recorded by the  $\beta_1$  coefficient as positive and statistically significant (1%)<sup>11</sup>. The effect of JA causes an increase of 0.0721 in the level of debt, supporting H1a and rejecting H1b.

This analysis indicated preliminary conclusions. First, being under JA is associated with lower profitability; and second, the leverage of firms increases after a JA event. Therefore, the decrease in performance indicates a loss in the ability of the management to earn a return on resources, suggesting that firms after JA use their assets less efficiently (see following paragraphs)

The final step is to consider the effect of JA on technical and cost efficiency. Table 4 presents the results of the estimation of the stochastic profit frontier. The results of the estimated translog profit frontier (column 1) show that the selection of variables is appropriate, and the fit between the model and the data is good. The estimated output elasticities in comparison to capital are positive and statistically significant at 1%. The output elasticity for capital is equal to 0.46 and is more significant than that obtained for labour (0.34). The total elasticity of scale, which shows a local measure of returns to scale, equals 0.79. As explained before, under the premise that the sectors in which these types of companies operate are multiple, the decreasing returns to scale at the sample mean are prevalent for the analysed companies, indicating that increasing all inputs by 1% would raise output by 0.79% only.

The results for the coefficient of efficiency determinants ( $Z_{it}$ ), included in the inefficiency function, are reported below the table. The estimated coefficients of the technical efficiency factors show their direct effect on technical inefficiency, which is the opposite of their effect on TE. The results of the JA variable always show a statistically significant and positive (5%) impact on inefficiency ( $u_{it}$ ). This implies that with JA, the treated companies are less technically

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<sup>11</sup>When estimating each ratio including controls for sector-by-year FE and region-by-sector-by-year FE, the results were unchanged.

efficient than in the pre-measure phase, in line with the previous results. Firms use their inputs less efficiently obtaining a lower level of output, since they have also access to a less profitable business than at the criminal stage. First, in the pre-measure JA phase, criminal firms are able to exploit network effects in order to conduct profitable business, which is no longer acceptable under JA. Second, the output may be higher as criminals find it easier to smooth variation in demand using their methods. The table also summarises statistical estimates of TE scores. The mean TE score is about 0.69, with a standard deviation of 0.27.

Table 5 presents the results of the estimation of the stochastic cost frontier. Since total cost and all the independent variables are expressed in logarithms, the computed first-order coefficients can be understood as cost elasticities evaluated at the sample median. The cost frontier function is non-decreasing in input prices since both the capital and labour price coefficients are positive. However, the estimation shows the violation of monotonicity against output represented by added value.

The estimated coefficient of efficiency determinants ( $Z_{it}$ ), which are included in the inefficiency function, are reported below. In line with the results for the profit frontier and also in the case of cost efficiency (both rejecting H2a and supporting H2b), JA has a significant effect (1%) on the change in efficiency level. When JA is implemented, companies become less technically efficient in cost than in the pre-measure phase. This indicates that the same output level (added value) is obtained with higher costs when JA is implemented. Hence, paying the same price, firms are less efficient in cost management. The estimated cost efficiency has a mean of 0.74, with a standard deviation of 0.23.

## 6.2 Additional Results

Here, the effect of enforcement actions on firms is analysed, taking into account sectoral heterogeneity, in order to test H3(a,b). In table 6 I replicate the analysis of the effect of JA on financial performance and leverage, distinguishing by sector<sup>12</sup>.

The primary classification applied was whether a firm operated in a labour-intensive or capital-intensive sector (Acemoglu and Guerrieri, 2008). Indeed, the literature highlights how the performance of OC-infiltrated firms is associated with greater labour input (Mirenda et al., 2019) as well as differential access to capital (Arlacchi, 1983, 2010; Calamunci, 2020). The results (Panel

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<sup>12</sup>The non-linearity of the econometric specification for the stochastic efficiency analysis obstructs the convergence of the two stochastic frontiers using the subsamples, leading to imprecise results. However, the precisely estimated coefficients are consistent with the main results and coherent with the results provided by Table 6.

A) suggest that JA policy impacts both groups of sectors. In more capital-intensive sectors, however, the divergence is larger and more significant, indicating a greater difficulty in business that require large amounts of investment.

The second distinction was whether a sector was tradable or non-tradable. It is reasonable to assume that firms in the non-tradable sector would benefit more from the presence of organized crime, and hence that anti-mafia measures would be more detrimental to them. Firms in the non-tradable sector are more protected from competition and can count on OC power in the local market, gaining access to certain business or fixing more favorable trade conditions. In contrast, firms in tradable sectors are more exposed to competition since they can extend their reach beyond their local territories.

The results in Panel B show that non-tradable sectors undergo a more significant loss of performance and increase in leverage compared to tradable sectors, consistent with the idea that for judicial administrators it is harder to offset the potential benefits of OC management in this group.

## **7 Robustness Tests**

### **7.1 Placebo Test and Robustness Check**

In the absence of experimental design, the identification of the causal effect rested on the assumption (supported by the institutional setting) that the entry year of treated firms is exogenous to their performance. Therefore, to evaluate the robustness of the results, I ran a placebo experiment following the approach of Belloc et al. (2016). The sample of companies covered the years from 2004 to 2016, thirteen years in total. The year event was then randomly assigned 10,000 times and the corresponding fake JA dummy was generated for each randomly assigned fake year.

After building the placebo JA dummy variables, I estimated a model 1 to replace the real one. The procedure was repeated 10,000 times, saving the estimated coefficient in each test. With the generation of random events and the assignation of placebo dummy variables, the test aimed to verify how many times these placebo point estimates were closer or lower than the true point estimate. A significant effect of the artificial treatment might mean anticipation of preventive measures that would induce effects on firms before the policy was implemented. As a result, if the estimations erroneously imputed to JA an impact on the firms' performance that did not exist in reality, I would obtain a placebo coefficient close to the real point estimate. To do so, estimated



point coefficients are reported in the probability density function, with the inclusion of a vertical line that indicates the true point estimate of the estimated model without the addition of control variables.

The procedure was repeated for each dependent variable used in the analysis. As shown in Figures 4, the point estimates are generally larger than the real value. In the cases of ROA and ROI, which have a negative effect, the results of the placebo test were usually to the right of the true coefficients, except for a small left-tail. Conversely, for leverage, which has positive effects, the fake coefficients are to the left of the true coefficient, with a slight right tail.

Using the same methodology, I also ran an experiment to determine the efficiency aspects (Berenguer et al., 2016). However, given the complexity of estimation for the stochastic frontier, the procedure was repeated only 5,000 times. Hence, I randomly generated 5,000 fake year-events. Generating fake environmental variables, I used these regressors (JA fake) in equation 4 in both cost and profit aspects (equations 2 and 3). As shown in the figures, the fake coefficients are to the left of the true coefficient with a thin right tail.

Although the majority of empirical studies using stochastic frontier analysis do not consider this potential econometric problem, a central concern of efficiency analysis literature is to understand whether the policy intervention can be considered exogenous in the sense that it contrasts in unanticipated ways to the past investment choices of companies. The use of a heteroskedastic frontier makes the endogeneity risks less severe, as  $u$  must be independent of  $x$ , conditionally to  $z$ . However, the assumption remains that all  $z$  (in this case JA) are exogenous. In this regard, the placebo test is a strong robustness check to state that the entry year of JA is exogeneous to the firms' decisions, and hence unexpected compared to past investment choices.

Overall, these exercises show the considerable robustness of the variables considered, according to which the evaluation of the true JA is not artificial, and the year of entry of a treated firm is exogenous to its performance.

As a second robustness check and alternative test of causality, for the model equation 1, I checked the identifying assumption of the explanatory variable JA, estimating a dynamic model including leads and lags<sup>13</sup> in the sense of Sims causality (1972) as in Wooldridge (2005, p. 41):

$$y_{it} = \alpha_i + \gamma_t + \sum_{\tau=-1}^3 \beta_{\tau} JA_{it(t-\tau)} + \sum_{\tau=0}^2 \beta_{\tau} JA_{it(+\tau)} + \epsilon_{it} \quad (5)$$

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<sup>13</sup>Leads and lags are estimated separately to preserve a meaningful number of observations.

where  $y_{it}$  is a time-variant outcome variable (ROA, ROI and Leverage) of firm  $i$  in year  $t$ .  $\sigma_i$  are firm-fixed effects,  $\gamma_t$  year-fixed effects, and  $\varepsilon_{it}$  is an error term. In all estimations, errors are clustered at the firm level. The key variable,  $JA_{it}$ , is one in the years in which firms enter the status of JA. In this specification, the coefficients  $\beta$  for  $\tau < 0$  test for the presence of pre-trends, as they reflect the relationship between current changes in JA status and past firm outcomes. The coefficient  $\beta$  for  $\tau = 0$  captures the on-impact change in JA on firm performance. The coefficients  $\beta$  for  $\tau > 0$  capture the post-treatment effects.

The estimated leads and lags, running from 3 years ahead to 2 years behind, are reported in Figures (5) with a 95% confidence interval. The point estimates on the leads show no effects in the three years before JA is implemented, whereas in the first few years after JA, they show a decrease or increase in performance and leverage, respectively. These results, in line with the falsification test, suggest that there is no threat to the identification assumption in my empirical design: the identifying assumption is supported by the data inasmuch as there were no clear pre-trends of JA in the three variables that I considered (ROA, ROI and Leverage).

Lastly, to complete the analysis, I estimated a more flexible modelling strategy. Such a modelling strategy allows the time path of the causal effect to be identified in a differentiated way. Indeed, to investigate whether there is an anticipation effect, I added a full set of dummies for the years before JA, as follows:

$$y_{it} = \alpha_i + \lambda_t + \sum_{\tau=-10}^{-1} \beta_{\tau} D_{it}^{\tau} + \varepsilon_{it} \quad (6)$$

Where  $D_{it}^{\tau}$  takes the value 1 in the  $T$ th year (with  $\tau = -1, -2, -3, \dots, -10$ ) before criminal firms enter into the JA, and the treatment year ( $\tau=0$ ) is used as a reference category.  $y_{it}$  is measured by ROA, ROI, Leverage, Technical efficiency (TE) and Cost Efficiency (CE). I also control for firm- and year-fixed effects, whilst  $\varepsilon_{it}$  is the error component of the model. In all regressions, standard errors are clustered at the firm level.

In the case of anticipation effects, I would have expected firms to be characterized by a gradual decline in performance and efficiency, and a rise in leverage. Instead, the results reassure that firms do not anticipate their behaviour, since the point estimates, not significant at the conventional levels, are positive for performance and efficiency and negative for leverage (see Figures 6).

## 7.2 Corporate Failure: Survival Analysis

Once criminal firms are placed under JA and experience a deterioration in performance, they might also change their probability of survival by diverging from legislative provisions. At any particular time, the probability of firms with different corporate governance characteristics experiencing distress as a result of administrative measures will vary. To analyse the impact of JA corporate governance restructuring on firms, I used a survival analysis technique, calculating a (nonparametric) Kaplan-Meier survival function (1958). The following equation shows the basic Kaplan-Meier function:

$$S_t = \prod_{j|t_j \leq t} \left( \frac{n_j - d_j}{n_j} \right) \quad (7)$$

where  $S_t$  refers to the survivor function,  $n_j$  is the number of subjects at risk (the risk set) at time interval  $t_j$ , and  $d_j$  is the number of failures at time interval  $t_j$  (Cleves et al., 2010).

For any K-M plot, the horizontal axis represents the time variable expressed in years. All firms start at the top of the vertical axis, which indicates the proportion that has not experienced an exit event. The Kaplan-Meier curve is not a smooth function but is characterized by a unidirectional, step-like appearance. The lengths of the horizontal lines along the horizontal axis represent the survival duration in years for each interval, while the vertical distances between horizontal lines correspond to the change in cumulative probability as the curve moves to the right; thus, drops in the plots are associated with failure events.

This graphical representation is a useful tool to compare survival functions between groups. Figure 7 illustrates changes in the possibility of firms' survival by considering the pre- and post-JA periods. The estimates indicate that the pre-JA(=1) probability of survival is about 41 p.p. higher than after JA (when Before JA=0) (90% vs. 49%), although a few failure events nonetheless occurred in the period under analysis.

## 8 Discussion and Conclusions

In this work, I analysed the dynamic change that occurs in firms' performances when a judicial administrator, appointed by authorities, has to re-define the business and cut all links with criminal organisations. Following judicial administration, changes occur in ownership decisions and the systems in which companies operate. Indeed, such companies are of particular interest to the scientific community, given their social responsibility and the importance of market competition.

The growing number of enforcement activities and the unique jurisdictional framework in

Italy offers the possibility of gathering significative firm-level data and considering exogenous shocks by applying a quasi-experimental research design. Using a selection of newly-available panel data, with yearly firm-level observations of criminal firms from all regions of Italy between 2004 and 2016, I assessed the economic consequences of these companies' transformation into legitimate entities. In particular, the evaluated measures were of profitability (ROA and ROI), efficiency (cost and profit), and debt level (leverage). The empirical strategy was based on the within variation in criminal firms exposed to JA. Specifically, I did not infer the causal effect from a comparison of different firms but by comparing within-firm change that is induced by a random treatment event, controlling for common annual shocks that affect all firms, as well as firm time-invariant characteristics.

Starting from the graphical evidence, I provided a series of proofs that overall demonstrate a change in the economic aspects of firms. The comparison before and after the implantation of the preventive measure pinpoints that the move into legality reduces profitability and efficiency (cost and profit) and increases debt levels.

However, the results raise doubts about the effectiveness of the judicial administration process and shed light on the burden that organized crime firms impose on the economy. As established by anti-mafia legislation, the goal of the entire judicial administration process is to maintain and increase the profitability of criminal firms by allowing them to become legal, competitive and to remain in the market. The considerable decline in these companies' levels of profitability and efficiency underlines that the management of firms under JA is less effective; indeed, it demonstrates a deterioration in the probability of survival. One reason why this management may underperform persistently is that through JA, firms encounter barriers and lose advantages, which ultimately threatens their existence. Criminal firms earn higher profits due to the advantages of OC and their governance structure, while firms that enter JA status must alter their approach and run the business through legal control mechanisms. The judicial administrator, who restores legality in controlled companies according to sound management principles, has to manage criminal firms not only from an economic perspective but also by analysing the investment relationships established by previous stakeholders.

Overall, the results derived from both financial ratio and technical/cost-efficiency analysis outline that JA, which restores legality in controlled companies according to sound management principles, leads to a loss of performance and efficiency. JA management struggles to maintain the company's economic and financial balance, having to initiate procedures that require higher

management costs. This finding is consistent with the theoretical approach according to which criminal management is able to shape different sets of production possibilities (Fama and Jensen, 1983; Jensen and Meckling, 1976, 1979). Yet, reshaping a firm's management involves also a change in economic relationships, transnational networks, input and output allocation markets and in the cultural background in which the firm operates.

The empirical evidence shows how organized crime firms are intrinsically managed by their dark criminal side. Removing criminal ties, having the characteristics of *inimitability* (Barney, 1991), makes it challenging to maintain profitability and efficiency. In particular, the outcomes suggest that the corporate restructuring process is characterized by higher costs induced by greater regularisation of labour and capital relations. Therefore, the aims of preserving company assets while curtailing its illegal advantages are difficult to reconcile. The judicial administrator has the complex task of instituting managerial strategies that aim to restore the legal function of the business while trying to keep the company competitive (D'Amore et al., 2016).

This study has a number of important policy implications. Firstly, the economic implications indicate that reducing the economic and financial balance and procedures requiring higher management costs may lead to economic consequences, such as the dispersion of the wealth produced and loss of employment. A second implication points to the need for revision of the law dealing with criminal assets management. Indeed, Italy's 2016 Stability Law introduced some measures (Article 1, paragraphs 99-102) aimed at enhancing the seized and confiscated productive assets through support for investments and meeting the cost of corporate restructuring. All these practices should orientate judicial management towards an entrepreneurial perspective, establishing new economic relationships and defining new legal competitive advantages. The aim should be to improve the business relationships of confiscated companies, institute more integrated models and develop novel management approaches to restore the companies in question. Similarly, a third implication targets the need of promoting specific courses on the topic, related to the diffusion of "entrepreneurship skills" (Hahn et al., 2020) that the administrator and policy-makers, in general, should have. In this direction, recent is the Advanced Training Course promoted by Campania Region for the management of seized and confiscated companies.

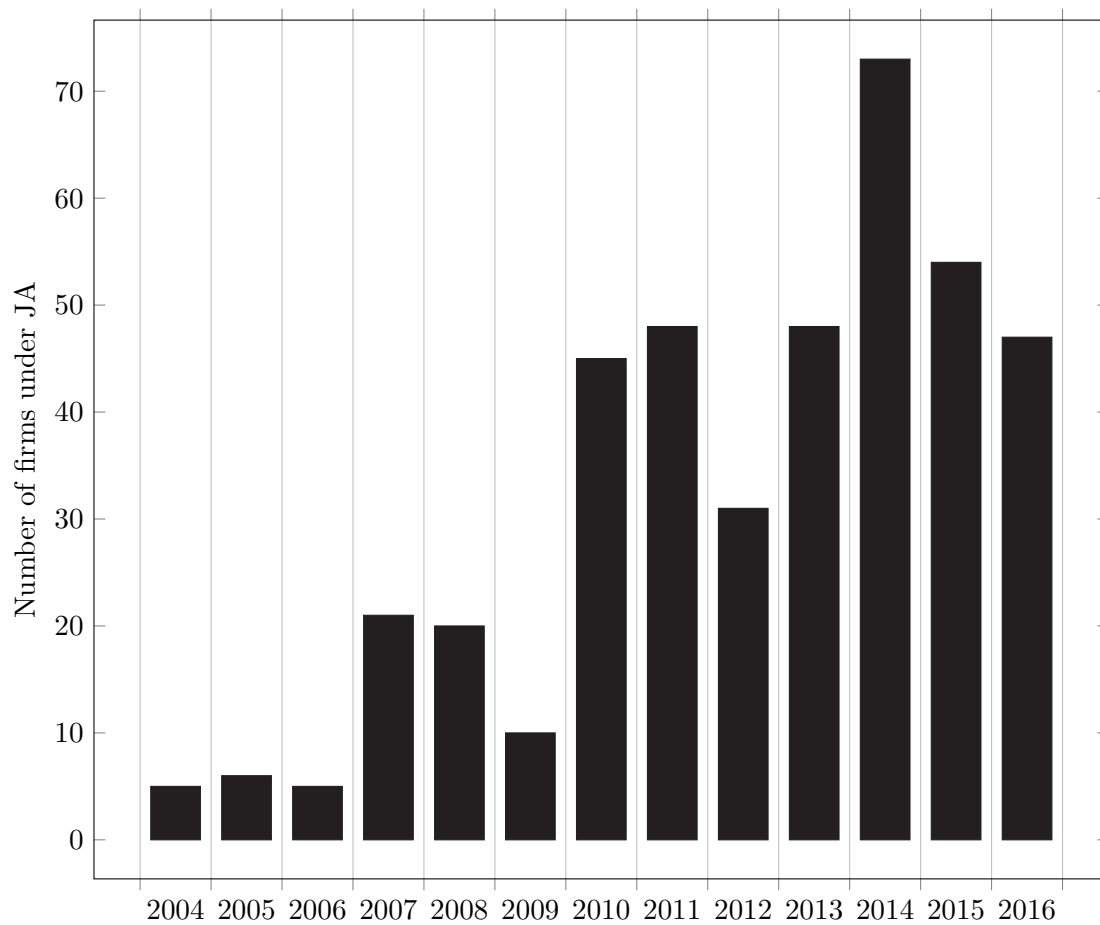
Future research should investigate additional factors impacting companies under judicial administrative procedures. The process of disentangling the effects of multiple channels intrinsic to the transformation of firms' business models is complex. Studying the specific factors that impede firms' performance would be important to develop further policy insights. At this point,

data limitations do not allow me to understand the precise mechanisms behind my results. These limits could be taken as a suggestion for further research from different perspectives. For example, it may be productive to take a management perspective on the issue, which focuses on administrators' skills to develop a definition of best practice for judicial administrators of the present and future. Furthermore, this study provides insights for developing a theoretical model. Future studies should focus on other channels such as uncertainty and relations in the business environment and economic agents' cultural backgrounds. Research topics might include the effects of JA on firm-bank relationships, how changes to the network of firms, suppliers and employees impact prices, as well as additional financial and non-financial information through which JA could affect the performance of firms.

Additionally, future research efforts should seek to build empirical evidence on the infiltration of legal businesses by criminal organisations, and evaluate the impact this has on markets and firms, exploiting the shock provided by enforcement policies. Besides, it is worthy of investigation the overall impact (social and economic) of this enforcement measure, considering the severe direct consequences of adopted policy (on OC firms' performance) and indirect positive ones (spillover effects on legal competitors (Calamunci and Drago, 2020)), as a continuation of these studies. Finally, although the results presented in this study are based on the Italian scenario, the implications could be generalized to other countries where organized crime is deeply rooted, given that asset confiscation has become a priority in the battle against organized crime at the global level (UNODC, 2017).

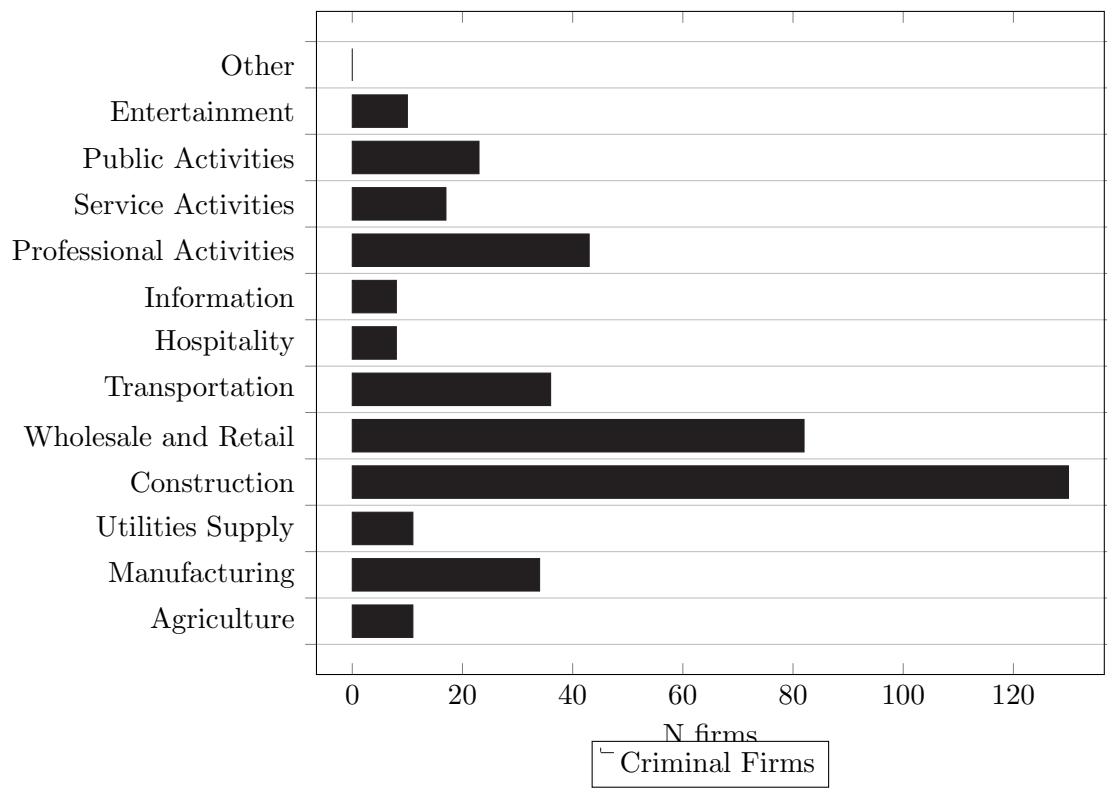
## Figures and Tables

Figure 1: Number of Criminal firms subject to JA by year



*Notes:* The figure reports the number of firms subject to judicial administration by year.

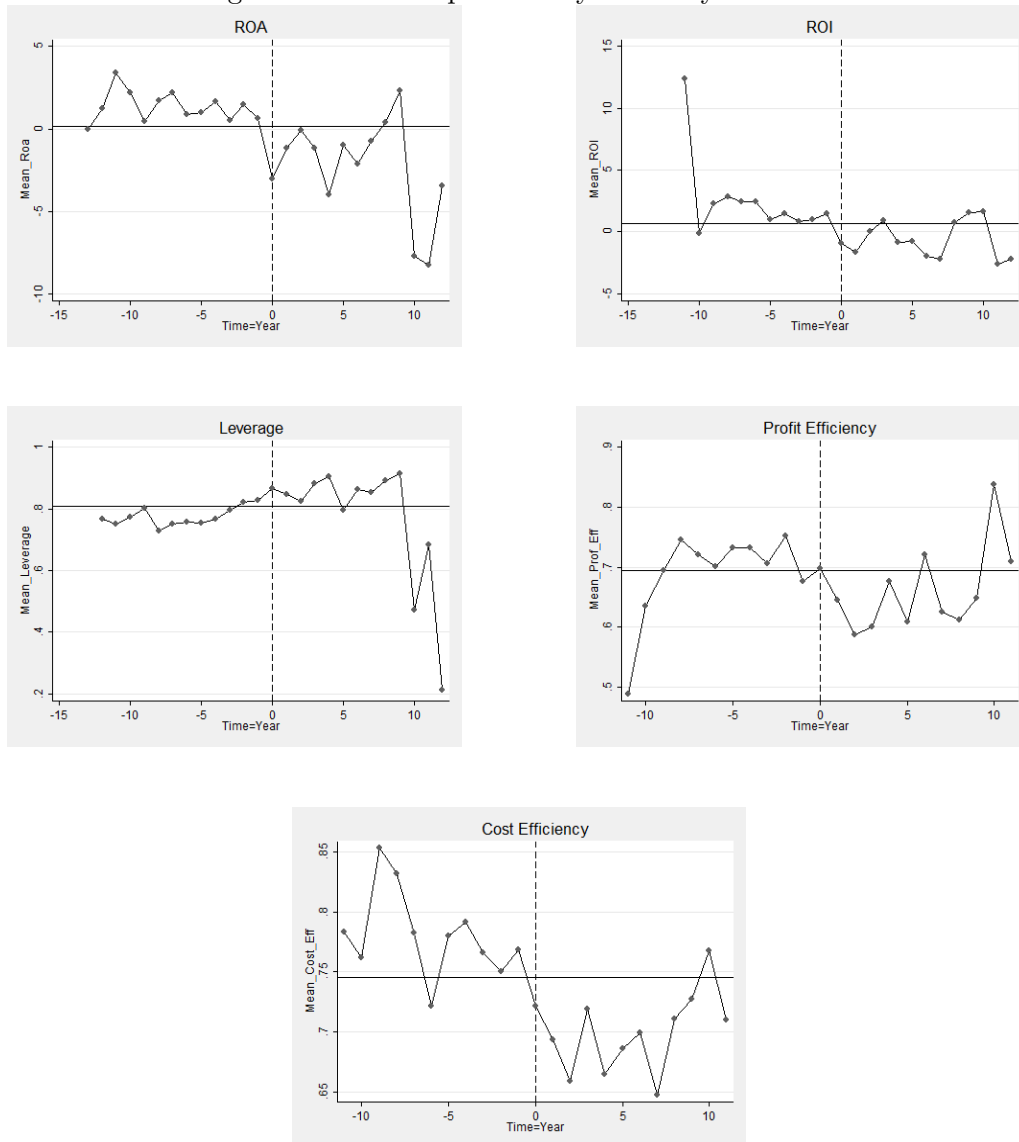
Figure 2: Criminal firms under JA by sector



Notes: The figure reports the number of criminal firms subject to judicial administration by sector.

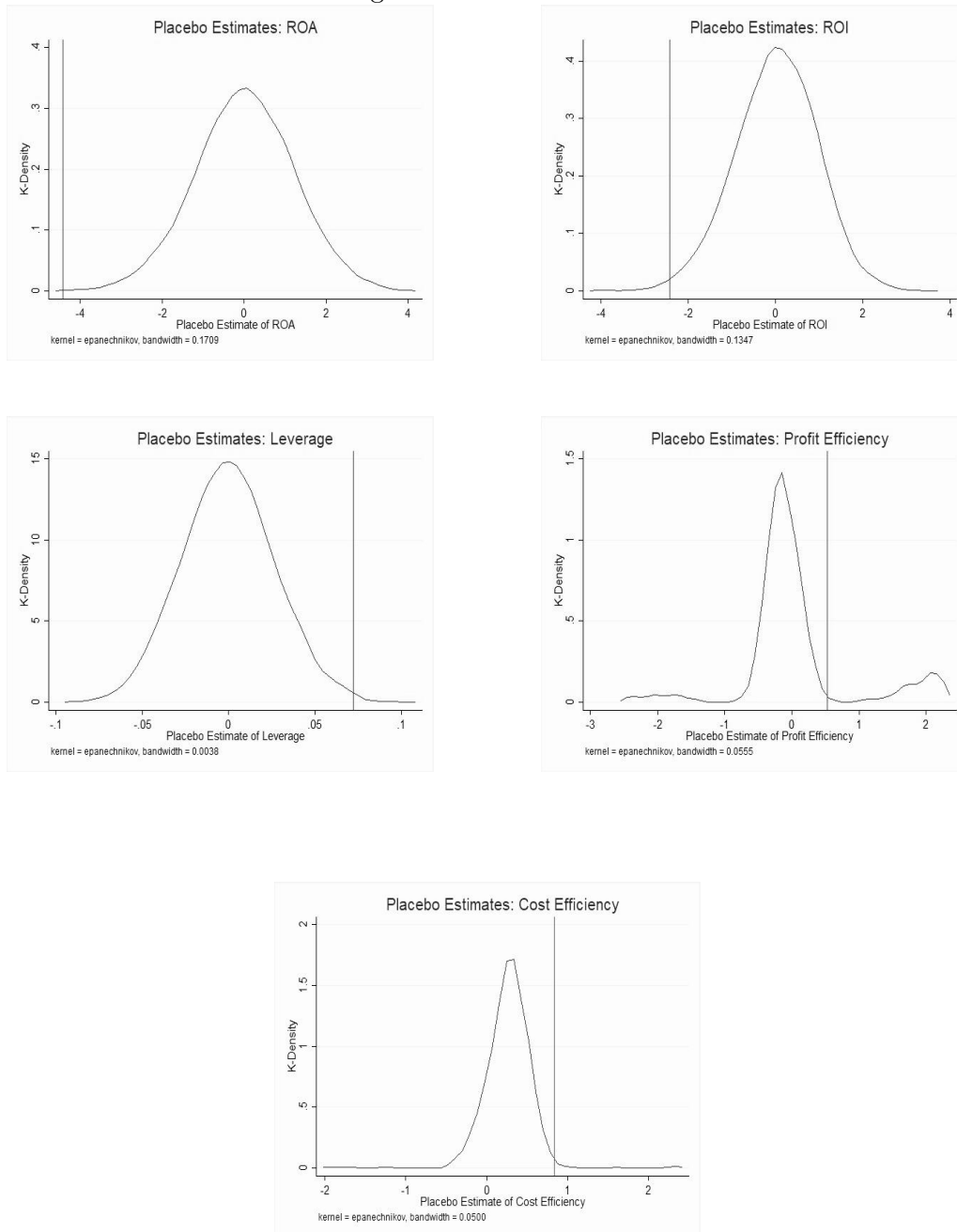


Figure 3: Inter-temporal analysis of Key variables



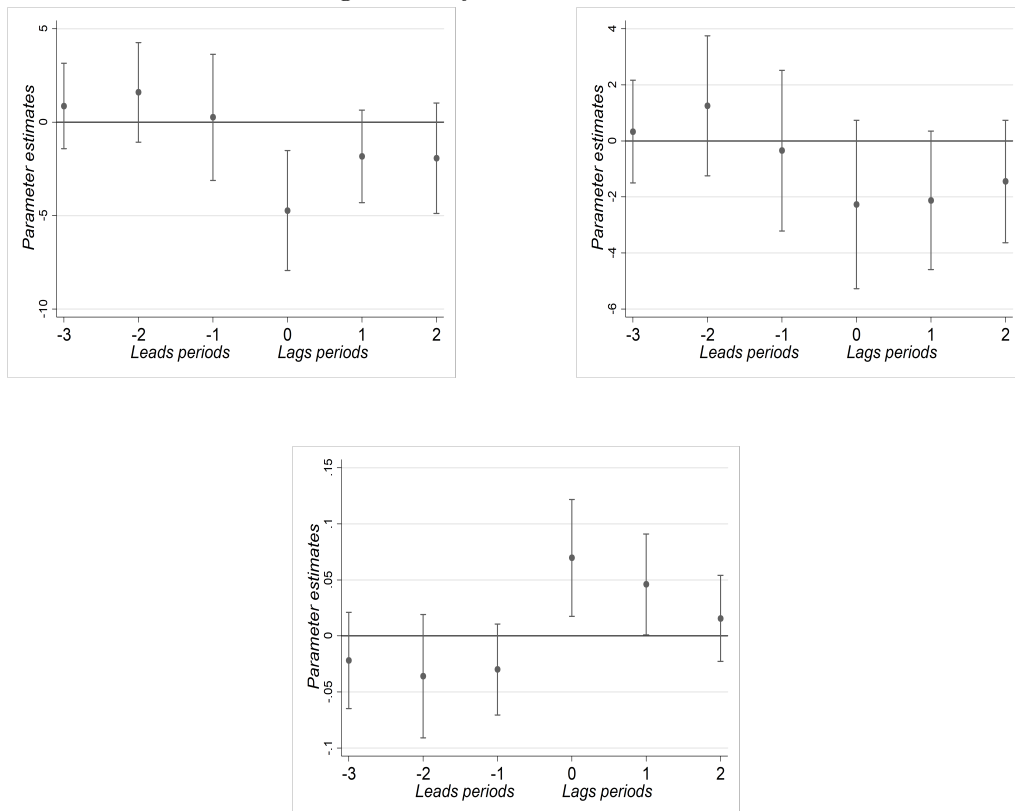
*Notes:* The figure reports the firms' performance variables before and after JA, comparing the variables mean for each year before and after the event.

Figure 4: Placebo Tests



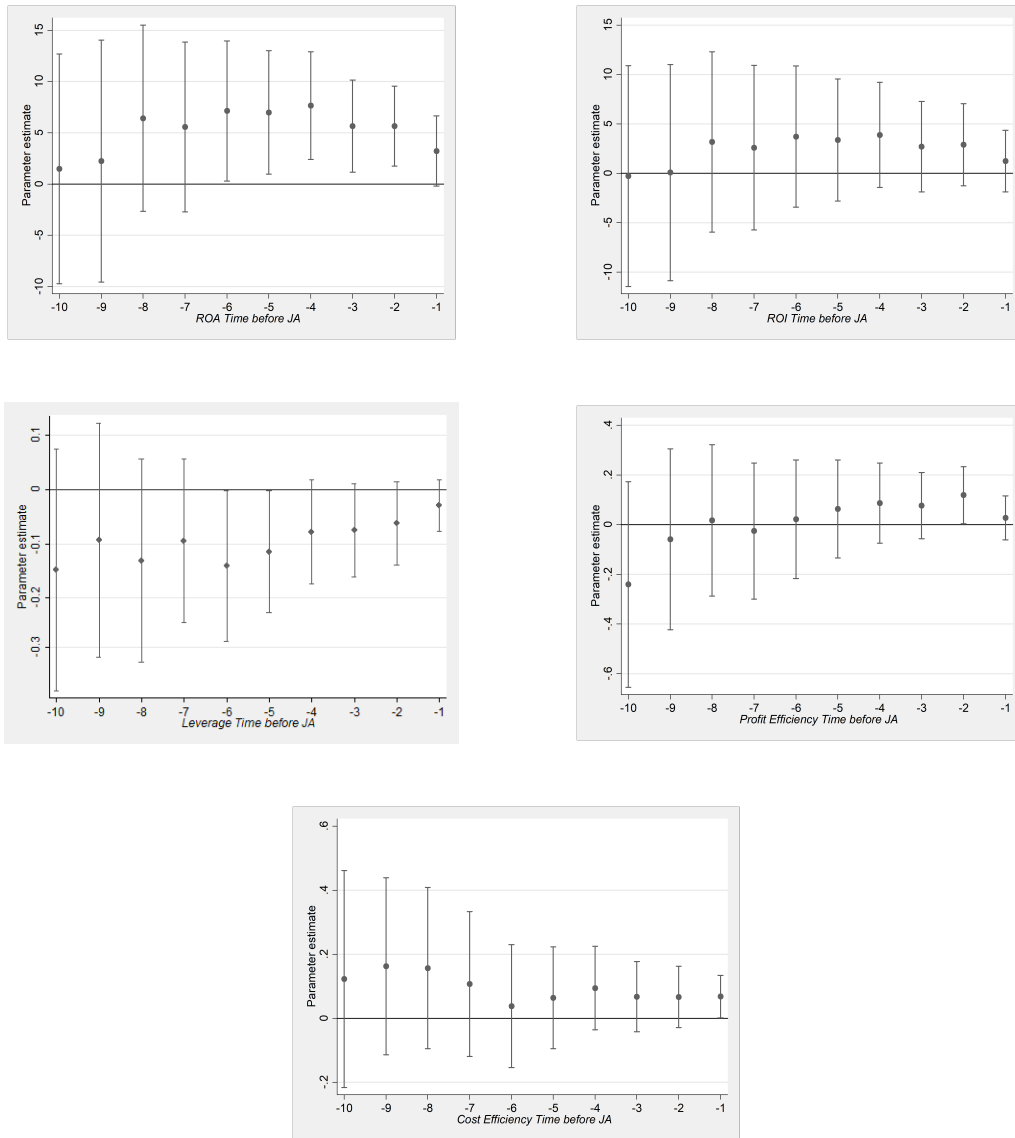
Notes: Probability density function of the coefficients obtained by estimating regression 1, 2 and 3 with the placebo JA dummies as independent variable.

Figure 5: Dynamic effects of JA



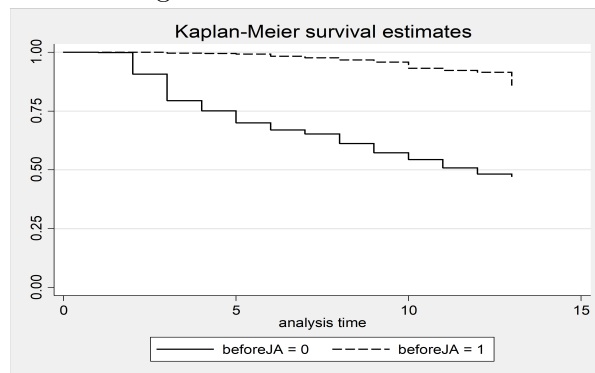
*Notes:* Figures report the estimated leads and lags from 3 years ahead to 2 years behind JA with a 95% confidence interval. Standard errors are clustered at the firm level. They show the impact of JA on firm performance (ROA, ROI and Leverage) for years before, during and after implementation.

Figure 6: Year-on-year change before JA



Notes: The figures show the results of equation 6 along the firm performance aspects. Bars represent 95% confidence intervals. Standard errors are clustered at the firm level.

Figure 7: Survival function



Notes: This figure plots the changes in the survival probability of firms based on the estimation results of the Kaplan-Meier survivor function (equation 7). The vertical axis denotes the survival probability, while the horizontal axis denotes the observation period.

Table 1: Organized Crime Firms–Geographical distribution and summary statistics

| Panel A               |  |                     |                       |                      |                       |
|-----------------------|--|---------------------|-----------------------|----------------------|-----------------------|
| Geographical Area     | AIDA Sources                                   | Other sources       | Total Number          | Final Sample         |                       |
| North Area            | 7  | 47                  | 53                    | 42                   |                       |
| Center Area           | 21   | 9                   | 25                    | 20                   |                       |
| South Area            | 350  | 129                 | 429                   | 351                  |                       |
| Total                 | 378  | 185                 | 563                   | 413                  |                       |
| Panel B               |  |                     |                       |                      |                       |
| Firm characteristics  | Variables definition                           | (1)<br>Mean         | (2)<br>Before JA      | (3)<br>After JA      | (4)<br>Difference     |
| Dependent Variables   |  |                     |                       |                      |                       |
| ROA                   | Net Income/Average Total Assets                | 0.8412<br>(14.1426) | 1.7014<br>( 13.6476)  | -0.8687<br>(14.9426) | 2.570***<br>(3.81)    |
| ROI                   | Net income / Investment                        | 0.8321<br>(11.7632) | 1.4851<br>(11.2464)   | -0.4659<br>(12.6373) | 1.951***<br>(3.47)    |
| Leverage              | Total debt/Total Assets                        | 0.7924<br>(0.4027)  | 0.7844<br>(0.3798)    | 0.8085<br>(0.4444)   | -0.0241<br>(-1.25)    |
| Output                | Ln Added Value                                 | 6.1551<br>(1.7356)  | 6.1536<br>(1.6800)    | 6.1584<br>(1.8473)   | -0.00483<br>(-0.05)   |
| Ln Production Cost    | Ln Production Cost                             | 7.7797<br>(1.5385)  | 7.7999<br>(1.5145)    | 7.7381<br>(1.5881)   | 0.0618<br>(0.66)      |
| CE                    | Cost Efficiency                                | 0.7456<br>(0.2299)  | 0.7709<br>(0.2155)    | 0.6932<br>(0.2492)   | 0.0776***<br>(5.66)   |
| TE                    | Profit Efficiency                              | 0.6940<br>(0.2729)  | 0.7168<br>(0.2584)    | 0.6471<br>(0.2955)   | 0.0697***<br>(4.25)   |
| Independent Variables |  |                     |                       |                      |                       |
| Sales/Ta              | Revenue/Total Asset                            | 0.9584<br>(2.8539)  | 0.9304<br>(2.7895)    | 1.0140<br>(2.9790)   | -0.0837<br>(-0.61)    |
| Size                  | Log(Revenue)                                   | 6.8275<br>(2.0236)  | 6.9245<br>( 1.9548)   | 6.6349<br>(2.1423)   | 0.290**<br>(2.99)     |
| Profit                | EBIT/Total Asset                               | -0.0059<br>(0.3167) | 0.0017<br>(0.3028)    | -0.0209<br>(0.3424)  | 0.0226<br>(1.49)      |
| Fixed Asset           | Tangible+Intangible Assets/Total Asset         | 0.2924<br>(0.4560)  | 0.2633<br>(0.3588)    | 0.3501<br>(0.6004)   | -0.0868***<br>(-3.98) |
| Ln L                  | Ln (N° Employees)                              | 2.4419<br>(1.3326)  | 2.4500<br>(1.3108)    | 2.4251<br>(1.3781)   | 0.0249<br>(0.31)      |
| Ln K                  | Ln(Total Asset)                                | 7.9539<br>(1.8260)  | 7.9205<br>(1.8647)    | 8.0228<br>(1.7438)   | -0.102<br>(-0.93)     |
| Ln L Price            | Personal expenses/N° Employees                 | 3.2590<br>(0.7983)  | 3.2397<br>(0.8093)    | 3.2986<br>(0.7747)   | -0.0589<br>(-1.22)    |
| Ln K Price            | Depreciation and Financial Charges/Total asset | -3.5414<br>(1.2823) | -3.541978<br>(1.2491) | -3.5420<br>(1.3497)  | -0.0589<br>(-1.22)    |

Notes. Geographical distribution for criminal firms in Panel A and Summary statistics in Panel B are reported. In columns (1)-(2)-(3) of Panel B standard deviation in parenthesis. In column (4) of Panel B t-statistics of the difference between the variables in column (2) and (3).

Significance at the 10% level is represented by \*, at the 5% level by \*\*, and at the 1% level by \*\*\*.

Table 2: Profitability Aspects

|                 | (1)                    | (2)                    | (3)                    | (4)                   | (5)                  | (6)                   |
|-----------------|------------------------|------------------------|------------------------|-----------------------|----------------------|-----------------------|
|                 | ROA                    | ROA                    | ROA                    | ROI                   | ROI                  | ROI                   |
| JA              | -3.7638***<br>(1.0481) | -4.4218***<br>(1.5802) | -3.2217**<br>(1.4583)  | -2.1459**<br>(0.9811) | -2.4243*<br>(1.3514) | -2.2161*<br>(1.3415)  |
| Sales/TA        | -                      | -                      | 1.6382***<br>(0.3165)  | -                     | -                    | 2.4535***<br>(0.8797) |
| Size            | -                      | -                      | 1.6851***<br>(0.5514)  | -                     | -                    | 0.9964**<br>(0.4084)  |
| Debt            | -                      | -                      | 16.5173***<br>(3.2557) | -                     | -                    | -                     |
| Year FE         | YES                    | YES                    | YES                    | YES                   | YES                  | YES                   |
| Firm FE         | NO                     | YES                    | YES                    | NO                    | YES                  | YES                   |
| Observations    | 1957                   | 1957                   | 1957                   | 1957                  | 1957                 | 1957                  |
| R-squared       | 0.018                  | 0.5040                 | 0.5985                 | 0.0111                | 0.4367               | 0.5051                |
| Number of Firms | 413                    | 413                    | 413                    | 413                   | 413                  | 413                   |

Dependent variable are indicated in the first row: ROA (1-3) and ROI (4-6). The estimated coefficients are from model 1 in the text. Models estimated are with OLS. Standard errors clustered at the firm level are in parentheses. Significance at the 10% level is represented by \*, at the 5% level by \*\*, and at the 1% level by \*\*\*.

Table 3: Leverage Aspect

|                 | (1)                 | (2)                  | (3)                    |
|-----------------|---------------------|----------------------|------------------------|
|                 | Leverage            | Leverage             | Leverage               |
| JA              | -0.0003<br>(0.0325) | 0.0721**<br>(0.0291) | 0.0597***<br>(0.0267)  |
| Profit          | -                   | -                    | -0.4341***<br>(0.1183) |
| Size            | -                   | -                    | -0.0203*<br>(0.0112)   |
| Fix asset       | -                   | -                    | 0.0866<br>(0.0955)     |
| Year FE         | YES                 | YES                  | YES                    |
| Firm FE         | NO                  | YES                  | YES                    |
| Observations    | 1957                | 1957                 | 1957                   |
| R-squared       | 0.0090              | 0.7791               | 0.8053                 |
| Number of Firms | 413                 | 413                  | 413                    |

Dependent variable are indicated in the first row: Leverage. The estimated coefficients are from model 1 in the text. Models estimated are with OLS. Standard errors clustered at the firm level are in parentheses. Significance at the 10% level is represented by \*, at the 5% level by \*\*, and at the 1% level by \*\*\*.

Table 4: Technical Efficiency

| Variables                                | (1)<br>Technical Efficiency |
|--|-----------------------------|
| Translog production function coefficient |                             |
| lnK                                      | 0.4565***<br>(0.1325)       |
| lnL                                      | 0.3426<br>(0.2812)          |
| lnK*lnL                                  | -0.0929<br>(0.0778)         |
| $\ln K^2$                                | -0.0225<br>(0.0394)         |
| $\ln L^2$                                | 0.1641*<br>(0.0932)         |
| JA                                       | 0.5284**<br>(0.2153)        |
| Constant                                 | -0.5265***<br>(0.1499)      |
| Year Effect                              | Yes                         |
| Observations                             | 1244                        |
| Number of Firms                          | 254                         |
| Mean (TE)                                | 0.6940                      |
| St. Dev. (TE)                            | 0.2729                      |
| Min (TE)                                 | 0.0027                      |
| Max (TE)                                 | 1                           |
| Return scale                             | 0.7991                      |

Robust Standard errors are in parentheses. Significance at the 10% level is represented by \*, at the 5% level by \*\*, and at the 1% level by \*\*\*.



Table 5: Cost Efficiency

| (1)             |                        |
|-----------------|------------------------|
| Variables       | Cost Efficiency        |
| Cost Frontier   |                        |
| lnPL            | 0.0502<br>(0.1531)     |
| lnPK            | 0.1242<br>(0.1063)     |
| lnY             | -0.1027<br>(0.1615)    |
| lnPL*lnPK       | 0.0597<br>(0.0534)     |
| lnPL*lnY        | 0.0738<br>(0.0510)     |
| lnPK*lnY        | -0.0735**<br>(0.0244)  |
| $\ln PL^2$      | -0.0340<br>(0.0221)    |
| $\ln PK^2$      | -0.0076<br>(0.0136)    |
| $\ln Y^2$       | 0.0626*<br>(0.0361)    |
| JA              | 0.8333***<br>(0.2454)  |
| Constant        | -1.4391***<br>(0.1259) |
| Year Effect     | Yes                    |
| Observations    | 1244                   |
| Number of Firms | 254                    |
| Mean (CE)       | 0.7456                 |
| St. Dev. (CE)   | 0.2299                 |
| Min (CE)        | 0.0098                 |
| Max (CE)        | 1                      |

Robust Standard errors are in parentheses. Significance at the 10% level is represented by \*, at the 5% level by \*\*, and at the 1% level by \*\*\*.

Table 6: Effects of Judicial Administration by Sectors

|                 | (1)                  | (2)                  | (3)                 | (4)                    | (5)                   | (6)                   |
|-----------------|----------------------|----------------------|---------------------|------------------------|-----------------------|-----------------------|
|                 | ROA                  | ROI                  | Leverage            | ROA                    | ROI                   | Leverage              |
| Panel A         |                      |                      |                     |                        |                       |                       |
|                 | Labour-Intensive     |                      |                     | Capital-Intensive      |                       |                       |
| JA              | -4.1613*<br>(2.4311) | -1.4210<br>(1.6444)  | 0.0754*<br>(0.0435) | -4.6104**<br>(2.1375)  | -3.0396<br>(2.4657)   | 0.0832**<br>(0.0393)  |
| Year FE         | YES                  | YES                  | YES                 | YES                    | YES                   | YES                   |
| Firm FE         | YES                  | YES                  | YES                 | YES                    | YES                   | YES                   |
| Observations    | 1033                 | 1033                 | 1033                | 924                    | 924                   | 924                   |
| R-squared       | 0.4771               | 0.4711               | 0.8032              | 0.5340                 | 0.4115                | 0.7619                |
| Number of Firms | 222                  | 222                  | 222                 | 191                    | 191                   | 191                   |
| Panel B         |                      |                      |                     |                        |                       |                       |
|                 | Tradable             |                      |                     | Non-Tradable           |                       |                       |
| JA              | -3.3182*<br>(1.9257) | -2.2999<br>( 3.0764) | 0.0510*<br>(0.0291) | -5.0261**<br>( 2.1595) | -2.5419*<br>( 1.3348) | 0.0852**<br>(0.04123) |
| Year FE         | YES                  | YES                  | YES                 | YES                    | YES                   | YES                   |
| Firm FE         | YES                  | YES                  | YES                 | YES                    | YES                   | YES                   |
| Observations    | 605                  | 605                  | 605                 | 1352                   | 1352                  | 1352                  |
| R-squared       | 0.6077               | 0.4356               | 0.7989              | 0.4704                 | 0.4440                | 0.7770                |
| Number of Firms | 124                  | 124                  | 124                 | 289                    | 289                   | 289                   |

(Add) Models estimated are with OLS. Standard errors clustered at the firm level are in parentheses. Significance at the 10% level is represented by \*, at the 5% level by \*\*, and at the 1% level by \*\*\*.

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## Online Appendix

The concepts of production and cost frontier can be studied because production and cost functions in economic theory are functions of the maximum and minimum value of the optimisation problem. Indeed, if I consider an output  $y$  obtained combining a set of inputs  $x$ , then the production function  $y=f(x)$  indicates the map that matches a combination of inputs with the maximum output obtainable using that combination. Similarly, the cost function matches a combination of quantity output  $y$ , and the vector of input prices, with the minimum expense necessary to produce  $y$  at that price. Hence, the profit frontier is specified, looking at the maximum profit possible, and profit efficiency is determined as the ratio of actual to the maximum possible (Kumbhakar et al., 2015). Similarly, the cost frontier is set by the relationship between the potential minimum cost, and the actual cost that resides above the minimum frontier owing to inefficiency. Therefore, in both cases, the frontier is unobserved and is determined by the optimal level (i.e., the maximum level for profit, and the minimum level for cost).

Following Pitt and Lee (1981), the stochastic frontier model for panel data can be written as:

$$y_{it} = \alpha + \beta'x_{it} + v_{it} \pm u \quad (8)$$

Where  $y_{it}$  is the performance expressed in profit or cost forms of firm  $i$  in period  $t$ ,  $x_{it}$  is the vector of inputs or prices,  $v_{it}$  is the statistical noise term zero mean and constant variance, and  $u$  is a one-sided strictly non-negative term representing inefficiency which follows a half-normal distribution, that is,  $u_{it} \sim iidN^+(0, \sigma_u^2)$ . The sign of the  $u$  term is positive or negative according to whether the frontier defines a cost or production function, respectively.

All time-varying models are characterised by the same intercept  $\alpha$  across productive units. This assumption is a cause of misspecification bias, when in the case of time-invariant unobservable factors, unrelated to the production process but related to the output. Consequently, the inefficiency term can capture the influence of these factors, producing biased results (Belotti, Daidone, et al., 2013).

However, the analysis provided in the paper used the Greene (2005) approach, using a time-varying model, which deals with the misspecification issue through a model that can be expressed as:

$$y_{it} = \alpha_i + \beta'x_{it} + v_{it} \pm u_{it} \quad (9)$$

Considering the specific intercept  $\alpha_i$  intended to capture all time-invariant heterogeneities. Using this specification time-varying, inefficiency is disentangled by unit specific time-invariant unobserved heterogeneity. Accordingly, depending on the assumptions on the unobserved unit-specific heterogeneity, Greene defined these models as 'true' fixed (TFE) or random effects (TRE). Following this, the log-likelihood function for the true fixed-effects stochastic frontier model is expressed as:

$$\log L = \sum_{i=1}^N \sum_{t=1}^T \log \left[ \frac{2}{\sigma} \Phi \left( -\lambda \left( \frac{y_{it} - \alpha_i - x_{it}\beta}{\sigma} \right) \right) \phi \left( \left( \frac{y_{it} - \alpha_i - x_{it}\beta}{\sigma} \right) \right) \right] \quad (10)$$

where  $\phi(\cdot)$  and  $\Phi(\cdot)$  are the probability and cumulative density functions of a standard normal distribution respectively;  $\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$  is the standard deviation of the composite error term  $\varepsilon_{it} = v_{it} - u_{it}$  and  $\frac{\sigma_u}{\sigma_v}$  is the ratio of inefficiency standard deviation to noise standard deviation.

As Greene (2005) argued, the simultaneous estimation of all  $N+K+2$  parameters is required because no transformation or conditioning operation will produce a likelihood function that is free of fixed effects. The variance parameters for this half-normal model are given by  $\Lambda^2 = \frac{\sigma_u^2}{\sigma_v^2} \geq 0$ . If  $\Lambda = 0$ , there are no technical inefficiency consequences, and all the deviation from the production function are caused by noise. The error term  $u_{it}$  is the log-difference between the maximum output and the actual output; hence, technical inefficiency is equal to the percentage by which the actual output could increase without adding inputs. The efficiency index (TE) of firm  $i$  in year  $t$  could be written as:

$$TE_{it} = \frac{y_{it}}{\exp(x_{it}\beta + v_{it})} = \frac{\exp(x_{it}\beta + v_{it} - u_{it})}{\exp(x_{it}\beta + v_{it})} = \exp(-u_{it}) \quad (11)$$

where  $0 \leq TE_{it} \leq 1$ .

This indicates the ratio of realised production over the maximum technical output obtainable for a firm (when there is not inefficiency).

The ML estimation of the true fixed-effects variant presents more problems such that the true random effects that can be conveniently estimated using simulation-based techniques. The two main issues of the true fixed effects are related to the estimation of nonlinear panel data models. One is mostly computational considering the extensive dimension of the parameters space. The second one regards the incidental parameters problem that results when the number of units is somewhat large compared to the dimension of the panel. In both cases, since only  $T$  observations are used to estimate each unit-specific parameter,  $\alpha_i$  are inconsistently determined as  $N \rightarrow \infty$  with fixed  $T$  (Lancaster, 2000; Neyman, Scott, et al., 1948). Since this inconsistency

mostly biases the variance parameters, which constitute the key ingredients in the post-estimation of inefficiencies as shown Belotti and Ilardi (2012), the maximum-likelihood dummy variable (MLDV) approach is applied correctly when  $T \geq 10$  (the length of the panel is large).

The Greene model has advantages mainly for two reasons. The TFE models disentangle firm effects (fixed or random) from inefficiency, where inefficiency can either be independent and identically distributed or can be a function of exogenous variables. Secondly, they take into account unobserved heterogeneity, such that systematic differences between firms are considered by including a firm-specific fixed effect,  $\alpha_i$ , which accounts for firm-specific characteristics not captured by the included variables.