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Mustafa Caglayan
(Heriot-Watt University)

Alessandro Flamini
(Università di Pavia)

Babak Jahanshahi
(Università di Pavia)

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Via San Felice, 5
I-27100 Pavia
http://epmq.unipv.eu/site/home.html

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Mustafa Caglayan[†] Alessandro Flamini[‡] Babak Jahanshahi [§]

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Abstract

This paper investigates the organized crime-technology relationship. We show that forced resettlement of bosses affected mafias rooting in northern Italy. Using forced resettlement as an exogenous source of variation, we unveil that mafia reduces technology. Moving from the technology stock to a flow generating it -innovation- we demonstrate that mafia hampers innovation. We argue that without mafia, Nature selects agents for their capacity to innovate. Instead, with mafia, agents face an alternative strategy: relate with mafia; this strategy introduces frictions in competition hindering innovation. Using evolutionary game theory, we show that mafia decreases innovation and how sanctions/indemnities address the problem.

Keywords: Organized crime, evolutionary game theory, innovation, *silent mafia*, technology, technology index, mafia index, northern Italy.

JEL Classification Numbers: O17, O30, C73, R11, K14, K42.

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[†]Heriot Watt University, m.caglayan@hw.ac.uk

[‡]University of Pavia, alessandro.flamini@unipv.it

[§]University of Cambridge and University of Pavia, babak.jahanshahi@unipv.it

"*[Mafias] work in different ways, with intimidations and violence, try to grasp everything, but what should not be forgotten is that it is rare that who endures is not aware of what is happening; it is rare that there are victims 100 per cent innocent. It happens indeed more and more often, that even the very entrepreneurs be the ones that look for mafia's support, because it is the easiest and most secure way to reach determined results.*" Gaetano Saffioti[1]

I Introduction

Every day, all over the world, societies experience criminal offences committed by mafia-type organizations.[2] Drug trafficking, murder, slaughter, arson, illegal disposal of toxic waste, corrupted elections are examples, to name only a few. These daily-frequency crimes attract public attention, and can ruin or end the life of the victims directly involved. Nevertheless, can organized crime damage the whole of society at a lower frequency too? Would part of the society, if left alone, increasingly adapt to or cooperate with mafia-type organizations and, if so, would there be long-lived negative effects on the evolution of the whole society?

In addressing these questions, one can embark upon an investigation from different standpoints. Here, we start by examining very detailed data collected from Italy's northern provinces to show that the forced resettlement of high-ranking mafia bosses to northern Italy significantly affected the location of mafia in that area. Then, using this source of variation we unveil a causal negative effect of mafia on technology levels. To understand this finding we wondered how organised crime could interfere with the process that determines the technology level. Considering that innovation is a flow that adds to the technology stock, we then conjectured that organised crime could harm innovation and, in this way, impact on technology. Testing this assumption, we found fairly large evidence of a significant negative relationship of mafia on innovation.

This result, beyond corroborating the previous findings, poses the following questions: why should organised crime affect innovation? and since innovation is a flow which, by definition

[1] From an interview appearing in *La Provincia Pavese* on the 27 October 2016 with the entrepreneur Gaetano Saffioti who, on January 25 2002, started denouncing 20 years of threats and extortions by 'ndrangheta, which led to the investigation "Tallone d'Achille" resulting in more than 40 arrests. Since then Saffioti has become witness under guard, lost friends, work and public procurements, yet won his freedom back.

[2] Throughout this paper the terms 'organized crime' stand for 'mafia-type organized crime' so that 'organized crime' and 'mafia' are used interchangeably.

refers to a time period, how will this flow evolve in presence of organized crime? will it reduce continuously or will it reach an equilibrium? These questions matter as they allow us to think at the relationship between mafia and technology in an evolutionary perspective *via* the intermediate variable innovation.

We then model how the agents' strategy mutates when mafia organizations enter the picture adopting evolutionary game theory and show that the presence of mafia does reduce innovation by introducing a friction in competition. The model also allows us to discuss how governments can design policies to contain this mutation and in which direction the society would evolve if governments did not take proper action.

To the best of our knowledge, this is the first study which demonstrates a relationship between organized crime and technology/innovation. It is also an initial attempt to discuss how governments can affect the evolutionary path of a country with respect to technology, where account is taken of the presence of mafia-type organizations.

We think that the issues raised here are relevant for all societies. It is well known that technology is a key driver of economic growth and that growth occurs over time. Hence, if organized crime were to adversely impact technology, it should also slow growth down. Second, if in the presence of mafia organizations the strategies of the agents tend to deviate from the standard goal of innovation for adapting to or cooperating with the mafia, it is appropriate to ask if this mutation bears evolutionary consequences on societies and, if so, what governments could do to prevent this process. These hypotheses motivate our work.

A Empirical Approach

To examine the effect of organized crime on technology, we scrutinize data from Italy, as this country has been experiencing mafia-type associations extensively since the 19th century. We look specifically at the provinces in the North for two reasons. First, the massive presence of organized crime in a rich and highly developed area is a new and interesting phenomenon.[3] Northern Italy, indeed, is the richest and most productive area of the country, and also ranks highly above the

[3]The main investigations (*Infinito* in Lombardy and *Minotauro* and *Alba Chiara* in Piedmont) resulted in 198 convictions by the Court of Cassation in 2016. Only for *Infinito* this implied more than eight centuries of prison. As to investigations in 2016 like *Maglio 3* in Liguria or *Aemilia* in Emilia-Romagna the Supreme Court has not yet issued its judgment, but the number of arrested defendants is impressive, 160 for *Aemilia* alone. Regarding organized crime in Veneto, Luana et al. (2015) provide an interesting and well-documented journalistic probe.

median in the European Union. A solid explanation for such a surprising fact seems to include two factors: mafia organizations prefer to colonize areas which produce more wealth (Gratteri and Nicaso, 2016, p. 133)[4], and the so called *silent mafia* approach. The latter is a novel expression of the mafia-intimidation method that avoids striking acts like murder and slaughter, but is effective due to the criminal fame of the head office (Cassazione, 2015; DNA, 2014). The silent mafia approach, thus, contributes to explain why only since 2010 the public in northern Italy has started to realize that organized crime has spread its roots in this part of the country. A relevant question that follows, therefore, is how organized crime would impact on a rich and highly developed area and, in particular, if it could harm its technological level.

Second, northern Italy has experienced an interesting natural experiment with respect to organized crime. On the basis of three laws dating back to 1956, 1965, and 1982, southern Italy courts convicted high-ranking bosses, suspected of belonging to clans, to forced exile in the northern provinces. This special institution remained in force until 1990 so that, for decades, criminals that, *de facto*, belonged to organized crime were sent to the northern provinces. Here, beyond the wealth of the area, what has determined organized crime taking root was its ability to settle a spectrum of relationships with part of the society (Sales, 2015, p. 44); relationships that range from subjugation to cooperation and leverage fears and ambitions of part of the society. Thus, the adaptability of organized crime to the new environment, that is, its skill to change skin well captured by the *silent-mafia* approach, corrupted the immune system of the society and thus slowed down its reaction.

On this basis, we used the natural experiment provided by forced resettlement to instrument organized crime *via* the number of high-ranking bosses belonging to clans who faced forced exile to provinces in northern Italy per province population. This ratio, provides the source of exogenous variation for organized crime that we exploited for investigating to what extent, if any, mafia affects technology.

[4]See also the corroborating reference therein to the 2015 report by the Antimafia Investigative Directorate (DIA), which is the Italian inter-force law enforcement agency that collects intelligence and conducts investigations on organised crime.

B From Organized Crime to Technology

Why should mafia organizations harm technology? Intuitively, the mechanics work through various inter-sector and intra-sector channels, where some type of competition is attenuated or eliminated by mafia organizations leading to a fall in innovation which, in turn, reduces the flow that adds to the technology level.

By recycling illegal profits in specific industrial sectors which tend to be low-tech, the remaining sectors can no longer fairly compete for resources. This directly initiates a brake in innovation and changes the industrial structure of the territory. Nevertheless, the transmission mechanism from organized crime to a fall in innovation and to a change in the industrial structure can be more complex. Although transmission channels tend to be entangled, to fix the ideas it would be useful to present them separately.

One channel works through supplying or imposing private protection to firms[5]; firms that, for example, buy services such as illegal disposal of toxic waste, unfairly compete with their peers. Generally, a fall in competition leads to a fall in innovation (Aghion et al., 2014) and productivity (Nickell, 1996; Blundell et al., 1999; Aghion et al., 2004, 2009). Innovation and productivity, in turn foster technological progress. Thus, we can expect that the private protection industry run by organized crime reduces technological progress.

Another channel works by altering public procurement. Firstly mafia-type associations distort the competition between alternative projects that are financed with public money. Secondly, they distort the competition between bidding firms. Thirdly, if we look at competing incentives for entrepreneurs to start business in different sectors, they distort these incentives making the sectors which are more closely related to public procurement more attractive. All such activities affect the industrial fabric of the society because they favor industries which are associated with mafia-type organizations like construction (Scognamiglio, 2015; Di Cataldo and Mastrorocco, 2016), to the detriment of others.

A final channel works by altering public elections (Alesina et al., 2016; Buonanno et al., 2014; De Feo and De Luca, 2017). In this way organized crime damages competition between candidates, establishes a convenient partnership with the winners elected thanks to the clans' support, and

[5]See Gambetta (1996) for a revealing characterization of organized crime as the business of private protection.

also tends to intimidate the other politicians elected without the clans' support.[6] Clearly, such a channel amplifies the scope of the previous ones. This, in turn, biases politics in favour of mafia-type organizations by means of laws and influence on courts on the one hand, and via decisions and behaviours that favor their economic activities on the other.

Now, focusing on the competition damages that feature in all these channels, we can foresee that in the presence of organized crime innovation is no longer necessarily the leading strategy available to agents for success. The reason is that innovation flourishes in the presence of competition, while the rooting of mafia in a territory occurs *via* its pernicious interactions with the society that alter the competition rules. This leads to another strategy that consists of relating with mafia organizations to survive or prosper. As a result, Nature selects the two strategies according to their ability to replicate which, interestingly, is not constant but depends upon the presence of organized crime. Thus, a larger presence of organized crime results in the greater likelihood that most of the agents will drop innovation in favor of a relationship with the mafia.

C Related Literature and our Contributions

To the best of our knowledge the relationship between organized crime and technology/innovation has not yet been studied. The closer strands of the literature to which this paper relates regard organized crime and firms' performance, and organized crime and economic growth.

As to the first, Albanese and Marinelli (2013) find a negative impact of organized crime on Italian firms' productivity, and that this is due to the power of organized crime to control the territory in which it operates. Ganau and Rodríguez-Pose (2017) investigate how organized crime affects the relationship between the context in which Italian firms operate and their productivity. In particular for small firms, they find that organized crime adversely impacts on productivity by reducing the positive externalities that stem from agglomeration and industrial clustering. Looking at firms in Lombardy, northern Italy, Bianchi et al. (2017) find that corporations with at least one director, whose criminal record displays potential involvement with criminal organizations, show lower levels of cash holdings and profitability due to misappropriation of firm resources.

Regarding mafia and economic growth, Pinotti (2015) considers two regions in southern Italy,

[6] Alesina et al. (2016) show that in Sicily, for the period 1945-2013, mafia-type murders occurring in the electoral season generally deter appointed politicians from openly talking about mafia in the following legislature.

exposed to organized crime after the 1970s, and compares the actual development with their estimated counterfactual development in the absence of organized crime. He shows that the presence of the mafia reduces the rate of growth of these regions. Barone and Mocetti (2014) find an opposite long-term impact of earthquakes on GDP in two different Italian areas, and provide evidence that pre-quake institutional quality matters in explaining this result. Although their variables for the quality of local institutions do not relate directly to organized crime[7], it is interesting to note that most of the area associated with lower long-term economic outcome, Campania, was already permeated by Camorra before the quake.[8]

Adopting forced exile in the identification strategy, the current paper also relates to mafia transplantation. This is defined by Varese (2011) as the ability of a mafia group to operate an outpost over a sustained period outside its region of origin and routine operation. He identifies a special combination of factors that favor the emergence of organized crime in new territories. Specifically, these are the presence of members of the organization in the territory, the absence of other established organized crime groups, and the sudden emergence of new markets where the state is not able to protect property rights. With respect to Italy, mafia transplantation is investigated by Buonanno and Pazzona (2014) and Scognamiglio (2015) who find that forced resettlement is a key factor to analyse the diffusion of organized crime in northern Italy. Buonanno and Pazzona (2014) consider the interaction of this factor along with the large influx of southern migrants to the North and conclude that it favored criminal organization transplantation to the central and northern regions. Scognamiglio (2015) looks at the impact on the industrial sector and finds that organized crime positively affected the construction sector.

Our study makes empirical and theoretical contributions to the literature. The first lies in providing an index of technology at the province level grounded on the technology intensity of the population of all firms. As a consequence, differing from all earlier studies, our empirical investigation employs a fine-grained snapshot of the technological level associated with the industrial fabric for all northern Italy provinces.

Our second contribution consists of developing a mafia-index to portray the new *silent mafia*

[7]These variables measure the intensity of corruption and fraudulent behaviour, scandals involving members of parliament appointed in each region, political participation, citizens' civic engagement.

[8]Regarding infiltrations of organized crime in public procurements during the aftermath of the quake, see p.154-155 and 520-522 of the report by Italian Parliament (1991).

profile of organized crime outside the head office, which is located in southern Italy. The innovation, here, is to employ, for what was possible through data availability, the operating procedure followed by specialized anti-mafia prosecutors at the Italian National Antimafia Directorate (DNA) and Antimafia District Directorates (DDAs).

Thirdly, the current work provides empirical evidence that organized crime has exerted a negative impact on technology in a wealthy and highly developed European area. In particular, we provide evidence that a greater presence of organized crime in a province results in more low-tech industrial structure in that province as a consequence of lower innovation. This finding is new and constitutes the main empirical contribution of our investigation. Interestingly, when we interpret directly this result in terms of balanced growth using the Solow model, it suggests that for a province with median mafia presence, a 10% increase in the presence of organized crime leads to a 1.6% fall in output-per-capita growth.

The last contribution of our study is analytical. Given the negative empirical relationships between organized crime and technology and between organized crime and innovation, we construct an evolutionary game theory model to study the strategy choices of economic agents when mafia enters the picture. By analysing some key interactions between organized crime and the society, we then show the conditions under which the presence of organized crime, through natural selection, leads agents to choose the strategy of relating with organized crime instead of the strategy of innovation. Our theoretical model also shows how to design two policy instruments, sanction and indemnity, to address the problem. To the best of our knowledge, our model is the first attempt to understand the relationship between organized crime and the society based on Evolutionary Dynamics.

The rest of the paper is organized as follows. Section II describes the data and presents, step-by-step, the construction of our new indexes of technology and organized crime. Both indexes are measured at the province level. We then present and discuss the covariates. Section III lays out the empirical model, the identification strategy, the empirical results and the robustness checks. Section IV explains the mechanics underpinning the empirical results: it first describes the key interactions between mafia and society extracting an important commonality: mafia introduces a friction in competition. Next it builds an Evolutionary Game Theory model to explain how this friction in competition can hinder innovation, and how sanctions and indemnities can serve as

useful policy tools to address the problem. Section V concludes the study, also discussing the social implication of these results.

II Data, Mafia Index and Technology Index

We assembled a new annual dataset covering 46 provinces from northern Italy spanning the period between 2005 and 2012. The reason why we focused on provincial data is that provinces are the minimal territorial aggregations from which we can gather sufficient information to characterize the presence of organized crime. We collected data for three groups of variables. The first group is used to portray technology and innovation. As to the former, it consists of firms' revenues per industrial sector, extracted from Orbis, and of census data extracted from IPMUS concerning the university degree attained by each person in the sample and the type of establishment in which the person works.[9] Regarding innovation, it is measured with applications to European Patent Office (EPO) extracted from Eurostat, and with patent applications extracted from the Italian State Archive for the year 1960 when EPO did not exist yet. The second group of variables captures the presence of organized crime and consists of special crimes reported by the security forces to judicial authorities extracted from ISTAT, and of data for exiled high-ranking bosses made available in 1974 by the Minister of the Interior. The third group contains the covariates which have been extracted from *Unioncamere* (Value Added and Total University Graduates), from *Unione Provincie d'Italia* (Households' Deposits), and from the Institute for Research on Population and Social Policies (Migration data).

A Technology Index

To portray the technology level of each province we introduced a technology index consisting of the average of the sectoral technologies weighted by sectoral relative revenues. We built this measure in three steps: First, we associated each industrial sector with its own level of technology in a way that is province-independent. Such a step is crucial because a fine-grained order of sectors in terms of the technology level was missing in the literature as discussed in detail below. We thus obtained a set of sectors ordered by technology. This ordered set acted as a support for the

[9]The set of establishment types is based on INDNAICS industrial codes according to the North American Industrial Classification System developed in 1997.

distribution of industrial sectors in terms of their technology level. Second, each element of this support, i.e., each technology level corresponding to a specific sector, was associated with a weight aiming to capture the mass of that sector.[10] We used as a weight the revenues of the sector divided by the total revenues of the province. For each sector, then, we obtained a sector technology level weighted by its own relative revenues. Third, by summing up sector technology levels weighted by relative revenues we obtained a weighted average of the technology for each province by year. This series acted as one of our two dependent variables.

Going back to the first step, the motivation to build our own set of sectors ordered by technology is that in the literature such a sufficiently fine-grained description of sectors for the phenomenon at issue was not available. Surveying the literature, we found that Heckler (2005) has considered industries to be high-tech if employment in both research and development, and all technology-oriented occupations account for at least twice as much as the average of all industries.[11] Separately, the OECD Directorate for Science and Industry (2011) classified the manufacturing industries into four categories based on R&D intensities.[12]

With respect to the OECD methodology, the key drawback is that one cannot rank services' activities based on direct R&D intensities. Therefore, the ranking is only available for manufacturing industries. Instead, in the methodology adopted by Heckler (2005) the service industries were ranked as well, but sorted into two categories only.

Researchers have used both methodologies in the past.[13] For instance, Raymond et al. (2010) used the OECD's four-group classification to study the persistence of innovation in Dutch manufacturing. Kearns and Ruane (2001) used the OECD sectorial classification to aggregate sectors into

[10] We followed Ciccone and Papaioannou (2009) and used the IPMUS census data to build that support.

[11] Heckler (2005) updated the list of high-tech industries for the three-digit industrial group level in the 1987 edition of the Standard Industrial Classification Manual.

[12] The division of manufacturing industries into high-technology, medium-high-technology, medium-low-technology and low-technology groups was made after ranking the industries according to their average over 1991-99 against aggregate OECD R&D intensities.

[13] Other researchers have also developed their own methodology to classify industries (or firms), or used different sources in comparison with those discussed above. Bustos (2011), in her firm level analysis, constructed a direct measure of spending on technology to study the impact of a regional free trade agreement, MERCOSUR, on technology upgrading by Argentinean firms. This measure included i) spending on computers and software; ii) payments for technology transfers and patents; and iii) spending on equipment, materials, and labour related to innovation activities performed within the firm. Carpenter and Petersen (2002) used the set of high-technology industries based on the United States Department of Commerce classification of high-technology. The list of industries in the sample consisted of drugs and medicinals (SIC 283); office and computing equipment (SIC 357); communications equipment (SIC 366); electronics components (SIC 367); industrial measuring instruments (SIC 382); and surgical instruments (SIC 384), which are highly R& D intensive, in comparison to the rest of the US manufacturing sectors.

four groups to examine the role of the technology level in the relationship between foreign direct investment and economic growth in Ireland. Fallah et al. (2014) used the Heckler (2005) definition of high-technology industries to investigate the role of geography in high-tech employment growth across US counties.

In this paper we propose an index that covers all the industrial sectors and is close in spirit to Heckler (2005). Specifically, we identified high-tech oriented occupations[14] following Heckler (2005) and we computed the ratio of employees who held a degree related to those occupations with respect to all the other employees in each industrial sector.[15]

Figures 1-4 present our own industrial sector classification ordered in terms of technology. The vertical axis shows the ratio of employees with high-tech degrees to all the employees in each sector. The horizontal axis covers all 65 industries in the NAICS divided in four groups assigned to the figures.

B Mafia Index

B.1 Selecting Variables

The origin of organized crime in Italy dates back to the nineteenth century. It was only in 1982, however, that the mafia-type association was considered as a distinguished offence with the introduction of article 416-bis in the Italian Penal Code (P.C.). Since then, the use of indexes aiming to capture the presence of criminal organizations has increased in the literature. Clearly, being illegal, mafia-type associations cannot go public and thus are invisible. Nevertheless, they leave tracks of their presence on the territory by committing crimes that could be detected by the security forces, and which then possibly lead to sentences issued by the judicial authorities. Indexes have subsequently been built using these crimes. Calderoni (2011) used mafia-type murders, mafia-type association, city council dissolved for mafia infiltration, and asset confiscated from organized crime. Transcrime (2013) added variables distilled by open sources (DNA and DIA reports[16]) to

[14] Computer and Information Systems; General Engineering; Engineering Technologies; Biology; Physical Science; Nuclear, Industrial Radiology, and Biological Technologies; General Social Sciences.

[15] The difference with Heckler (2005) is that we do not include employment in R&D as fine-grained sectorial data are not available.

[16] DIA stands for Antimafia Investigation Directorate and belongs to the police force.

those contained in Calderoni (2011).[17] By adding to mafia-type murders other features of the organized crime phenomenon, these indexes represent an important innovation. Indeed, they allow us to reveal, at least partially, the presence of organized crimes also in the central or northern Italy. Here, organized crime is present (as shown for instance by the sentences stemmed by the leading investigation called *Infinito* in Lombardy,[18] or *Minotauro* and *Albachiara* in Piedmont), but mafia-type murders, a distinctive feature of organized crime in southern Italy, are not that common.

Nonetheless, according to (Pinotti, 2015), mafia-type crimes can be severely under-reported due to *omerta*, which is the solidarity with the mafia due to practical interests or fear that leads to willingly abstaining from denouncing crimes, and intimidations. For this reason he uses mafia-type murders by looking at the southern regions where homicides have been a common practice.[19]

Neither approach, however is fit to capture mafia-type organizations in particular outside southern Italian provinces. Indeed, in northern regions, the last decade of investigations and sentences has shown a massive dispersal of 'ndrangheta, which has kept its genotype of *unitary organization* over the country, but has mutated its phenotype in *silent mafia* outside the area of origin.[20]

It is interesting, in this respect, as remarked by DNA (2015) a deep and irreversible mutation of the ways in which the mafia-type intimidation is rooted in the territory. For example, a DDA investigation in Perugia called *Quarto Passo* shows that 'ndrangheta fellows had simply to qualify as members of that criminal association to obtain the subjugation of the victims. Furthermore, the thousands of murders in Calabria throughout the decades to consolidate the force of intimidation were unnecessary as a few violent actions such as damage and arson quickly caused intimidation due to the criminal reputation of the organisation.[21] This mutation implies that organized crime

[17] These variables describe clans belonging to mafia-type organizations in cities and provinces. They include the presence of clans, number of clans, name of the clans, and number of clans for each organized crime association.

[18] *Infinito*, the main enquiry on 'ndrangheta in northern Italy, was run by the Milan DDA and terminated in 2015 with more than 99 percent of conviction sentences confirmed in the first instance, appeal, and Supreme Court proceedings. This investigation represents an historical step in the knowledge of organized crime because it shows that 'ndrangheta rules in northern Italy with a unitary structure.

[19] Pinotti (2015) finds that mafia-type murders and the crime of mafia-type association for Italian regions and for the period 1983-2007 are positively related. Although the crime of mafia-type association can remain unreported, extrapolating backward this relationship allows the author to capture organized crime before 1982 when the mafia-type association crime did not yet exist.

[20] For a definition of 'silent mafia' as a particular expression of the intimidation method characterising mafia-type organisations, which avoids striking offences like murders and/or slaughters, see sentence n. 436/2015 delivered by the Court of Cassation, Cassazione (2015). Sparagna (2015) offers an interesting discussion of the jurisprudence of the Court of Cassation on silent mafia and the mafia-type method.

[21] See also the sentence of the Turin Court of Appeal delivered in the *Minotauro* trial which considers as mafia-

looks like a very inertial phenomenon in the northern area when it is described by previous indexes. Instead, sentences based on both concepts of the unitary nature of the mafia association and *silent mafia* turned out to be very effective to convict criminals belonging to the clans.

The special nature of organized crime in northern Italy is also analyzed in Dalla Chiesa (2017) which provides a categorical index of the mafia's presence based on a rich variety of sources balanced by subjective evaluation.[22] Given our identification approach, we propose an index which is appropriate with the instrumental variable technique and therefore is a continuous variable. A natural and effective way to construct this index is to adopt the investigation standpoint of the DNA and DDAs, the judicial authorities that, respectively, coordinate and carry out anti-mafia investigations in Italy. We thus focus on the same set of crimes that are currently considered most revealing by these institutions to detect mafia-type organisations.

Specifically, according to article 51 c. 3 bis of the Italian Code of Penal Procedure, C.P.P., there is a set of crimes whose exclusive competence belongs to DDAs.[23] This set of crimes has been continuously increasing since 1991 when article 51 c. 3 bis first appeared in the Code. Such an expansion reflects the evolution of the antimafia investigation techniques that need to adapt to tactical changes of mafia-type organisations. Indeed, as suggested by the DNA and DDAs, there are other crimes which are tell-tale crimes and therefore should be included in article 51 c. 3 bis.[24] Or, as argued by the (DNA, 2014, p. 428-437), there should be cooperation between the DDAs prosecutors, ordinary prosecutors, and other institutions working in the same district for the prompt detection of tell-tale crimes. Two cases clearly make the point. While there are few criminal proceedings for slavery and human trafficking, which are an exclusive competence of the

type method, and therefore that art. 416 bis C.P. is applicable, the mere use of the "criminal fame" of the syndicate even without the ascertainment of concrete intimidations. This method is different from that used in the southern provinces from which the criminal association originates.

[22] Our index is consistent with Dalla Chiesa's although the two indexes differ in that the former is continuous while the latter is categorical.

[23] The crimes belonging to this set for which provincial data are available for the whole period 2005-2012 are the following: Mafia-type murders; slaughters; kidnappings; drugs trafficking; mafia-type associations; criminal associations.

[24] See DNA (2014, p. 895-896 and p. 375-379) as to manufacturing and sale of goods made by usurping industrial property titles (art. 517 ter in P.C.) and counterfeiting of geographical indications or appellations of origin of food products (art. 517 quarter in P.C.), which are tell-tale crimes for the more serious crimes of counterfeit, alteration or use of distinctive signs of original works or industrial products (art. 473 in P.C. and referred to in art. 51 c. 3 bis in C.P.P.) and introduction in the country and commerce of false signs products (art. 474, P.C. and referred by art. 51 c. 3 bis in C.P.P.). Similarly for activities of unauthorized waste management (art. 256 in D.Lgs. 152/2006) and illegal trafficking of waste (art. 259 in D.Lgs. 152/2006), which are the most significant tell-tale crimes for the more serious crime of organized activities for the illegal trafficking of waste (art. 260 in D.Lgs. 152/2006 and referred by art. 51 c. 3 bis in C.P.P.)

DDAs, there is a considerable amount of criminal proceedings for pimping and pandering, whose competence instead belongs to ordinary prosecutors. Yet, the two groups of crimes are highly connected as maintained by ONGs working in this field and reported by the DNA. Also, according to DDA prosecutors, arson is a very revealing tell-tale crime. Interestingly, it cannot be under-reported as it is impossible to hide it. In fact, when it occurs it has to be professionally dealt with by the fire brigade. Although not all arson is necessarily mafia-type arson, when it happens security forces and judicial authorities attribute a high chance that it is. The reason is that arson is an effective tool used by the mafia, perfectly consistent with its own essence as captured by article 416 bis, c. 3.[25]

For this reason, whenever data were available, we followed the DNA and DDAs' operating procedure and included tell-tale crimes in our set of variables.[26] We think that this approach offers a substantial innovation in crafting mafia-type indexes.

B.2 Synthesizing Variables

Following this approach, we gathered 14 observed variables which provide tracks of a latent variable, organized crime, and tend to be correlated. It is therefore possible to describe their variability in terms of a smaller number of underlying unobserved variables which, finally, can be condensed into one index. We found it useful to proceed in this way and implemented factor analysis as follows. First, we identified the underlying factors that explain the pattern of correlation within our set of organized crime related variables. Next, we verified the validity of factor analysis using Bartlett and KMO measures. Then Varimax rotation was carried out to minimize complexity of factors by maximizing the variance of loading on each factor. In the next step based on various criteria (e.g. Kaiser Criteria) we extracted the first two factors which explained more than 80% of the total variation. Corresponding factor scores were subsequently produced for each province-year by means of regression method. The importance of the factors depended upon the percentage of

[25] Art. 416 bis, c. 3 reads: "The organisation is a mafia-type organisation when those members who take part in the organisation use the force of intimidation of the member encumbrance and the condition of subjugation and the code of silence that stem from it to commit offences, to directly or indirectly acquire the management and, therefore, the control of economic activities, concessions, authorisations, tenders, and public services or to gain profits or unjust advantages for the organisation itself or for others."

[26] The tell-tale crimes we managed to include are: extortions; trafficking in stolen goods; usury; criminal damages; criminal damages by arson; arson; threats; pimping and pandering. These crimes appear often in the sentences and the official documentation produced by anti-mafia institutions.

variance explained by each. Hence, a composite index was eventually developed as a weighted sum of the scores for each year-province where the weight presents the percentage of the variation explained by the factors. Finally, in order to compute the log transformation of the index we standardized it between 0 and 1 to eliminate the negative values as follows:

$$M_{py} = (S_{py} - S_{min})/(S_{max} - S_{min}), \tag{1}$$

where M stands for the mafia index, py denotes for province-year, and S is the score value of each province-year with S_{min} and S_{max} denoting the minimum and maximum values of the aforementioned score.

C Covariates

Following the literature in the field of technology, innovation and mafia transplantation, in our empirical analysis we control for several variables after standardizing by population. Acemoglu et al. (2006) investigate how the distance from the technology frontier affects economic growth and consider education as their control variable. In our paper we proxy for education by the total number of new university graduates, which suggests the extent of the available skilled labor force.

We next control for value added and households' deposits. The former is a proxy for production related variables (Aghion et al., 2009; Bustos, 2011) and carries useful information about the efficiency of both employees and fixed capital stock in generating quality products. The latter measures wealth, and it is well known that mafia organizations prefer to colonize areas which produce more wealth (Gratteri and Nicaso, 2016, p. 133). Deposits also capture the availability of funds and are essential for the development of innovations via new companies: innovators tap into their own funds long before they seek money through banks or equity markets as such a route would require a track record and success in innovation. [27]

Furthermore we control for migrations. As noted by Buonanno and Pazzona (2014), several prominent sources agreed that massive workers migration from southern Italy to the northern provinces along with forced resettlement of mafia-type bosses favored mafia transplantation. These

[27] A long line of research, indeed, shows that small and new innovative firms experience high costs of capital. Evidence also shows limits to venture capital options, especially in countries where public equity markets for venture capital exit are not highly developed (Hall and Lerner, 2010). To aggravate the problem, in Italy venture capitalism is still far from the EU standards.

authors, indeed, find that the interaction between forced resettlement and migration was key in favoring the transplantation of criminal organizations. For this reason, we also control for migrations to the North from three regions: Sicily, Campania and Calabria which stand out for developing mafia-type organization as of the second half of the 19th century and provided an important migration of workers to the North Italy.

Finally, we control for two provincial specificities. First, size and relevance of the province's capital proxied by a dummy that is set to one when the capital of the province is also the capital of the region[28]; the idea being that provinces where the capital is also the capital of the region may foster technology more than other provinces due to larger public procurements associated with political relevance, and the stylized fact that more densely populated areas are more inventive (Akcigit et al., 2017). Second, provinces' special rights: in northern Italy, Trentino Alto Adige stands out as the only region where its provinces, Trento and Bolzano, enjoy full autonomy. This marks an important difference with all the other provinces which we captured with a dummy. The cross-provinces summary statistics of aforementioned variables and indexes are reported in Table 1.

III Empirical Model and Results

During the initial stages of our investigation, we noticed that some of the current provinces did not exist when southern Italy courts adopted the institute of forced resettlement. In fact, the provinces of *Lecco, Lodi, Rimini, Biella, Verbano-Cusio-Ossola* came into being in 1992, followed by the province of *Monza e Brianza* in 2004.[29] The fact that these provinces did not exist during that period, however, did not mean that convicted bosses were not sent there. In other words, some leading gangsters were resettled in municipalities that later in 1992 or 2004 were carved out from the existing provinces and included into the new ones. Yet, data on organized crime and part of the data on technology are only available for the period post-2005. Indeed, for the pre-2005 period it has not been possible to build the technology index due to problems associated with data

[28] This occurs for the following provinces: Turin, Milan, Genoa, Bologna, Venice and Trieste.

[29] Concerning borders, each of these provinces was created by reorganizing one or more of the existing northern provinces.

availability[30], and data on the crimes capturing the presence of the special *silent mafia* in the North were incomplete.

We argue that this mismatch between the forced resettlement dataset, and the technology and organized crime datasets could potentially bias the analysis. We thus addressed the issue by reconstructing six synthetic provinces corresponding to the six new provinces that were created later and inserting these provinces in the forced resettlement dataset. This was achieved by retrieving information on the municipality where each boss was sent to and locating the province where that municipality is currently situated. In this way, we obtained the effective distribution of bosses over the actual provinces the other datasets refer to.

Having eliminated the mismatch of the datasets, we examined the impact of organized crime on technology using aggregate data and allowing for the fractional nature of the dependent variable. Indeed, since the technology index is in per capita terms, we used the Fractional Probit model[31] and estimated the following cross-sectional model:

$$E\left(T_i \mid \boldsymbol{X}_i, M_i, \epsilon_i\right) = \Phi\left(\boldsymbol{X}_i\boldsymbol{\beta} + \gamma M_i + \epsilon_i\right), \tag{2}$$

where i captures the unit (province), Φ is the probit function, T indicates technology, $\boldsymbol{X}$ the vector of control variables, M the presence of mafia, and ϵ an omitted factor potentially correlated with the mafia presence but independent of the exogenous variables $\boldsymbol{X}$. Equation (2) is the structural equation and γ is the coefficient of interest: the impact of mafia on technology. We expect to find that γ would take a negative sign: An increase in the organized crime would reduce the extent of technology. Before turning to the results, we present how we dealt with the potential endogeneity between organized crime and technology.

A Identification Strategy

In our examination of the relationship between organized crime and technology, we paid special attention to the estimates obtained from the control function methodology. We felt that this approach was important in a study such as ours where the endogeneity problem may affect the

[30] The Orbis data-set, which is the most complete source of firm-level data, starts in 2005 to provide data also for small firms, which are key in the Italian industrial fabric.

[31] This is important because with standard linear models it is difficult to impose a positive yet bounded effect of explanatory variables on the dependent variable.

results due to the potential correlation between the explanatory variables and the disturbance term. If the residual (ϵ) in equation (2) was correlated with the mafia index due to reasons such as omitted variables or reverse causality, this would lead to biased parameter estimates. For instance, one would arrive at a biased estimate for the effect of organized crime if one were not able to properly control for all of the determinants of technology at the province level, such as the efficiency of local provincial institutions, which may also affect the presence of organized crime. Or, results could be biased because some specific provinces could attract more organized crime due to the specialty of their industrial technology profile.

Now, with a probit model, an appealing way to surmount the endogeneity problem is provided by Rivers and Vuong (1988) who developed a control function approach when the explanatory endogenous variables are continuous. This approach is discussed for example in Wooldrige (2010) and is, inherently, an instrument variables method. Accordingly, we add to the structural equation (2) an equation that models the potential esplicative endogenous variable in equation (2) as a linear function of the exogenous variables $\boldsymbol{X}$, but that needs to have at least one exogenous variable that causes variation in T not appearing in $\boldsymbol{X}$:

$$M_i = \boldsymbol{\alpha}\boldsymbol{X}_i + \delta B_i + \upsilon_i, \tag{3}$$

where B stands for the high-ranking bosses convicted to forced resettlement and υ is the error. Next, assuming that

$$\epsilon_i = \kappa\upsilon_i + e_i, \qquad e_i \mid \boldsymbol{X}_i, B_i, \upsilon_i \sim \text{Normal } \left(0, \sigma_e^2\right),$$

we can apply the control function approach that consists of two steps. In the first, we obtain the OLS residuals υ_i from the regression of M_i on $(\boldsymbol{X}_i, B_i)$ which are the control functions. Then, in the second step, we use the fractional probit of T_i on $\boldsymbol{X}_i$, M_i, $\widehat{\upsilon}_i$ to estimate the coefficients.

Our control function/ instrumental variable approach adopted the episode of forced resettlement to instrument the organized crime variable. As in Buonanno and Pazzona (2014) and Scognamiglio (2015), we used as an instrument the number of convicted high-ranking bosses who faced forced exile to provinces in northern Italy per province population. This ratio provides a source of exogenous

variation in mafia that we conjectured to be initially responsible for the subsequent low-tech mutation in the industrial fabric of the provinces. Figure 5, Panel A plots the technology index against standardized exiled mafia bosses. It shows a negative relationship: provinces that experienced forced resettlement more in the past feature lower levels of technology recently. The first question then is how this virus spread in the municipalities where bosses were sent and next contaminated the surrounding areas. To answer this question it is instructive to consider the two-regime scheme proposed by Dalla Chiesa (2017) consisting of a *necessity regime* and a *freedom regime*. The first, *necessity regime*, spans the 1950s to early 1980s and deals with the origin of the mafia in northern Italy. During this regime, forced resettlement, also due to negligence and superficiality of police forces, triggered a sequence of events that generated the first organized crime cell in a territory: senior boss arrival; building of a group of friends/affiliates; transplantation of criminal behaviours in a healthy area; and contagion.[32]

As noted by Dalla Chiesa (2017), in the same period there were bosses who either escaped or freely travelled North, thus contributing to the origin of organized crime in northern Italy. Moreover, focusing on small municipalities, he describes cases as *Buccinasco* that did not experience forced resettlement but offered a very fertile substrate for organized crime development due to local corruption. For these reasons, we share the view that forced resettlement cannot be considered a necessary condition for the origin of organized crime in northern Italy. Nevertheless, forced resettlement until the early 1980s was predominantly responsible among the joint causes that originated organized crime in the North as it provided a substantial exogenous flow of high-ranking bosses to the North.[33]

But how did organized crime further develop in northern Italy given the forced resettlement background? From the mid-1980s to nowadays the main flow of bosses that arrived in the North consisted of criminals that freely chose to go North attracted by the business opportunities of a wealthy and high developed area. Although forced resettlement was still intermittently used, this flow dramatically decreased and lost significance which is why this second period, opposed to the

[32] In this respect, hundreds of organized crime kidnappings occurred in the North during the 1970s were almost always close to villages where bosses had been resettled. This clearly reveals how the initial cells were already operative and became rooted in the territory by relating with the local society. Indeed, kidnapping requires an adequate control of the territory to be carried out, Dalla Chiesa (2017, p. 30)

[33] Dalla Chiesa (2017) notes that a complete accounting of forced resettlement is missing and its size can be assessed with some partial data, e.g., the figure by *Commissione parlamentare antimafia per la XI legislatura*: 1079 stock of people in 1994 stemming from the previous decades' flow.

first, has been called the freedom regime. This is the period in which northern Italy started to be crowded with bosses, including second-generation bosses. Importantly, these bosses tended to be connected with the previous organized crime networks on the territory.

Back to forced resettlement, it is worth noting that its application to organized crime has been governed by a sequence of laws. In the first and the second law, dated back to 1956 and 1965, it is not specified any criterion for the choice of the place to resettle the bosses. Only with the third law in 1982 - well known in Italy as *Rognoni-La Torre law* because it also introduced article 416 bis in the penal code - it is specified that the municipality should have no more than 5 thousands inhabitants and be far away from large metropolitan areas in order to ensure an effective monitoring of the people undergoing forced resettlement.[34] It is worth noting that the available data on forced resettlement refers to the period where the two initial laws were currently in force. So, for this period which is within the necessity regime, the law did not specify any criterion for the assignment.

Furthermore, there is no evidence that in northern Italy some provinces were preferred to other provinces for forced resettlement. Nevertheless, as it will be discussed in section III D, we investigated the possibility that the choices concerning forced resettlement could have been affected by the technology level of the provinces. Anticipating the results, we did not find any evidence that the technology level of the provinces impacted on the forced resettlement choices.[35]

Focusing on the relationship between forced resettlement and technology, when the high-ranking boss undergoes the preventive measure and is forced to resettle in the North he faces two alternatives: either starts behaving honestly, or tries keeping the status of organised crime boss.[36] In the former, he is a single unit within a community and there is no reason why he will have any impact on that community which affects negatively technology in the next decades. In the latter, he will adapt to the new territory his previous criminal experience to continue to be a mafia boss. To do so, the first necessary step is to set up a criminal group. But which type of criminal group? a mafia-type group, as it is the one he is more familiar with and, above all, the most effective one.

[34] The identification numbers of the three laws are respectively 1423, 575, and 646. Despite the Rognoni-La Torre law, convicted bosses, due to politics, were often sent to villages with plenty of business opportunities close to big cities like Milan and Turin, and under lazy and lenient monitoring that did not prevent them from meeting people and running daily business trips freely (Dalla Chiesa, 2017, pp. 46-47).

[35] Should the technology level of the province affect forced resettlement, then the instrument would not be randomly assigned with respect to technology.

[36] *Tertium non datur* as the pathopsychological profile of the high-ranking mafia boss tends to be inconsistent with criminal activities outside organized crime.

It is worth recalling that article 416 bis, which introduced in the Italian penal code the crime of mafia association defines mafia

> "[*W*]*hen those members who take part in the organisation use force of intimidation as the member encumbrance and the condition of subjugation and the code of silence that it derives from to commit crimes,* [...]"

This is what makes that special group so powerful and then, by means of that group, allows the boss to organize crime activities in the new territory which, ultimately, will affect the industrial fabric of that territory and therefore its technology level. For this reason, we think that it is plausible that the impact of the instrument (forced resettlement) on the outcome (the level of technology), can only occur via the treatment (the organised crime presence).

B Organized Crime and the Technological Fabric

In estimating the relation at issue, we first assumed that the explanatory variables are exogenous. We, then, allowed for the possibility that the mafia index could be endogenous and addressed the potential endogeneity of the explanatory variables with the control functions-instrumental variable approach.

Table 2 presents the parameter estimates and the robust standard deviations for the exogenous and endogenous cases. The standard errors in parentheses are fully robust and are obtained by 400 bootstrap replications. Table 2 shows that the effect of organized crime on technology is negative and highly significant. In the exogenous case, the coefficient is -0.028 and -0.034 excluding and including the control variables into the model respectively. Turning to the endogenous case, the first-stage coefficients are positive and significant and the F-test statistics are well over 10 suggesting that our model is not subjected to the weak instrument problem. Moving to the second stage, the coefficients of interest are -0.17 and -0.09, excluding and including the control variables, and the estimates of the control functions (i.e. $\hat{v}$) provide evidence against the null hypothesis that the mafia index is conditionally strictly exogenous.

Following Wooldrige (2010) we next provided estimates of the partial effect averaged across the provinces (APE) to gain a better understanding of the magnitude of the mafia effects on technology.

When we consider the endogenous case with controls reported in column 6, which is our main specification, the APE estimate implies that the elasticity of the technology index to the mafia index is 0.16 signaling a non negligible impact. To fix the ideas, we can consider, for example, a province with median mafia presence and let this province experience a 10% increase.[37] As a result the technology index for that province will fall by 1.6%. One may wonder what it would mean for a society to experience a 1.6% drop in technology as a consequence of a 10% increase in organized crime. Using continuous compounding we can show that that society will experience 7.68% less technological accumulation in five years, 14.78% less accumulation in 10 years and 32.96% less technological accumulation in 25 years in comparison to the cases where no such increase in mafia activities is observed.

Interestingly, taking our technology index as a proxy for the technological progress, and using the Solow model to make predictions, we gather a *prima facie* assessment of the impact of mafias on economic growth. Indeed, according to the Solow model, on a balanced-growth path, the rate of growth of output per capita equals the rate of growth of the technological progress. Thus, the 1.6% fall in technology, which we have found if the province with median mafia presence experiences a 10% increase in organized crime, suggests that that province would incur a loss in the growth of output per capita in the range of 1.6%. This result is substantial and could help to explain why Italy has not grown since the mid-1990s.

Given the unveiled relationship between organized crime and technology, the following section addresses the question: How does organized crime harm technology?

C Organized Crime and Innovation

To understand why mafia harms technology we wondered how organized crime can interfere with the process that determines the technological level. We thus focused on the innovation rate - the flow that adds to the technology stock - and following the literature on innovation, we captured this variable with patents applications. Then, given the stock-flow relationship between technology and innovation we tested if our technology index was related with innovation and found a correlation

[37] With 46 provinces, the median mafia index is the average of 23rd and 24th province's mafia index levels. Thus, increasing this value by 10% turns out to move that province from the 23rd/24th position (the median) to the 28th/29th position, which is a reasonable shift. It is also possible to calculate a one standard deviation increase in mafia index. But this would imply that for the median province the mafia's activities will increase by more than 65%, which would be an unrealistic increase. The resulting calculations are available from the authors upon request.

equal to 0.5255 statistically significant at the 0.01 percent level. We thus conjectured that if organized crime negatively impacts on technology this should occur *via* the intermediate variable innovation. A preliminary test of this conjecture is provided in Figure 5, Panel B, which plots standardized patent applications against standardized exiled mafia bosses. It shows a negative relationship: provinces that experienced forced resettlement more in the past feature lower levels of innovation recently. This finding, in line with our previous empirical results, led us to examine the extent to which, if any, organized crime harms innovation.

Since standardized patent applications is a fractional response variable, also in this case we use the Fractional Probit model and estimated the following relationship:

$$E\left(P_i \mid \boldsymbol{X}_i, M_i, \epsilon_i\right) = \Phi\left(\boldsymbol{X}_i\boldsymbol{\beta} + \gamma M_i + \epsilon_i\right), \tag{4}$$

where P indicates standardized patent applications. As to the potential explicative endogenous variable, we account for it like in the previous analysis and use equation (3) to obtain the control functions. Table 3 reports the coefficient estimates: The first two columns show the results when organized crime is considered to be exogenous, while the last four when it is considered to be endogenous. In both cases, the findings provide evidence that organized crime has a negative effect on the number of patents per province population. Similar to Table 2, when we include the control variables in the model, as we consider the possibility of endogeneity, the coefficient estimates remain negative and significant confirming the robustness of the results. Furthermore, the estimates of the control functions (i.e. $\hat{v}$) provide evidence against the null hypothesis that the mafia index is conditionally strictly exogenous. Regarding the magnitude of the findings, we can reconsider a province with median mafia presence and let this province experience a 10% increase. As a result, standardized patent applications for that province will fall by about 9% which is a sizeable effect.

In this section we have shown that organized crime affects negatively innovation. Since innovation is a flow that adds to the technology stock we can turn our attention on how mafia harms technology via innovation. The reader not interested in the robustness analysis can thus skip the next section to focus directly on this basic question.

D Robustness Analysis

To check the robustness of our findings and the validity of our instrument, we run a number of experiments focusing on four key aspects of the analysis: 1. the sensitivity of our findings to an alternative econometric model, 2. the exclusion of the synthetic variables, 3. the credibility of the instrument (the random assignment of the instrument and the reduced-form relationships), 4. the robustness of the results with respect to potential outliers.

As to the first aspect, the interest on the relationship between organized crime and innovation - stemming from the stock-flow connection between technology and innovation - also allowed us to use an alternative model to the Fractional Probit. Indeed, using patent applications as a count variable like, for example, Blundell et al. (1999) we could switch to the Poisson model. Thus, rather than examining the effect of organized crime on the number of patents per province population, we directly examined the relation between organized crime and the number of patents. Corroborating the previous findings, Figure 5, Panel C, plots patents against forced resettlement and shows a negative relationship between these variables. Moreover, Table 4 reports that the effect of organized crime on the number of patents is negative and significant and, similar to the previous results, this effect is increasing when we consider the presence of endogeneity.

Regarding the exclusion of the synthetic provinces, Tables 5-7, duplicate the regressions undertaken in Tables 2-4 after eliminating the synthetic provinces from the data-set. The findings remain very much similar to the previous ones suggesting the robustness of our results.

We next further assess our identification strategy which is based on the random assignment of high-ranking gangsters to the northern provinces with respect to technology and innovation. In order to check that bosses have not been exiled to the northern provinces on the basis of some of their technological determinants, we examined the relationship between standardized exiled bosses and standardized patent applications at the beginning of the forced resettlement period.[38] Our results reported in Table 8 suggest that the forced resettlement of mafia bosses in the northern provinces was not based on some technological feature of those provinces. We also provide further evidence concerning the credibility of our instrument running the reduced-form regressions as in Levitt (1996); Angrist and Lavy (1999); Acemoglu et al. (2001); Angrist and Krueger (2001);

[38] In running this experiment, we followed the previous literature, see for example Akerman et al. (2015).

Murray (2006).[39] Table 9 contains the findings and shows that all the coefficients of exiled bosses are negatively significant.

Regarding the last aspect, the robustness of the results as to potential outliers, we investigated the residual plot against fitted values for the first stage of our regression. From Figure 6 one can notice that all the residuals are distributed around zero and there is no obvious candidate for outlier. Following Li (1985)'s procedure, we also estimated a robust regression with respect to outliers and our coefficients remain significant. These findings are available for the interested reader upon request.

IV Evolutionary Mechanics: Organized Crime, Natural Selection, and Technology

Having shown that mafia impacts adversely on innovation, the first step to understand why we observe this relationship was focusing on how organized crime relates with entrepreneurs and politicians and searching for commonalities. This step led us to think that mafia, generally, introduces a friction in competition which causes a brake on the agents' incentives to innovate.

The premise to explain why this happens is that without organized crime, natural selection uses the ability to innovate as the main criterion to select who survives or prospers. When organized crime is present, however, this is not necessarily the case. We argue that, depending on the presence of organized crime, the ability to innovate can stop being the main criterion that Nature uses for selection as the strategy consisting of *innovating*, hereafter (I), may no longer be the main strategy to succeed, and, therefore, its replication declines. However, when organized crime is present, its mere capacity to eliminate or attenuate competition delivers another strategy which is captured by two behaviours: 1. Adaptation, i.e., not resisting subjection to the mafia in order to survive; 2. cooperation with the mafia to try to achieve faster growth. Thus, these behaviours define a new strategy that consists of *relating with mafia*, hereafter (R), and that strategy is counter to innovation as it will be explained in Section B.4.

Now, the existence of strategy (R) when organized crime is present implies that the criterion for

[39] According to Murray (2006) the reduced-form regressions, where the dependent variable of interest is regressed on the instrumental variable, provide valuable information to check the intuition of the validity of the instrument.

natural selection is no longer exclusively the ability to innovate but also the ability to relate with organized crime. As discussed below, since a larger presence of organized crime in the territory, results in a larger fitness of strategy (R) and smaller fitness of strategy (I), the role played by the second criterion in the natural selection process will be increasingly important up to and exceeding the first, the ability to innovate. Thus, choosing innovation (I) becomes a less successful strategy, while choosing to relate with the mafia (R), that is, subjection to and/or cooperation with mafia, becomes more successful. Hence, overall innovation falls. An illustrative example is the case of Mr Fiduli (Saviano, 2013, p.198-204). [40] Mr Fiduli is a brilliant entrepreneur able to innovate, who courageously denounces 'ndrangheta's attempts of extortion backed by thefts and vandalism, crimes that increasing its costs make the firm more exposed to the business cycle. Yet, when the economy slows down, clients stop paying and banks stop financing, he can no longer confront competition and faces the trade-off between default or subjugation to organized crime. This is the point where strategy (I) mutates to (R).

A mafia-type organization is, thus, an institution that adversely affects technology. This happens by introducing a friction in competition that modifies the natural selection process of the agents, which in turn, *via* a fall in the innovation rate, causes a decline in the technological level.

A Organized Crime Harmfully Mutates the Industrial Fabric of the Territory

We now focus on how mafia-type organisations, through the natural selection process, foster a mutation of the (I) strategy into the (R) strategy, thus, diverting the firms' distribution towards low-tech industrial sectors and, generally, reducing innovation. Although the mechanics of this mutation works through various inter and intra-sector channels which tend to be entangled, it is clearer to present them separately. Interestingly, in all of the cases organized crime stands out as a friction in competition.

A.1 Money Laundering and Credit Availability: an Inter-Sector Channel

Money laundering is necessary to fully enjoy illegal profits. Since it occurs by recycling illegal money into specific industrial sectors, the remaining sectors can no longer fairly compete for resources. For example, commercial centres or restaurants, which are low-tech and among the main

[40] Here, we refer to the Italian version but also report, in the References section, the English translation.

sectors controlled by organized crime (Transcrime, 2013), can grow faster due to easy access to illegal funds.[41] Instead, high-tech startups lag behind as they are generally required to follow strict procedures to obtain finance due to the presence of asymmetric information.

As a consequence, especially in the absence of a track record or collateral, innovative new startups experience difficulties in raising funds. Given the importance of access to capital in the innovation process (Akcigit et al., 2017), these firms will possibly defer or drop innovative plans that require large amounts of funds, thus limiting their competitiveness and growth opportunities. As a result, economic agents will have an incentive to enter the sectors controlled by organized crime rather than other sectors. Indeed, all else equal, this means increasing the likelihood to obtain finance and, therefore, survive and/or grow faster. Since the industrial sectors more connected with organized crime are low-tech, such a channel directly reduces the technological level of the industrial structure of the territory.

How does the presence of organized crime impact on the fitness of strategy (R) and (I)? Clearly, the larger money laundering, the lower (R)'s financing costs and therefore (R)'s fitness increases. Now, a larger fitness of (R) leads to a faster replication of (R) and, therefore, its frequency increases leading to an expansion of the low-tech sectors. But if the number of enterprises such as restaurants, construction firms or hotels increases, then organized crime would continue to grow. This happens because mafia-type organizations tend to impose their workforce and increasingly expand their network relations, thereby entrenching the territory with their presence. More organized crime, in turn, implies that the (R) strategy becomes more successful, in other words its fitness continues to rise. We are thus facing a vicious cycle.

We can now turn to the fitness of (I). Will it be affected by the presence of organized crime? Bonaccorsi di Patti (2009) found that in the Italian provinces where organized crime is more present, firms pay higher interest rates and experience less access to credit. We share her reading that in a territory with high crime borrowers are more fragile. For example, due to extortion payments, or to aggression such as arson if the firm chooses not to pay protection money, the likelihood of default is higher. Thus, the asymmetric information problem becomes exacerbated in the presence

[41] Using assets seized and confiscated from organized crime as a proxy of its investments in the legal economy, Transcrime (2013) finds that the preferred sectors seem to be wholesale and retail (29.4 percent) and construction (28.8 percent), followed by hotels and restaurants (10.5 percent) and real estate companies (8.9 percent).

of organized crime leading to higher interest rates and less access to credit.[42] This implies that the financing costs of (I) increase and (I)'s fitness falls when the presence of organized crime increases.

A.2 Private Protection: an Intra-Sector Channel

A second channel in which the mutation of strategy (I) into (R) takes place consists in the private protection of firms. Organized crime *imposes* or *offers* private protection through a variety of illegal services that lead firms, in some cases, to simply accept subjugation while in others to attempt some type of cooperation. In both, the fitness and frequency of the two strategies evolve according to the presence of organized crime.

Considering the *imposition* of private protection, choosing strategy (R) means not resisting subjection to the mafia in order to avoid risks to own life and firm. Examples include extortion, illegal imposition of workforce[43], and illegal imposition of suppliers.[44] Agents who choose (I) reject the imposition of illegal services and incur extra costs in the form of threat, arson, damage, aggression, murder. These costs lead to losses and often to default. As a result the fitness of (I) decreases. Instead, agents who choose (R) and accept the imposition of illegal services can generally survive; otherwise, the illegal payments' flow from their firms to organized crime stops. Overall, the mafia's attempt or success in imposing illegal services is a burden for the firm, and thus it can no longer fairly compete with its peers.

Considering the *offer* of illegal services, firms that follow strategy (R) and purchase services such as an illegal workforce[45], illegal disposal of toxic waste[46], elimination of competitors, and suppliers' imposition, unfairly compete with their peers on the market. Indeed, they have an advantage consisting of lower costs or extra revenues.[47] Now, the larger the advantage obtained by

[42] See Bonaccorsi di Patti (2009).

[43] In this case organized crime imposes his workforce upon the firm, thus preventing the firm from choosing the workforce that best suits its production activity, which negatively affects its profits.

[44] Suppliers' imposition is a cost for the firm that is not free to choose its suppliers, but is an extra revenue for the firm that has its products imposed to other firms. As argued by Gratteri (2016, p. 54) " 'ndrangheta is everywhere in the industry but it is mostly present in the supply industry. If the affiliates, for example, protect the interests of a coffee factory, they will impose on bar and restaurants in the area to buy only that type of coffee. The same happens with doors, window fixtures, toilets, tiles."

[45] In this case, illegal/undocumented workers are exploited by organized crime which supplies their under paid labour without labour rights protection to firms that buy this service.

[46] The *Star Wars* investigation run by Milan Provincial Police revealed 178 thousand cubic meters of toxic and hazardous waste illegally disposed of over 65 thousand square meters of Lombardy agricultural land. *Star Wars* was the first important investigation on the 'ndrangheta penetration in the illegal waste business. Notably, it contributed to the background of *Infinito* the major investigation on 'ndrangheta in northern Italy.

[47] See Varese (2006) and Dalla Chiesa (2017) along with the references therein for evidence on the following further

illegal services, the more honest competitors choosing (I) will be crowded out unless their ability to innovate more than offsets the advantage of the firms choosing (R). Indeed, without illegal services, all else equal, their profits will be smaller. Furthermore, their market share will be eroded by firms that choose (R), thus reducing profits more and increasing (I)'s vulnerability to possible dumping practiced by firms (R) or to exogenous shocks like a recession.[48]

All this means that in the presence of the mafia the fitness of (R) increases whereas the fitness of (I) falls, and this directly reduces innovation. Yet, there are two further reasons why innovation falls at the aggregate level. First, if we look at incumbent firms, a decrease in competition among these firms generally leads to a decrease in innovation (Aghion et al., 2014) and productivity (Nickell, 1996; Blundell et al., 1999; Aghion et al., 2004, 2009). Second, the relation between incumbent firms and new entrants is distorted leading to misallocation of resources and thus a fall in innovation. Indeed, the availability of illegal services, by increasing revenues and/or decreasing costs, allows low productive firms to survive. Put differently, illegal services work as a policy to subsidize the continued operation of low-productive incumbents. While an optimal policy should encourage the exit of low-type firms and support R&D by high-type incumbents and entry (Acemoglu et al., 2013), in the presence of organized crime the opposite happens: Illegal services act as a subsidy that prevents creative destruction, that is, low productive firms to be replaced by new more productive ones. Interestingly, resources misallocation has been documented in northern Italy since the mid-1990s (Calligaris et al., 2016).

A.3 Public Procurement: an Inter and Intra-Sector Channel

Public procurement is the third channel that affects the frequency and fitness of strategy (I) and (R) in the presence of organized crime. Firstly, mafia-type associations, by illegally lobbying or cooperating with administrators/politicians, or by direct action when mafia-associates are, themselves, administrators/politicians, distort the competition between alternative public projects. This happens because choosing projects according to organized crime preferences rather than society preferences is a strategy that allows consolidation of the politician's power the more organized

illegal services: intimidation of customers, workers, and trade unionists for the benefit of employers; intimidation of lawful right-holders; debt recovery; bogus invoices; false experts' reports.

[48] With respect to the financial and economic crisis started in 2008 Gratteri (2016, p. 55) maintained that "Many small and medium-sized enterprises faced a crossroads: on the one hand the certitude of default, on the other hand to make business with organized crime. In many cases they chose the second way".

crime is entrenched in the territory. And, importantly, the mafia's preferences favor projects in low-tech sectors, e.g. construction, because from these sectors it is simpler to misappropriate public money destined to the project. In this respect, Di Cataldo and Mastrorocco (2016) show that in Italy local governments infiltrated by organized crime experience a 14% increase in the share of total investments in construction and waste management along with a 29% decrease in police force investment. What would be the alternative innovative strategy? Responding to a new need of the society, or attempting to address an existing problem in a novel way can be broadly interpreted as a form of innovation or can indirectly favor innovation.[49] Nevertheless, if a politician follows this strategy he/she can lose power and easily be victim of threats and violence by organized crime. Hence strategy (I) has lower fitness the more organized crime is entrenched in the territory. The opposite happens with strategy (R). What are the implications of (R) in this context? Since organized crime has a bias for projects carried out by traditional low-tech sectors, this automatically implies fostering low-tech sectors to the detriment of others and, thus, slows down innovation.

Secondly, by favoring entrepreneurs close to organized crime, politicians/administrators distort the competition between bidding firms. For a firm that wants to enter into the industrial sectors involved in public procurement, of more importance is to establish a relationship with the mafia organisation in the territory. Thus, a larger presence of organized crime results in a larger incentive to play strategy (R) rather than (I). Also in this case, the fitness of (R) is positively related to the frequency of (R) and the opposite holds for (I).

Thirdly, if we look at competing incentives for entrepreneurs to start business in different sectors, mafia-type organizations distort these incentives to make the sectors which are closely related to public procurement more attractive. Again the (R) strategy tends to dominate the (I) strategy according to the mafia's presence.

A.4 Public Elections: an Indirect Channel

Altering public elections is a further channel through which organized crime disfavors technological progress.[50] *Via* this channel, mafia-type associations damage competition between candidates,

[49] For example, solving traffic problems by improving public transport has a cascade of benefits some of which, in terms of health and time allocation, clearly impact on human capital and labour productivity.

[50] The relation between public elections and organized crime is investigated by (Alesina et al., 2016; Buonanno et al., 2014; De Feo and De Luca, 2017).

establish a convenient partnership with the winners elected thanks to the clans' support, and tend to intimidate the other politicians elected without the clans' support.[51] Altering public elections biases politics in favor of mafia-type organizations. This happens by means of laws and influence on courts on the one hand, and *via* decisions and behaviours that favor their economic activities on the other hand. Clearly, this is a channel that amplifies the scope of the previous ones.

It could be argued that corruption also distorts political and administrative decisions, thus depressing innovation. A natural question, thus, is what makes mafia-type organizations so special. Certainly, organized crime is not the only institution that can limit the enforcement of the rule of law and distort public choices. Yet, its special nature, well captured by art. 416 bis in the Italian penal code, results in a formidable intimidating power. This power is based on the use of violence and marks a key difference with respect to corruption. Furthermore huge profits, in particular from drugs dealing, provide mafia-type organizations a strong corruptive power.[52] Both intimidating and corruptive powers then make this institution extremely effective in reducing the enforcement of law and distorting public choices.

Summing up, through all the channels described, the natural selection mechanism in the presence of organized crime affects the industrial fabric of the territory. By eliminating or attenuating competition, mafia-type associations change the agents' incentives. Agents now tend to abandon the innovation strategy because they cannot resist subjugation to the mafia which drains out their resources for investing in innovation and rips off their potential profits from innovation. Or they abandon the innovation strategy because they opt to establish looser or tighter forms of partnerships with the mafia to increase profits or reach other personal goals. Thus, while innovation generally falls, industries which can benefit from organized crime are favored in detriment to others and, importantly, those industries are conspicuously low-tech.

[51] Alesina et al. (2016) show that in Sicily, for the period 1945-2013, mafia-type murders occurring in the electoral season generally deterred appointed politicians from openly talking about the mafia in the following legislature.

[52] Calasanzio (2011) reports that in 2010 the mafia's revenue and profits amounted to 138 and 105 billions Euros, respectively. In the same year, the largest Italian company, *Generali*, featured 120 and 1.7 billions of Euros for revenues and profits respectively while the second, *Eni*, 83 and 6.3. What strikes the attention is the profit-revenue ratio equal to 76.1 for the mafia against 1.42 for *Generali* and 7.59 for *Eni*.

B Organized Crime and Technology in an Evolutionary Game Theory Framework

To model the mechanics that relate organized crime to technology through innovation we use evolutionary game theory.[53] In the presence of organized crime Nature faces two strategies to select: Innovation, (I), and Relation with organized crime, (R). The frequency of (I) and (R) are x_I and x_R respectively. The population, P, is defined as $P = x_I + x_R$ and set equal to unit, so that the frequency of (R) can be redefined as x and the frequency of (I) as $(1 - x)$. It follows that the composition of the population can be captured by x only: if $x = 0$ the population uniquely consists of (I) strategies, while if $x = 1$ there are only (R) strategies. Strategy's success in a game is translated in reproductive success of the strategy so that strategies that do well reproduce faster. Payoff is therefore interpreted as fitness. Selection depends upon the fitness of the strategies, F_I and F_R that, in turn, depends on the composition of the population given by x. We now capture two common denominators in the four channels described earlier with the following hypothesis: the frequency of (R) is directly proportional to the presence of organized crime, while the frequency of (I) is inversely proportional to the presence of organized crime.

B.1 Payoffs when (R) Consists of not Resisting Mafia Subjugation

For the sake of clarity, we separately consider the case in which (R) consists of not resisting subjugation to organized crime, and the case in which (R) consists of attempting cooperation with organized crime. In the former, the expected payoff matrix is

$$P = \begin{array}{c} \\ R \\ I \end{array} \begin{array}{c} \begin{array}{cc} R & \quad I \end{array} \\ \begin{pmatrix} b/2 - c & b/2 - c - (1-x)s \\ b/2 - xb/2 & b/2 \end{pmatrix} \end{array}$$

where b and $b/2$ are, respectively, the aggregate normal payoff and the individual normal payoff if all the strategies were (I); c is the payoff loss due to subjugation to the mafia; and s is a sanction incurred by (R) if the police detects that it has not denounced the subjugation attempts.

Starting with the payoff for strategy (R), entry $(1, 1)$ reports the payoff for (R) when (R) meets

[53] See Nowak (2006) for a general treatment of Evolutionary Dynamics.

(R). In this case two equivalent strategies split the aggregate payoff and, due to subjugation, incur the loss c. The payoff for (R) when meets (I) is reported in entry $(1, 2)$. Now, the fact that (R) is meeting strategy (I) which, by definition, resists subjugation to organized crime, implies that the police can detect (R). Indeed, the larger the frequency of (R), the larger the pressure that (I) undergoes in resisting subjugation to organized crime. Thus, (I) has an incentive in signalling to security forces (R) strategies followed by neighbours in its area, unless the presence of organized crime is not sufficiently large to expose (I) to major risks. Furthermore, the larger x, the larger the effort for police forces to intervene. The term $(1 - x)s$ model this assumption: the smaller the presence of organized crime captured by x, the larger the probability that (R) is detected.[54]

We next move to the payoff for strategy (I). Entry $(2, 1)$ reports the payoff for (I) when it meets (R). When (I) is in a playground with (R), the larger the presence of organized crime, the more it will undergo subjugation attempts by means of increasing threats, personal aggression and property crime. Clearly, these forms of violence against (I) imply a loss. We model this loss by reducing the normal payoff $b/2$ by $xb/2$, which accounts for the fact that when organized crime is very rooted in the territory, i.e., x close to 1, resisting subjugation can lead to default, i.e., payoff close to zero. The final case is when (I) meets (I). Since the two strategies are identical they split the aggregate payoff and each wins $b/2$.

B.2 Payoffs when (R) Consists of Cooperating with the Mafia

We next consider the case in which playing (R) means to cooperate with organized crime. Now the payoff matrix becomes

$$P = \begin{array}{c} \\ R \\ I \end{array} \begin{array}{c} \begin{array}{cc} R & \quad I \end{array} \\ \begin{pmatrix} (b+c)/2 - xs & (b/2+c) - xs \\ b/2 - c/2 & b/2 \end{pmatrix} \end{array}$$

where c in this case is the extra payoff stemming from cooperation with organized crime and s is a sanction paid by (R) if it is detected by the police.

[54] It could sound counterintuitive that (R), which is the victim of subjugation, also incurs a sanction by not denouncing this crime. The rationale of a sanction is contrasting the spread of the mafia and protecting (I) type strategies. In this respect, Confindustria, the Italian industrial association, introduced a norm in its code of ethics according to which members that do not denounce subjugation attempts by organized crime are expelled from the association. Such a punishment is a possible form that the sanction s can take.

When (R) meets (R), the payoff is split between the two strategies as they are identical.[55] We assume that the larger the presence of organized crime, the higher the likelihood that (R) is detected by the police. It follows that (R)'s payoff given by entry (1,1), consists of a constant part, the normal and the extra payoff, and a variable part, the sanction.

When (R) meets (I), there is no sharing of the extra payoff c: it goes entirely to (R) because (I), by definition, does not cooperate with organized crime. This marks a difference with the previous case where (R) met (R) and the extra payoff was $c/2$. Now the constant part of the payoff is larger than before and equal to $(b/2 + c)$, while the variable part is the same, xs. But the extra payoff c for (R), unfairly favored in the competition by cooperating with organized crime, implies a loss for (I) as argued above in section A.2.

As a result, the payoff for (I) when (I) meets (R), is equal to the normal payoff $b/2$, minus the loss which is set equal to $c/2$. The value of the latter captures the conservative assumption that the loss incurred by (I) - due to the fact that it faces an unfair competition - is less than the extra payoff accrued to (R).

Finally, the payoff for (I) when it meets (I) is set equal to $b/2$ as it was explained before.

B.3 Frequency Dependent Selection

How does Nature select (R) and (I)? To answer this question we start computing the fitness of each strategy by summing up the payoffs associated with each strategy. Since the frequency of a strategy, by the mere definition of frequency, is the probability to meet that strategy, when the agent plays (R) it meets (R) with probability x and meets (I) with probability $(1 - x)$. So the fitness of (R), equal to its expected payoff, is

$$F_R(x) = xP_{11} + (1 - x)P_{12}, \tag{5}$$

where P_{ij} stands for the i, j element of the payoff matrix P. Similarly, the fitness of (I) is given by

$$F_I(x) = xP_{21} + (1 - x)P_{22}. \tag{6}$$

Then, it is easy to show that the replication of strategy (R) is governed by

[55] An alternative interpretation is that (R) will win in half of the cases.

$$\dot{x} = x(1-x)[F_R(x) - F_I(x)], \tag{7}$$

which shows that there are always two equilibria when $x = 0$ and $x = 1$, where the population will consist only of (I) or (R) respectively, and possibly other equilibria for $x \in (0, 1)$ that solves $F_R(x) - F_I(x) = 0$, which features a mixed population. The replicator equation clearly shows that selection is *frequency dependent*: when x is such that $F_R(x) - F_I(x) > 0$, then the frequency of (R) increases, whereas when $F_R(x) - F_I(x) < 0$, then the frequency of (R) decreases. Furthermore, the sign of $\dot{F}_R(x) - \dot{F}_I(x)$ in the equilibrium point determines if such equilibrium is stable or unstable.

Calibration

Starting with the subjugation case, we calibrate the value of the loss parameter c to the 10 percent of the individual normal payoff $b/2$. This value can be considered as a lower limit and as a benchmark for sensitivity analysis. Next, we set the value of the sanction parameter s equal to 0.2. To have an idea of the corresponding sanction, for low levels of organized crime, e.g., $x < 1/5$, the sanction would be less or equal to the 7.5 percent of the normal payoff.

Moving to the cooperation case, we set the value of the parameter c such that the extra payoff is equal to the 10 percent of the value of the individual normal payoff $b/2$ when (R) meets (R), while it is equal to the 20 percent of the individual normal payoff when (R) meets (I). Finally, we set the value of the sanction parameter s equal to 0.8. To have an idea of the corresponding sanction, which depends on both s and the likelihood that (R) is detected by the police which, in turn, is proxied by x, for x increasing from zero to 1, the sanction will increase from zero to 40 percent of the individual normal payoff.

Results

Figures 7-8 portray the evolutionary dynamics of the strategies' population in the subjugation and in the cooperation case respectively. In these figures, the red circle denotes a stable equilibrium while the white circle an unstable equilibrium. Starting with the case in which (R) consists of not resisting subjugation to organized crime, Figure 7, Panel A, along with the two stable corner equilibria, there is an interior unstable equilibrium. For values of x below this value, the fitness

of (I) is larger than the fitness of (R). Hence, in this case, evolutionary dynamics will lead to the stable equilibrium where all the strategies are (I). The opposite, instead, occurs if x is on the right of the interior equilibrium. Now, natural selection will lead to a continuous growth in the number of the (R) strategies until (I) disappears. To fix the ideas, we can consider a province which is not the victim of mafia's subjugation attempts. Then, some bosses start to infiltrate the territory and impose illegal services. Such a shock to the value of x initially equal to zero can have two possible outcomes: if it is sufficiently low, that is less than the interior equilibrium value, then the infiltration will die out because the incentive to choose (R) instead of (I) is not strong enough. If, instead, the shock drives x beyond the interior equilibrium, organized crime will become more rooted in the territory as (R) becomes the best strategy.

A relevant question to ask is what the policy implications of this model are. In particular, given the level of direct contrast to organized crime[56], the extent to which the sanction instrument can help. Using sensitivity analysis, we report in Panels B and C the case in which $s = 0$ and $s = 0.4$ respectively. Comparing the position of the interior equilibrium in Panels B and C we notice that the sanction can mitigate but not solve the problem.

Does the model suggest the use of any other instrument? Yes, a compensation to (I) for the loss incurred due to organized crime aggressions. Indeed, aggressions are an important deterrent to follow strategy (I). Assuming that economically assessing the cost of any aggression is possible and that (I) is fully indemnified, the payoff for (I) when it meets (R) would be $b/2$. The payoff matrix then shows that (I)'s payoffs are always larger than (R)'s. Then, the fitness of (I) is always larger than the fitness of (R). As a result, if any shock takes place, natural selection will always take the population back to the equilibrium with all (I).

Yet, it could sometimes be impossible to fully indemnify (I). We then set the value of the limited indemnity such that the fitness of (I) is always larger or equal to the fitness of (R). This happens when the indemnity $x(b/2 - c)$ is added to the payoff for (I) when it meets (R). Panel D illustrates this case. It suggests that if the indemnity is sufficiently large, then natural selection will guarantee that with respect to imposing illegal services the mafia will not become rooted. Ultimately, this signals that indemnity can be a key instrument in the integrated contrast to organized crime.

[56] Clearly, if law enforcement is set at zero tolerance for organized crime, then direct contrast would always keep $x = 0$; here, realistically, we are implicitly considering that this is not the case.

We next turn to the case in which (R) consists of cooperating with organized crime. In Figure 8 we have three equilibria as in Figure 7; however, now their stability properties are inverted: the extremes are unstable while the interior is stable. This suggests that the economy is likely to end up in the interior equilibrium, as it is shown in Panel A, where it happens that the 50 percent of the strategies are (R). Clearly, such a percentage depends upon the value of the sanction parameter: when $s \leq 0.4$ the economy ends up in the corner equilibrium with all (R) strategies. In this respect, Panel B, which is drawn for $s = 0.4$, is illustrative. Thus, for the existence of strategy (I) in the strategies' population, the sanction has to be sufficiently large, specifically, larger than the extra benefit c. Intuitively, there will be a value of the sanction above which all the strategies are (I). Economically, however, if the sanction is too large it cannot be paid.[57] In this respect it is illustrative to consider the case in which s is set equal to the normal payoff, i.e., $s = 2$. If so, the interior equilibrium occurs at 20 percent of (R) strategies as shown in Panel C. This sensitivity analysis with respect to the value of s indicates that among the feasible sanctions, the actual sanction should be as high as possible.

Summing up, (i) the mixed population equilibrium is unstable when (R) consists of not resisting subjugation to organized crime, while it is stable when it consists of cooperating with organized crime; (ii) in the subjugation case, for a given contrast to organized crime carried out by the security forces, sanctioning (R) can mitigate the problem, while providing an appropriate indemnity to victims of the mafia's aggressions can be a key element for problem solution; (iii) in the cooperation case, the sanction for the agents that choose to cooperate with organized crime, in order to be effective, should be at least equal to their normal payoff accrued without benefiting from cooperation with organized crime.

A final remark as to the results for the subjugation case: An unstable interior equilibrium clearly suggests that there is a turning point in the composition of the population such that natural selection favors (R) instead of (I). The finding that the population could result in all (R) strategies can look extreme. Yet, the history of the mafia's subjugation cases reports that this has often been the case, for example in several southern Italy municipalities. All (R) strategies are also consistent with the idea proposed by the Nobel laureate Schelling (1971, p. 73) that the characteristic of organized crime is "*exclusivity*, or, to use a more focused term *monopoly*. From all accounts, organized crime

[57] Interestingly, yet, the sanction does not need to be exclusively pecuniary, it could also be custodial.

does not merely extend itself broadly, but brooks no competition."

B.4 A Key Feature of Strategy (R)

So far we have analyzed how mafia-type organizations impact the fitness of the two strategies. Then we analyzed how Nature selects the two strategies according to their frequency, which varies with the presence of organized crime, and showed the exogenous conditions under which Nature favors strategy (R). But when this happens, do we really have less innovation in the economy? Put differently, does strategy (R) disfavour innovation? Generally this is the case. To see why, it is convenient to recall that (R) can occur either by not resisting subjugation to organized crime or by attempting to cooperate with organized crime at various levels. Now, when (R) consists of the first behaviour, resources for innovation easily become exhausted so that agents' incentive to compete trough innovation slows down or stops. We can clearly observe this with the private protection channel. Indeed, firms subjected to mafia impositions, for example extortion, will make less profits, which means less funds available to invest in innovation. In addition, these firms tend to lose the incentive to compete *via* innovation as the potential profits from innovation will likely to be harvested by the mafia, thus endangering their property rights.[58,59] Finally, less profit increases the likelihood of default, in particular when the economy stagnates. Since innovating entails a risk of failure *per se*, and profits act as a buffer against risk, less profit implies a higher risk associated with innovation and therefore less innovation.

Regarding strategy (R) as cooperation with the mafia, condensing this behaviour, it generally allows buying out protection from competition. Indeed, this happens at various dimensions: Entrepreneurs involved in money laundering that do not need to compete to obtain finance, or that purchase illegal services to increase revenue or reduce costs or, finally, that join competition in public procurement and win as a result of being sponsored by organized crime. In all these cases, such an agent is not fairly competing with peers. Now, a fall in competition by itself reduces the incentive to innovate as explained in section A.2. Similarly, a politician elected with organized crime votes, on the one hand, is not competing fairly. On the other hand, once elected he/she can-

[58] As to property rights and investment incentives, see for example Besley (1995).

[59] The negative link between the mafia's predatory behaviour and innovation that we propose in this work at the province level is consistent with the theory put forward by Acemoglu et al. (2001) according to which more extractive institutions in the colonial era led to lower per capita income at the country level.

not support (I) agents otherwise this would contrast with the mafia's preferences and, thus, violate the binding constraint established with them. Thus, his/her behaviour has to support, more or less directly, the replication of strategy (R).

V Conclusions

This paper examines the effects of organized crime on the technology level. Our conjecture is that mafia-type organizations damage improvements in technology as their interaction with entrepreneurs, public administrators, and politicians tends to reduce competition and, as a result, to slow down innovation.

To test this conjecture, we crafted indexes that portray the technology level and the presence of organized crime, and we designed an identification strategy grounded on a natural experiment which occurred in northern Italy: forced resettlement from southern Italy of high-ranking bosses belonging to clans. The empirical results consistently provide support for the view that an increase in organized crime in a province leads to a fall of the technological level of that province. We document with fairly large evidence that this occurs through a negative impact of organized crime on innovation, which is a flow that adds to the technology stock. Specifically, we find that taking as a benchmark the median province in terms of mafia presence, should it experience a 10% increase in the mafia index, it would then incur a 9% loss in patents per capita.

To explain the results, we built an Evolutionary Game theory model and used it to study some key interactions between organized crime and the society. Such a model, most importantly shows that if the presence of organized crime is sufficiently large, then natural selection favors the strategy of relating with organized crime rather than the strategy of innovation. This happens because the strategy of relating with organised crime introduces a friction in competition which, in turn, hinders innovation.

Our evolutionary dynamic model also shows that to design a proper integrated policy that avoids that natural selection favors strategy (R), it does matter to distinguish the case in which (R) consists of subjugation to organized crime from the case in which (R) consists of cooperation with organized crime. In the former, a sanction can only mitigate the problem while providing full indemnity to the victims of organized crime aggressions is a key element for the problem solution.

In the latter, the sanction can strongly reduce the problem but to be effective has to be sufficiently large, specifically not less than the normal payoff.

Our empirical finding that organized crime disfavors technology contributes to show that the damage caused by mafia-type organisations is not limited to criminal offences harming individual victims. Indeed, by imposing a burden on the technological progress, the mafia places a brake on economic growth and, therefore, damages each member of the society in addition to the direct victims of its violence.[60] In this regard, taking a change in our technology index as a proxy for technological progress, and using the Solow model to make predictions, allows a *prima facie* assessment of the impact of the mafia on economic growth. Indeed, according to the Solow model, on a balanced-growth path, the rate of growth of output per capita equals the rate of growth of the technological progress. Thus, the 1.6% fall in technology, which we have found if the province with median mafia presence experiences a 10% increase in organized crime, suggests that that province would incur a loss in the growth of output per capita in the ballpark of 1.6%. This result is substantial and could help to explain why Italy has not grown since the mid-1990s.

Arguably, these results bear a social implication. In fact, whenever there is evidence that organized crime harms each member of the society, and not just the victims directly offended, public awareness of organized crime as a public bad grows. This matters as a lack of public awareness increases the likelihood that organized crime will continue spreading also in rich and developed areas.

[60] In a separate study we have conjectured and shown that organized crime affects the accumulation of human capital.

References

Acemoglu, D., P. Aghion, and F. Zilibotti (2006). Distance to frontier, selection, and economic growth. *Journal of the European Economic Association 4*(1), 37–74.

Acemoglu, D., U. Akcigit, N. Bloom, and W. R. Kerr (2013). Innovation, reallocation and growth. Technical report, National Bureau of Economic Research.

Acemoglu, D., S. Johnson, and J. A. Robinson (2001). The colonial origins of comparative development: An empirical investigation. *The American Economic Review 91*(5), 1369–1401.

Aghion, P., S. Bechtold, L. Cassar, and H. Herz (2014). The causal effects of competition on innovation: Experimental evidence. Technical report, National Bureau of Economic Research.

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl (2004). Entry and productivity growth: Evidence from microlevel panel data. *Journal of the European Economic Association 2*(2-3), 265–276.

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl (2009). The effects of entry on incumbent innovation and productivity. *The Review of Economics and Statistics 91*(1), 20–32.

Akcigit, U., J. Grigsby, and T. Nicholas (2017). The rise of american ingenuity: Innovation and inventors of the golden age.

Akerman, A., I. Gaarder, and M. Mogstad (2015). The skill complementarity of broadband internet. *The Quarterly Journal of Economics 130*(4), 1781–1824.

Albanese, G. and G. Marinelli (2013). Organized crime and productivity: evidence from firm-level data. *Rivista Italiana degli Economisti 3*, 367–390.

Alesina, A., S. Piccolo, and P. Pinotti (2016). Organized crime, violence, and politics. Technical report, National Bureau of Economic Research.

Angrist, J. and A. B. Krueger (2001). Instrumental variables and the search for identification: From supply and demand to natural experiments. *The Journal of Economic Perspectives 15*(4), 69–85.

Angrist, J. D. and V. Lavy (1999). Using maimonides' rule to estimate the effect of class size on scholastic achievement. *The Quarterly Journal of Economics 114*(2), 533–575.

Barone, G. and S. Mocetti (2014). Natural disasters, growth and institutions: a tale of two earthquakes. *Journal of Urban Economics 84*, 52–66.

Besley, T. (1995). Property rights and investment incentives: Theory and evidence from ghana. *Journal of Political Economy 103*(5), 903–937.

Bianchi, P., A. Marra, D. Masciandaro, and N. Pecchiari (2017). Is it worth having the sopranos on board? corporate governance pollution and organized crime: The case of italy. *Bocconi Legal Studies Research Paper 59*.

Blundell, R., R. Griffith, and J. van Reenen (1999). Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms. *Review of Economic Studies 66*(3), 529–554.

Bonaccorsi di Patti, E. (2009). Weak institutions and credit availability: the impact of crime on bank loans. *Bank of Italy-Working Paper 52*.

Buccirossi, P., L. Ciari, T. Duso, G. Spagnolo, and C. Vitale (2013). Competition policy and productivity growth: an empirical assessment. *Review of Economics and Statistics 95*(4), 1324–1336.

Buonanno, P. and M. Pazzona (2014). Migrating mafias. *Regional Sciences and Urban Economics 44*.

Buonanno, P., G. Prarolo, and P. Vanin (2014). Organized crime and electoral outcomes in sicily. *Quaderni-Working Paper DSE*.

Bustos, P. (2011). Trade liberalization, exports, and technology upgrading: Evidence on the impact of mercosur on argentinian firms. *The American Economic Review 101*(1), 304–340.

Calasanzio, B. (2011). *Mafia Spa: gli affari della più grande impresa italiana*. Editori internazionali riuniti.

Calderoni, F. (2011). Where is the mafia in italy? measuring the presence of the mafia across italian provinces. *Global Crime 12*(1), 41–69.

Calligaris, S., M. Del Gatto, F. Hassan, G. Ottaviano, F. Schivardi, et al. (2016). Italys productivity conundrum. a study on resource misallocation in italy. Technical report, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.

Carpenter, R. E. and B. C. Petersen (2002). Capital market imperfections, high-tech investment, and new equity financing. *The Economic Journal 112*(477), F54–F72.

Cassazione (2015). Sentence n. 436. *Sez. 2*.

Ciccone, A. and E. Papaioannou (2009). Human capital, the structure of production, and growth. *The Review of Economics and Statistics 91*(1), 66–82.

Dalla Chiesa, N. (2017). *Passaggio a Nord: la colonizzazione mafiosa*. Associazione Gruppo Abele Onlus-Edizioni Gruppo Abele.

De Feo, G. and G. De Luca (2017). Mafia in the ballot box. *American Economic Journal: Economic Policy 9(3)*, 134–67.

Di Cataldo, M. and N. Mastrorocco (2016). Organised crime, captured politicians and the allocation of publicresources. *Mimeo*.

DNA (2012). Relazione annuale nel periodo 1 luglio 2011 - 30 giugno 2012.

DNA (2014). Relazione annuale nel periodo 1 luglio 2012 - 30 giugno 2013.

DNA (2015). Relazione annuale nel periodo 1 luglio 2013 - 30 giugno 2014.

Fajnzylber, P., D. Lederman, and N. Loayza (2002). What causes violent crime? *European Economic Review 46*(7), 1323–1357.

Fallah, B., M. D. Partridge, and D. S. Rickman (2014). Geography and high-tech employment growth in us counties. *Journal of Economic Geography 14*(4), 683–720.

Gambetta, D. (1996). *The Sicilian Mafia: the business of private protection*. Harvard University Press.

Ganau, R. and A. Rodríguez-Pose (2017). Industrial clusters, organized crime, and productivity growth in italian SMEs. *Journal of Regional Science*.

Gratteri, N. (2016). Scuola 'ndrangheta. In S. Danna (Ed.), *Prodotto interno mafia. Cosi la criminalita organizzata e diventata il sistema Italia*, pp. 43–71. Torino: Einaudi.

Gratteri, N. and A. Nicaso (2016). *Padrini e padroni. Come la 'ndrangheta diventata classe dirigente classe dirigente*. Mondadori.

Hall, B. H. and J. Lerner (2010). The financing of R&D and innovation. In B. Hall and N. Rosenberg (Eds.), *Handbook of the Economics of Innovation*, Chapter 14, pp. 609–639. Elsevier.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the Econometric Society*, 1251–1271.

Heckler, D. E. (2005). High-technology employment: a naics-based update. *Monthly Labor Review 128*, 57.

Italian Parliament (1991). Commissione parlamentare d'inchiesta sulla attuazione degli interventi per la ricostruzione e lo sviluppo dei territori della basilicata e della campania colpiti dai terremoti del novembre 1980 e febbraio 1981 istituita con legge 7 aprile 1989, n. 128. Technical report.

Kearns, A. and F. Ruane (2001). The tangible contribution of R&D-spending foreign-owned plants to a host region: A plant level study of the irish manufacturing sector (1980–1996). *Research Policy 30*(2), 227–244.

Kleibergen, F. and R. Paap (2006). Generalized reduced rank tests using the singular value decomposition. *Journal of Econometrics 133*(1), 97–126.

Levitt, S. D. (1996). The effect of prison population size on crime rates: Evidence from prison overcrowding litigation. *The Quarterly Journal of Economics 111*(2), 319–351.

Li, G. (1985). Robust regression. In M. F. Hoaglin, D. C. and J. W. Tukey (Eds.), *Exploring Data Tables, Trends, and Shapes*, Chapter 8, pp. 281–344. Hoboken, NJ: John Wiley Sons, Inc.

Luana, D. F., U. Dinello, and G. Rossi (2015). *Mafia a Nord-est*. Rizzoli.

Murray, M. P. (2006). The bad, the weak, and the ugly: Avoiding the pitfalls of instrumental variables estimation.

Nickell, S. J. (1996). Competition and corporate performance. *Journal of Political Economy*, 724–746.

Nowak, M. A. (2006). *Evolutionary dynamics*. Harvard University Press.

Papke, L. E. and J. M. Wooldridge (2008). Panel data methods for fractional response variables with an application to test pass rates. *Journal of Econometrics 145*.

Pinotti, P. (2015). The economic costs of organised crime: evidence from southern italy. *The Economic Journal 125*(586), F203–F232.

Raymond, W., P. Mohnen, F. Palm, and S. S. Van Der Loeff (2010). Persistence of innovation in dutch manufacturing: Is it spurious? *The Review of Economics and Statistics 92*(3), 495–504.

Rivers, D. and Q. H. Vuong (1988). Limited information estimators and exogeneity tests for simultaneous probit models. *Journal of Econometrics 39*, 347366.

Sales, I. (2015). *Storia dell'Italia mafiosa: perché le mafie hanno avuto successo*. Rubbettino.

Saviano, R. (2013). *ZeroZeroZero*. Feltrinelli.

Saviano, R. (2015). *ZeroZeroZero: Look at Cocaine and All You See Is Powder. Look Through Cocaine and You See the World.* Penguin.

Schelling, T. (1971). What is the business of organized crime? *Journal of Public Law 20*, 71–84.

Scognamiglio, A. (2015). When the mafia comes to town. *CSEF working paper 404*.

Sparagna, R. M. (2015). Metodo mafioso e c.d. mafia silente nei più recenti approdi giurisprudenziali. *Diritto Penale Contemporaneo*.

Staiger, D. O. and J. H. Stock (1994). Instrumental variables regression with weak instruments. *National Bureau of Economic Research Cambridge, Mass., USA*.

Transcrime (2013). *Progetto PON Sicurezza 2007-2013: Gli investimenti delle mafie. Rapporto Linea 1.* Milano: Ministero dellInterno. www.investimentioc.it.

Varese, F. (2006). How mafias migrate: the case of the ndrangheta in northern italy. *Law & Society Review 40*(2), 411–444.

Varese, F. (2011). *Mafias on the Move*. Princeton University Press.

Wooldrige, J. (2010). *Econometric Analysis of Cross Section and Panel Data, 2nd edition*. Cambridge: MIT Press.

Figure 1: Industrial Sectors' technological classification based on US NAICS 2009 (1)

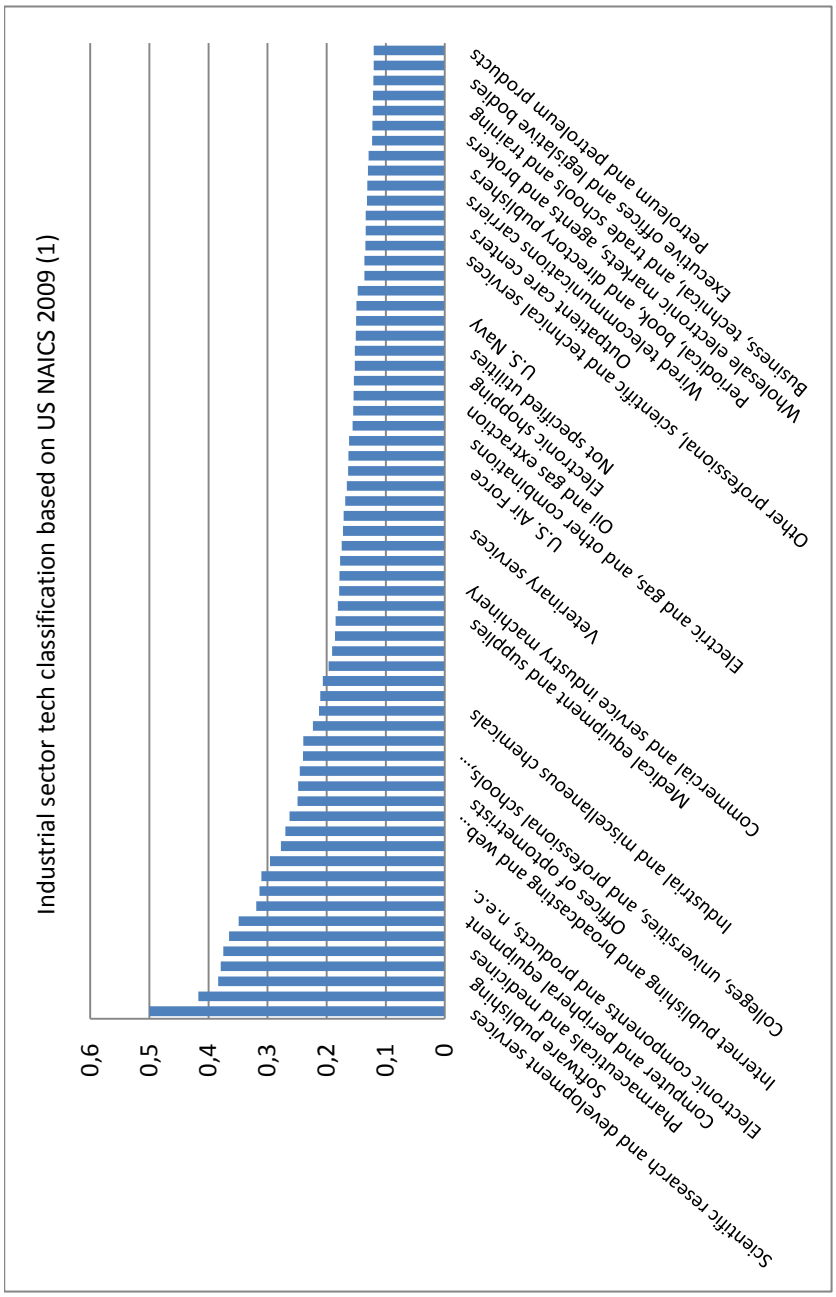


Figure 2: Industrial Sectors' technological classification based on US NAICS 2009 (2)

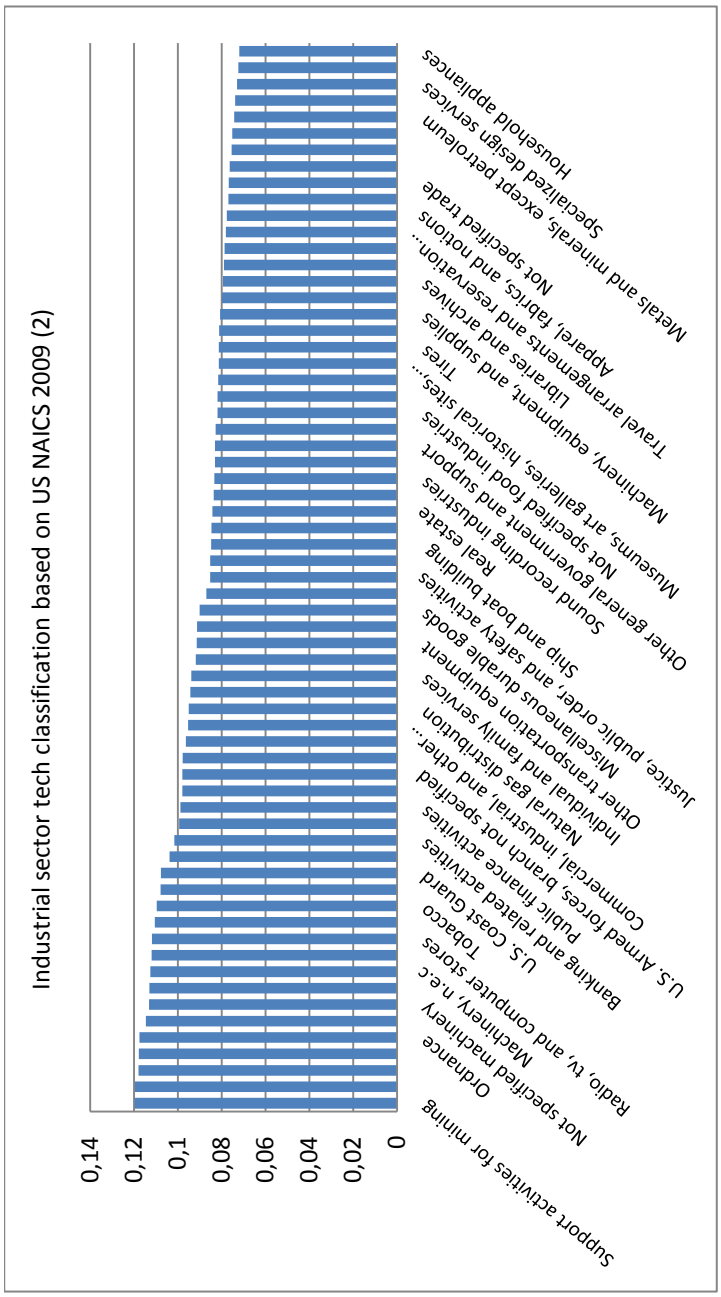


Figure 3: Industrial Sectors' technological classification based on US NAICS 2009 (3)

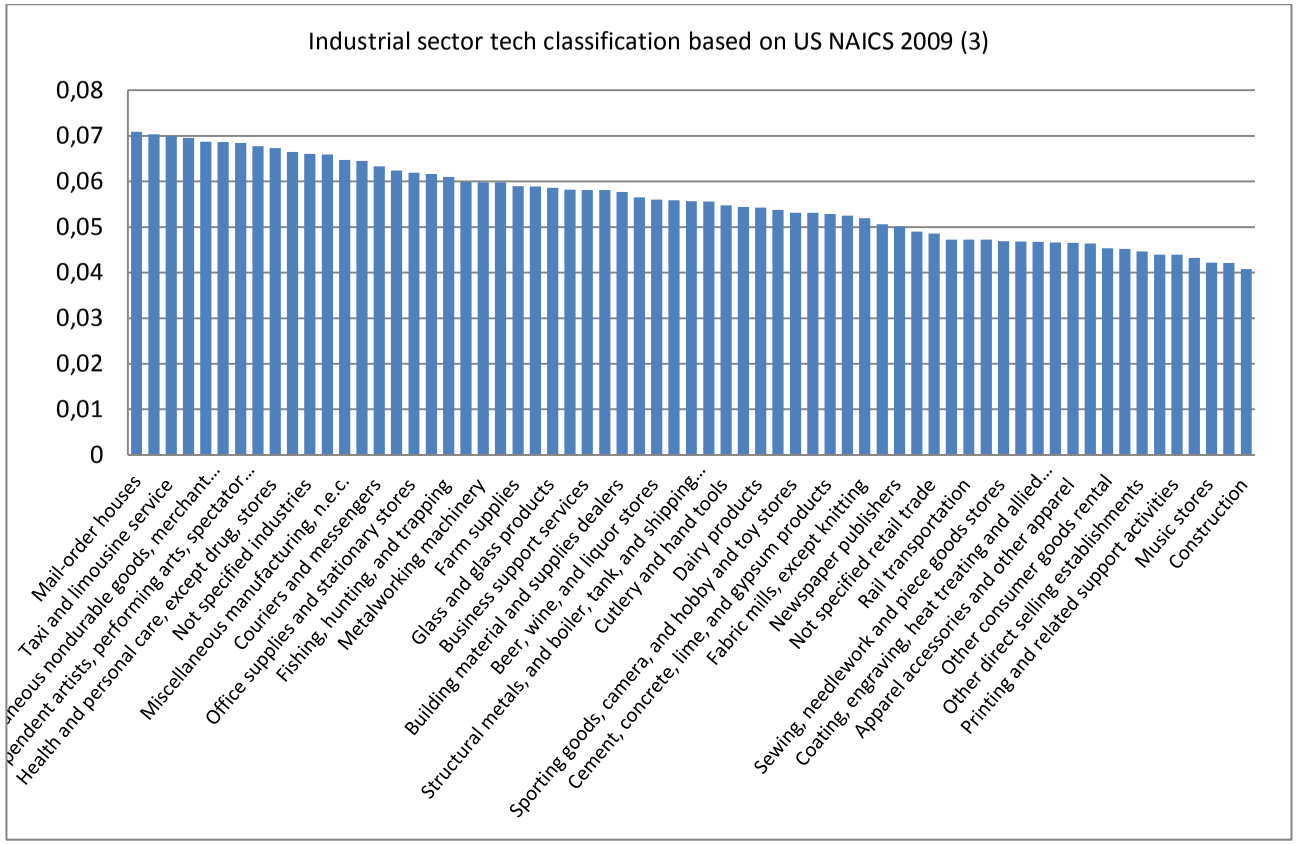


Figure 4: Industrial Sectors' technological classification based on US NAICS 2009 (4)

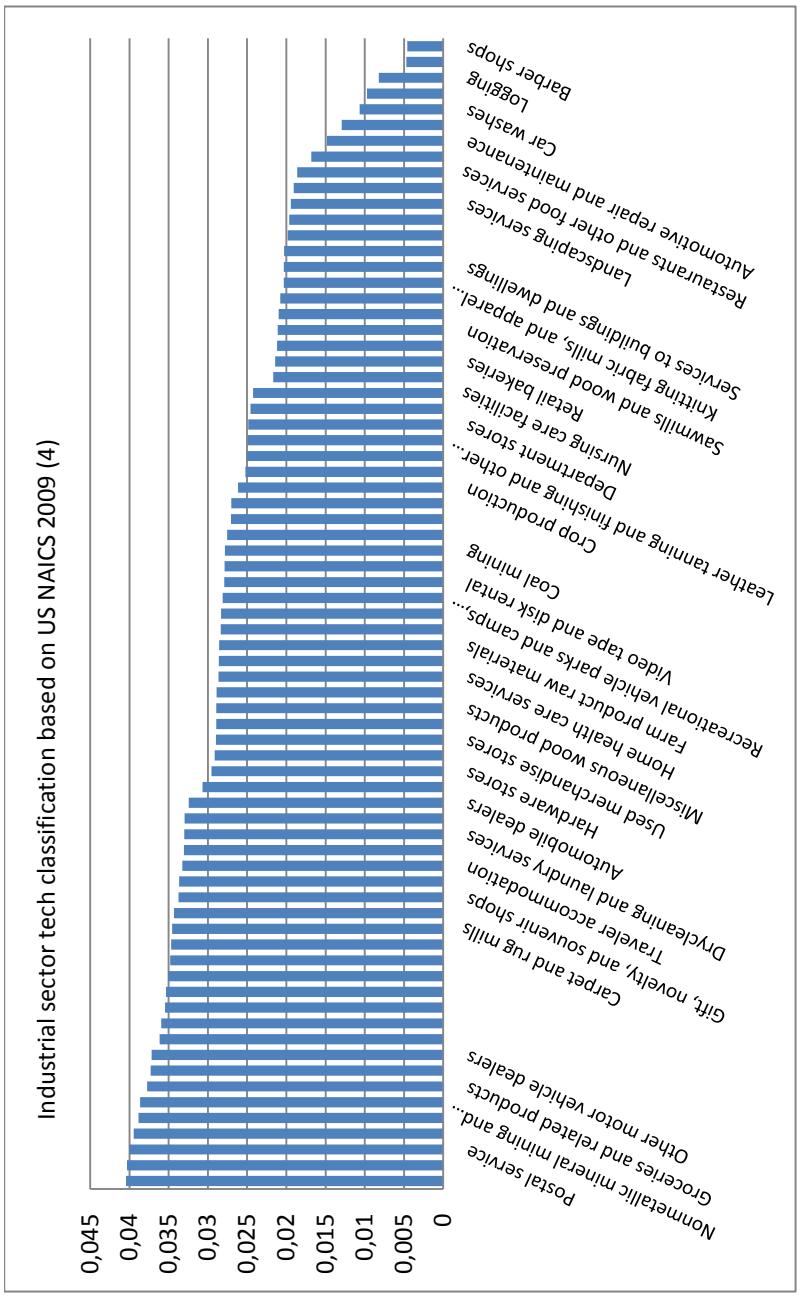
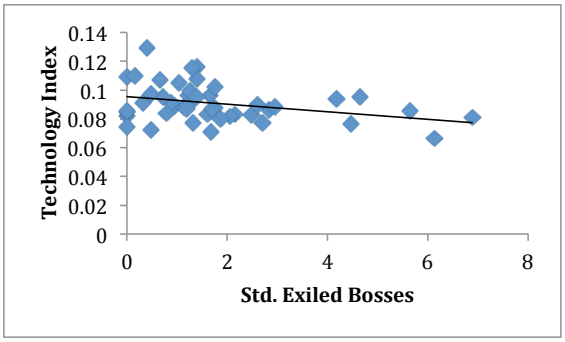
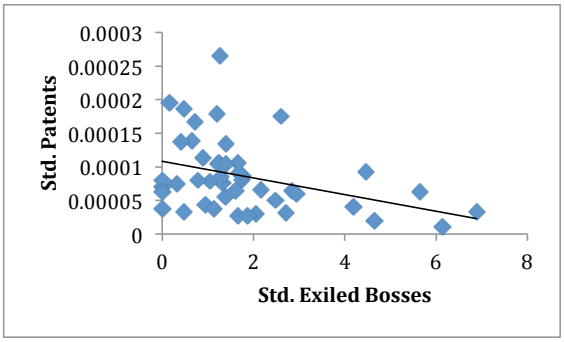


Figure 5: Reduced-form Relationships between Technology/Innovation Measures and Standardized Exiled Bosses

Panel A. Reduced-form Relationship between Technology and Standardized Exiled Bosses



Panel B. Reduced-form Relationship between Standardized Patents and Standardized Exiled Bosses



Panel C. Reduced-form Relationship between Patents and Standardized Exiled Bosses

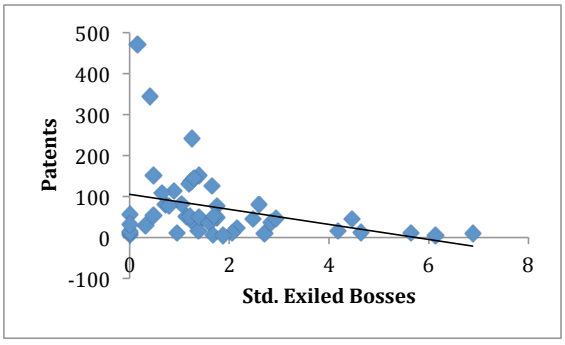


Figure 6: Residual Plot of Exiled Mafia Bosses against the Mafia Index

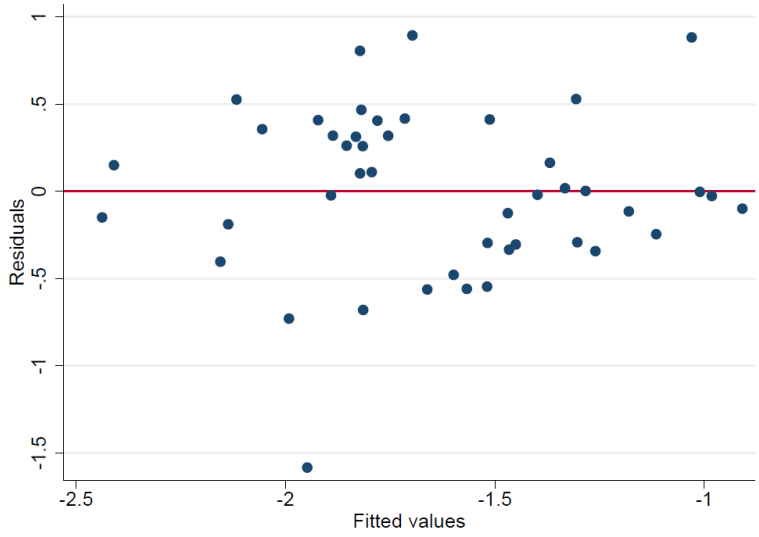
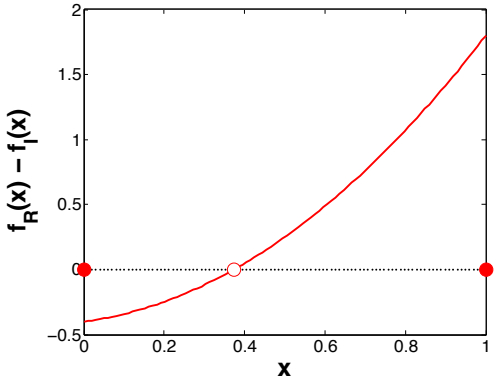
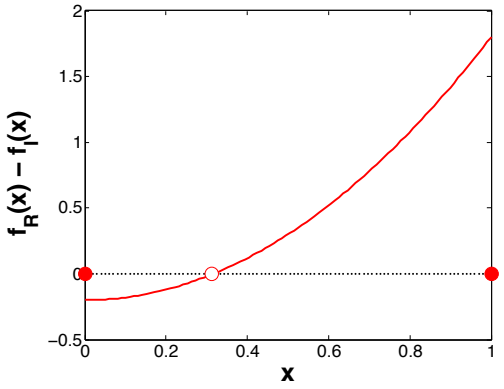


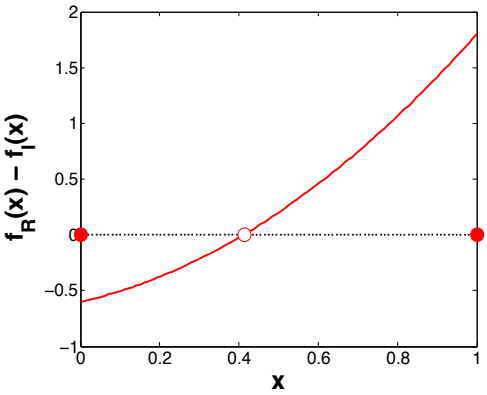
Figure 7: Evolutionary Dynamics of Strategies (R) and (I) in the Subjugation Case



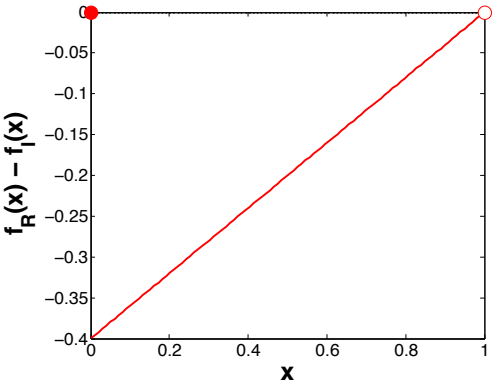
Panel A. c = 0.2 ; b = 4; s = 0.2.



Panel B. c = 0.2 ; b = 4; s = 0.

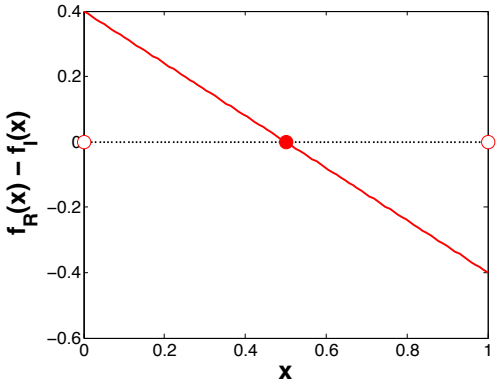


Panel C. c = 0.2 ; b = 4; s = 0.4.

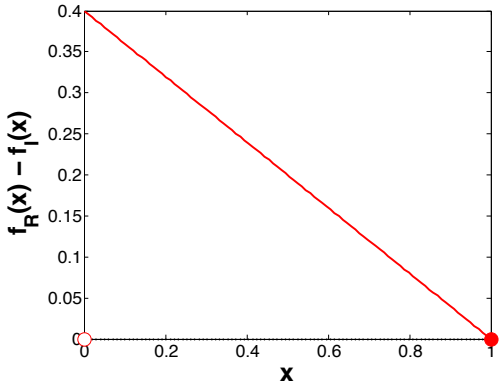


Panel D. c = 0.2 ; b = 4; s = 0.2; indemnity = x(b/2 – c)

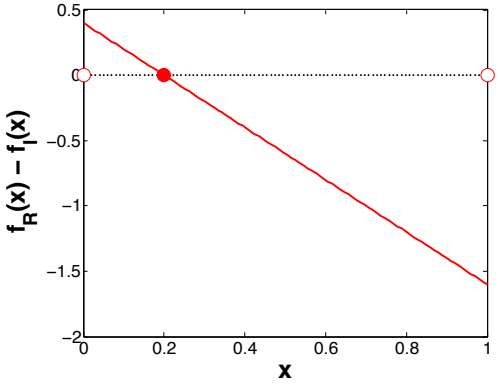
Figure 8: Evolutionary Dynamics of Strategies (R) and (I) in the Cooperation Case



Panel A. c = 0.4; b = 4; s = 0.8.



Panel B. c = 0.4; b = 4; s = 0.4.



Panel C. 13. c = 0.4; b = 4; s = 2.

Table 1: Descriptive Statistics

	N. obs	Mean	Stad. Dev.	Median	Min	Max
Mafia index	46	0.23	0.137	0.208	0.0296	0.868
Technology index	46	0.091	0.013	0.088	0.0666	0.13
Patents application	46	72	90	47	4	472
Standardized patents application	46	0.00011	0.00006	0.00009	0.000023	0.00035
Standardized exiled bosses	46	1.77	1.63	1.35	0	6.88
Value added	46	26235	3414	26068	19604	40175
University graduates	45	2491	2629	1553	578	15749
Population	46	581763	617290	390350	125442	3808450
Standardized migration	46	0.062	0.056	0.04	0	0.21
Houshold deposit per capita	46	11	1.76	10.9	8.7	18

Table 2: The Impact of Mafia on Technology - Fractional Probit

	Exogenous	Exogenous	1^{st} stage	2^{nd} stage	1^{st} stage	2^{nd} stage
	(1)	(2)	(3)	(4)	(5)	(6)
ln Mafia index	-0.028	-0.034*		-0.17***		-0.09**
	(0.018)	(0.017)		(0.058)		(0.04)
APE Mafia index	-0.0046***	-0.005*		-0.027***		-0.015***
	(0.0002)	(0.003)		(0.003)		(0.0009)
$\hat{v}$				0.15**		0.07
				(0.06)		(0.04)
Std. exiled bosses			0.117**		0.18***	
			(0.051)		(0.054)	
First stage F-stat			19		18	
Controls		✓			✓	✓
N. obs	46	45	46	46	45	45

Notes: Columns 1 and 2 report the Fractional Probit estimates of the impact of mafia on technology in the exogenous case without and with controls, respectively. Columns 3 and 5 report the first stage OLS estimates of the impact of the forced resettlement stock in 1974 on mafia without and with controls, respectively. Columns 4 and 6 report the second stage Fractional Probit estimates of the impact of mafia on technology without and with controls, respectively. APE Mafia index is the estimate of the average partial effect of the impact of mafia on technology. $\hat{v}$ is the control function. The data for forced resettlement consists of the stock of high-ranking bosses exiled to Northern provinces in 1974; for the other variables we used pooled data for the period 2005-2012. Robust standard errors in parenthesis. In all the specifications, there is a dummy equal to one if provinces are autonomous (Bolzano and Trento). Controls are value added, households' deposits, total university graduates, migrations from Sicily, Campania and Calabria, and the size of the provinces (i.e. dummy is equal to one if the provinces is also the capital of the region in which it is located). Number of observations reflects the administrative-territorial division of the provinces after 1992. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 3: The Impact of Mafia on Innovation - Fractional Probit

	Exogenous	Exogenous	1^{st} stage	2^{nd} stage	1^{st} stage	2^{nd} stage
	(1)	(2)	(3)	(4)	(5)	(6)
ln Mafia index	-0.08**	-0.085***		-0.34***		-0.24***
	(0.037)	(0.03)		(0.11)		(0.09)
APE Mafia index	-0.00003***	-0.00004**		-0.0001***		-0.0001***
	(0)	(0.00002)		(0)		(0)
$\hat{v}$				0.27***		0.18**
				(0.096)		(0.09)
Std. exiled bosses			0.12**		0.018***	
			(0.051)		(0.05)	
First stage F-stat			19		18	
Controls		✓			✓	✓
N. obs	46	45	46	46	45	45

Notes: Columns 1 and 2 report the Fractional Probit estimates of the impact of mafia on innovation in the exogenous case without and with controls, respectively. Columns 3 and 5 report the first stage OLS estimates of the impact of the forced resettlement stock in 1974 on mafia without and with controls, respectively. Columns 4 and 6 report the second stage Fractional Probit estimates of the impact of mafia on innovation without and with controls, respectively. APE Mafia index is the estimate of the average partial effect of the impact of mafia on technology. $\hat{v}$ is the control function. Innovation is captured by patent applications. The data for forced resettlement consists of the stock of high-ranking bosses exiled to Northern provinces in 1974; for the other variables we used pooled data for the period 2005-2012. Robust standard errors in parenthesis. In all the specifications, there is a dummy equal to one if provinces are autonomous (Bolzano and Trento). Controls are value added, households' deposits, total university graduates, migrations from Sicily, Campania and Calabria, and the size of the provinces (i.e. dummy is equal to one if the provinces is also the capital of the region in which it is located). Number of observations reflects the administrative-territorial division of the provinces after 1992. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 4: The Impact of Mafia on Innovation - Poisson specification

	Exogenous	Exogenous	1^{st} stage	2^{nd} stage	1^{st} stage	2^{nd} stage
	(1)	(2)	(3)	(4)	(5)	(6)
ln Mafia index	-0.49***	-0.32**		-1.5**		-1.2**
	(0.16)	(0.13)		(0.58)		(0.61)
$\hat{v}$				1.14*		1.02
				(0.6)		(0.66)
Std. exiled bosses			0.17***		0.18***	
			(0.05)		(0.05)	
First stage F-stat			36		18	
Controls		✓			✓	✓
N. obs	45	45	46	45	45	45

Notes: Columns 1 and 2 report the Poisson estimates of the impact of mafia on innovation in the exogenous case without and with controls, respectively. Columns 3 and 5 report the first stage OLS estimates of the impact of the forced resettlement stock in 1974 on mafia without and with controls, respectively. Columns 4 and 6 report the second stage Fractional Probit estimates of the impact of mafia on innovation without and with controls, respectively. APE Mafia index is the estimate of the average partial effect of the impact of mafia on technology. $\hat{v}$ is the control function. Innovation is captured by patent applications. The data for forced resettlement consists of the stock of high-ranking bosses exiled to Northern provinces in 1974; for the other variables we used pooled data for the period 2005-2012. Robust standard errors in parenthesis. In all the specifications, there is a dummy equal to one if provinces are autonomous (Bolzano and Trento), and a dummy equal to one if the province is also the capital of the region in which it is located. Controls are value added, households' deposits, total university graduates, migrations from Sicily, Campania and Calabria, and the size of the provinces (i.e. dummy is equal to one if the provinces is also the capital of the region in which it is located). Number of observations reflects the administrative-territorial division of the provinces after 1992. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 5: The Impact of Mafia on Technology - Provinces before 1992 - Fractional Probit

	Exogenous	Exogenous	1^{st} stage	2^{nd} stage	1^{st} stage	2^{nd} stage
	(1)	(2)	(3)	(4)	(5)	(6)
ln Mafia index	-0.026	-0.053***		-0.16***		-0.16**
	(0.02)	(0.017)		(0.05)		(0.07)
APE Mafia index	-0.004***	-0.005***		-0.026***		-0.02***
	(0)	(0.0001)		(0.001)		(0.0009)
$\hat{v}$				0.15**		0.12*
				(0.06)		(0.07)
Std. exiled bosses			0.12**		0.14***	
			(0.05)		(0.048)	
First stage F-stat			18		11	
Controls		✓			✓	✓
N. obs	41	40	41	41	40	40

Notes: Columns 1 and 2 report the Fractional Probit estimates of the impact of mafia on technology in the exogenous case without and with controls, respectively. Columns 3 and 5 report the first stage OLS estimates of the impact of the forced resettlement stock in 1974 on mafia without and with controls, respectively. Columns 4 and 6 report the second stage Fractional Probit estimates of the impact of mafia on technology without and with controls, respectively. APE Mafia index is the estimate of the average partial effect of the impact of mafia on technology. $\hat{v}$ is the control function. The data for forced resettlement consists of the stock of high-ranking bosses exiled to Northern provinces in 1974; for the other variables we used pooled data for the period 2005-2012. Robust standard errors in parenthesis. In all the specifications, there is a dummy equal to one if provinces are autonomous (Bolzano and Trento). Controls are value added, households' deposits, total university graduates, migrations from Sicily, Campania and Calabria, and the size of the provinces (i.e. dummy is equal to one if the provinces is also the capital of the region in which it is located). Number of observations reflects the administrative-territorial division of the provinces before 1992. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 6: The Impact of Mafia on Innovation - Provinces before 1992 - Fractional Probit

	Exogenous	Exogenous	1^{st} stage	2^{nd} stage	1^{st} stage	2^{nd} stage
	(1)	(2)	(3)	(4)	(5)	(6)
ln Mafia index	-0.08**	-0.11**		-0.31***		-0.4***
	(0.04)	(0.04)		(0.11)		(0.14)
APE Mafia index	-0.00003***	-0.00004		-0.0001***		-0.0001***
	(0)	(0)		(0)		(0)
$\hat{v}$				0.25***		0.32***
				(0.1)		(0.12)
Std. exiled bosses			0.12**		0.14***	
			(0.05)		(0.048)	
First stage F-stat			18		11	
Controls		✓			✓	✓
N. obs	41	40	41	41	40	40

Notes: Columns 1 and 2 report the Fractional Probit estimates of the impact of mafia on innovation in the exogenous case without and with controls, respectively. Columns 3 and 5 report the first stage OLS estimates of the impact of the forced resettlement stock in 1974 on mafia without and with controls, respectively. Columns 4 and 6 report the second stage Fractional Probit estimates of the impact of mafia on innovation without and with controls, respectively. APE Mafia index is the estimate of the average partial effect of the impact of mafia on technology. $\hat{v}$ is the control function. Innovation is captured by patent applications. The data for forced resettlement consists of the stock of high-ranking bosses exiled to Northern provinces in 1974; for the other variables we used pooled data for the period 2005-2012. Robust standard errors in parenthesis. In all the specifications, there is a dummy equal to one if provinces are autonomous (Bolzano and Trento). Controls are value added, households' deposits, total university graduates, migrations from Sicily, Campania and Calabria, and the size of the provinces (i.e. dummy is equal to one if the provinces is also the capital of the region in which it is located). Number of observations reflects the administrative-territorial division of the provinces before 1992. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 7: The Impact of Mafia on Innovation - Provinces before 1992 - Poisson specification

	Exogenous	Exogenous	1^{st} stage	2^{nd} stage	1^{st} stage	2^{nd} stage
	(1)	(2)	(3)	(4)	(5)	(6)
ln Mafia index	-0.46***	-0.32**		-1.4**		-1.6***
	(0.16)	(0.16)		(0.5)		(0.77)
$\hat{v}$				1.1*		1.4*
				(0.6)		(0.8)
Std. exiled bosses			0.19***		0.14***	
			(0.051)		(0.046)	
First stage F-stat			37		10	
Controls		✓			✓	✓
N. obs	40	40	41	40	40	40

Notes: Columns 1 and 2 report the Poisson estimates of the impact of mafia on innovation in the exogenous case without and with controls, respectively. Columns 3 and 5 report the first stage OLS estimates of the impact of the forced resettlement stock in 1974 on mafia without and with controls, respectively. Columns 4 and 6 report the second stage Fractional Probit estimates of the impact of mafia on innovation without and with controls, respectively. APE Mafia index is the estimate of the average partial effect of the impact of mafia on technology. $\hat{v}$ is the control function. Innovation is captured by patent applications. The data for forced resettlement consists of the stock of high-ranking bosses exiled to Northern provinces in 1974; for the other variables we used pooled data for the period 2005-2012. Robust standard errors in parenthesis. In all the specifications, there is a dummy equal to one if provinces are autonomous (Bolzano and Trento), and a dummy equal to one if the province is also the capital of the region in which it is located. Controls are value added, households' deposits, total university graduates, migrations from Sicily, Campania and Calabria, and the size of the provinces (i.e. dummy is equal to one if the provinces is also the capital of the region in which it is located). Number of observations reflects the administrative-territorial division of the provinces before 1992. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Randomness: evidences on credibility of instrument

	Std. exiled bosses	Std. exiled bosses
	(1)	(2)
A: OLS		
Std. patents 1960	-0.0151	0.032
	(0.02)	(0.027)
B: GLM		
Std. patents 1960	-209	592
	(312)	(377)
Controls		yes
N.obs	45	45

Notes. Robust standard errors in parenthesis. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. Control is the dummy for the large city.

Table 9: Reduced-form regression: evidences on credibility of instrument

	Tech. index (1)	Tech. index (2)	Patents (3)	Patents (4)
A:GLM				
Std. exiled bosses	-0.016***	-0.015**	-0.033***	-0.047***
	(0.006)	(0.006)	(0.011)	(0.015)
B: Poisson				
Std. exiled bosses			-0.36***	-0.21*
			(0.13)	(0.11)
Controls		yes		yes
N.obs	46	45	46	45

Notes. Robust standard errors in parenthesis. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.