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Organised Crime and Technology

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Abstract

This paper shows that organised crime harms technological development. We provide evidence that forced resettlement of bosses promoted the mafia's rooting in northern Italy. With forced resettlement as an exogenous source of variation, we unveil that mafias cause a reduction in technology levels. Moving from the technology stock to a flow generating it -innovation- we demonstrate that mafias stifle innovation. We argue that without mafia, Nature selects agents for their innovation capacity. Instead, with mafia, agents face an alternative strategy: relate with mafia; this strategy, infringing property rights and competition, hinders innovation. Using evolutionary dynamics, we show that while mafias decrease innovation, proper sanctions/indemnities can address the problem.

Keywords: Organised crime, evolutionary game theory, innovation, technology.

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

I Introduction

Every day, all over the world, societies experience criminal offences committed by mafias.[1] Drug trafficking, murder, extortion, arson, illegal disposal of toxic waste, corrupted elections

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[1]Throughout this paper the terms 'organised crime' stand for 'mafia-type organised crime' .

are some examples of daily-frequency crimes that can ruin or end lives, but not necessarily hurt people's sensitivity. Indeed, as [Beccaria, 1764, p. 110] put it, "[...] Crimes which men consider as productive of no bad consequences to themselves, do not interest them sufficiently to excite their indignation." Yet, do these mafia crimes really produce no bad general consequences? Could instead organised crime damage the evolution of the whole society, too? Would part of the society, if left alone, increasingly adapt to or cooperate with mafias and, if so, would there be long-lived negative effects on key drivers of development as technology and innovation?

In this paper we show the adverse effects of organized crime on technological development and its evolutionary implications. Understanding this relationship, which has not been done before, is important as technology is a key driver of economic growth.

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 fostered the location of mafias in that area. Then, using this source of variation we unveil a causal negative effect of mafias on technology levels. To understand this finding we examined how organised crime could interfere with the process that determines the technology level. Considering that innovation is a flow which adds to the technology stock, we conjectured that organised crime could harm innovation and, in this way, hamper technology. Testing this assumption, we found fairly robust evidence of a significant negative impact of the mafia on innovation. Indeed, Figure 1 visualizes the examined interrelations by plotting the prevalence of forced resettlement, mafia, and innovation at the province level, where mafia is captured by the index described in section III. B and innovation by patent applications. Provinces appearing darker show more prevalence. Western provinces tend to be dark in forced resettlement and mafia presence, yet light in innovation; Eastern provinces show the opposite.

But why should organised crime affect innovation? We argue that the mechanics work through various inter- and intra-sector channels, which are based on money laundering and credit availability, illegal imposition/offer of private protection, and distorted public procurement and public elections. Through these channels mafias undermine property rights and competition in the society. Intuitively, it is this very infringement of property rights and competition that hampers innovation which, in turn, reduces the flow that adds to the technology level. Focusing on the damages to property rights and, mostly, to competition we can foresee that in the mafias' presence innovation is no longer necessarily a successful strategy. In fact, it is well known that innovation flourishes in the presence of secure property rights and competition. At the same time, the mafia's presence generates another strategy: relating with the mafia to survive or prosper. Here mafia causes the mutation of the innovation strategy into the relation strategy.

As a result, Nature will face two strategies and will select them according to their fitness, i.e. their ability to replicate. Interestingly, strategies' fitness is not constant but depends upon the relative abundance of the strategies, i.e. their frequency, which depends on the mafia presence. Such a mechanism made us wonder how the innovation flow evolves in the presence of mafias. This question matters as it allows to think the relationship between mafia and technology in a medium run perspective *via* the intermediate variable *innovation*. Clearly, the most appropriate way to address this question is to adopt an evolutionary perspective. Accordingly, we use evolutionary game theory which allows to account for the possibility that strategies' fitness depends on their relative frequency. Our model shows that generally the presence of mafias does reduce innovation. It also enables us to design specific policies favoring the innovation strategy, and points at the direction the society would evolve if governments did not take proper actions.

Altogether, our study makes both empirical and theoretical contributions to the literature. First and foremost, it provides empirical evidence that organised crime exerted a negative impact on technology in a wealthy and highly developed European area. In particular, we provide evidence that a greater presence of the mafia 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. It also suggests that the mafia arrival in a new province can easily lead to a fall in output-per-capita growth in the 1% ballpark.

The second contribution is analytical. Constructing an evolutionary game theory model, we explain why innovation falls in presence of mafia and the evolutionary implications of this result. Specifically, our model shows the importance to distinguish two type of relationship with the mafia: 1. subjugation by mafia and 2. collusion with mafia. Indeed, in the former we find a turning point level of mafia beyond which all agents turn out to be subjugated by mafia and cannot innovate; here a proper indemnity can effectively address the problem. Instead in the latter we find a locally stable level of mafia, in which a substantial part of the agents tend not to innovate but cooperate with the mafia to the detriment of the others; here we show that the sanction is a proper policy tool and should be set not less than the sanction for the mafia association felony.

Our study also offers two indexes that can be used in future research. The first is a technology index at the province level grounded on the technology intensity of the population of all firms.[2] The second is a mafia-index to portray the new *silent mafia* profile of organised crime outside the head office, which is located in southern Italy. The novelty, here, is to use, for what

[2]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.

was possible through data availability, the operating procedure followed by specialised anti-mafia prosecutors at the Italian National Antimafia Directorate (DNA) and Antimafia District Directorates (DDAs).

The rest of the paper is organised as follows. Section II relates our paper to the previous literature. Section III provides background information, describes the data, explains how to construct the proposed indexes of technology and mafia, and finally presents the covariates. Section IV lays out the empirical model, the identification strategy, the empirical results and the robustness checks. Section V explains the mechanics underpinning the empirical results: it first describes the key interactions between mafia and society; next it builds an evolutionary game theory model to explain how these damages to property rights and to competition hinder innovation, and how proper sanctions and indemnities can serve as useful policy tools to address the problem. Section VI concludes and discusses the social implication of these results.

II Related Literature: a Brief Survey

To the best of our knowledge the relationship between organised crime and technology/innovation has not yet been investigated. The closer strands of the literature related to our study are organised crime and firms' performance, and organised crime and economic growth.

As to the first, Albanese and Marinelli [2013] find a negative impact of organised crime on Italian firms' productivity, and that this is due to the power of organised crime to control the territory in which it operates. Ganau and Rodríguez-Pose [2017] investigate how organised crime affects the relationship between the context in which Italian firms operate and their productivity. In particular for small firms, they find that organised 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. Our work relates to this literature offering a complementary explanation of the negative impact of mafias on productivity. Indeed, we show that organized crime hinders the technological progress, and it is well known that productivity depends on the technological progress.

Regarding mafia and economic growth, Pinotti [2015] considers two southern Italian regions exposed to organised crime after the 1970s, and compares the actual development with their estimated counterfactual development in the mafia absence. He shows that the mafia presence

reduces the growth rate of these regions. Barone and Mocetti [2014] find an opposite long-term impact of earthquakes on GDP in two Italian areas, and provide evidence that pre-quake institutional quality explains this result. Although their variables for the quality of local institutions do not relate directly to organised crime, 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.[3] Our empirical results are consistent with this growth literature related to mafias. In fact, interpreting directly our findings in terms of the balanced-growth path in relation to the Solow model, they suggest that for a province with median mafia presence, a 10% increase in the mafia presence leads to a 1.6% fall in output-per-capita growth.

Adopting forced exile in the identification strategy, the current paper also relates to the 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 mafia's emergence in new territories. Specifically, the presence of members of the organization in the territory, the absence of other established organised crime groups, and the sudden emergence of new markets where the state is unable to protect property rights. With respect to Italy, mafia transplantation is investigated by Buonanno and Pazzona [2014] and Scognamiglio [2018] who find that forced resettlement is a key factor to analyse the mafia's diffusion 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 mafias transplantation to the central and northern regions. Scognamiglio [2018] studies the impact of mafia on provincial crime rates and on employment in different industrial and service sectors, and finds that mafia favoured employment particularly in the construction industry.

III Background Information and Data Construction

To examine the effect of organised crime on technology, we scrutinise data from Italy, as this country has been experiencing mafia-type associations extensively since the mid-19th century. We look specifically at the provinces in the North for two reasons. First, the massive presence of organised crime in a rich and highly developed area which, historically, did not experience mafia is an interesting phenomenon.[4] Northern Italy, indeed, is the richest and most productive

[3] As to infiltrations of organised crime in public procurements during the aftermath of the quake, see p.154-155 and 520-522 of the report by Italian Parliament [1991].

[4] The main investigations already concluded (*Infinito* in Lombardy and *Minotauro* and *Alba Chiara* in Piedmont) resulted in 212 convictions by the Court of Cassation since 2015. Only for *Infinito* this implied more than

area of the country, and also ranks highly above the median in the European Union. A solid explanation for such a surprising fact seems to include two factors: mafia organizations prefer to colonise areas which produce more wealth [Gratteri and Nicaso, 2016, p. 133][5], 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 [DNA, 2014]. The silent mafia approach, thus, contributes to explain why only since 2010 the public in northern Italy has started to realise that mafia spread its roots in this part of the country.

Second, northern Italy has experienced an interesting natural experiment with respect to organised 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 organised crime were sent to the northern provinces. Here, beyond the wealth of the area, what has determined organised 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 mafia adaptability 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.

To carry out the empirical analysis, we assembled a new annual dataset covering 46 provinces from northern Italy spanning the period between 2005 and 2012. The reason to focus on provincial data is that provinces are the minimal territorial aggregations to gather sufficient information characterizing the mafia presence. 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 IPUMS concerning the university degree attained by each person in the sample and the type of establishment in which the person works.[6] Regarding innovation, it is measured with applications to European Patent Office (EPO) extracted from Eurostat, and with patent applications hand-collected from the Italian State Archive for the year 1960 when EPO did not exist yet. The second group of variables captures the mafia presence and consists of special crimes extracted

eight centuries of prison. As to several other criminal trials like *Maglio 3* in Liguria and *Aemilia* in Emilia-Romagna, the final sentences still have not been issued, but the number of defendants is impressive: 240 for *Aemilia* alone, where the prosecution asked for more than seventeen centuries of prison.

[5]See also the corroborating reference therein to the 2015 report by the Antimafia Investigative Directorate (DIA).

[6]The set of establishment types is based on INDNAICS industrial codes.

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 extracted from *Unioncamere* (Value Added and Total University Graduates), *Unione Provincie d'Italia* (Households' Deposits), and the Institute for Research on Population and Social Policies (Migration data).

A Technology Index

To portray the technology level of each province, we constructed a technology index computing the average of the sectoral technology levels weighted by sectoral relative revenues. The construction of this index is not trivial and we summarise it in the Appendix.

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. Separately, the OECD Directorate for Science and Industry (2011) classified the manufacturing industries into four categories based on R&D intensities. 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 sectors only. Our proposed index covers all the industrial sectors and is close in spirit to Heckler [2005].

B Mafia Index

The origin of organised crime in Italy tends to date back to mid-nineteenth century. It was only in 1982, yet, that the mafia-type association was considered as a distinguished offence with the introduction of article 416-bis in the Italian Penal Code. 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 assets confiscated from organised crime. Transcrime [2013] added variables distilled by open sources (DNA

and DIA reports[7]) to those contained in Calderoni [2011].

By adding to mafia-type murders other features of the organised crime phenomenon, these indexes allow to reveal, at least partially, the presence of organised crimes also in northern Italy. In this area, the mafia is present (as shown for instance by the sentences stemmed by the leading investigation called *Infinito* in Lombardy,[8] or *Minotauro* and *Albachiara* in Piedmont), but mafia-type murders, a distinctive feature of organised crime in southern Italy, are uncommon. However, as noted by Pinotti [2015], mafia-type crimes can be severely under-reported due to *omerta*. For this reason he uses mafia-type murders to track mafias in the southern regions where homicides have been a common practice. Nonetheless, 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: in brief a mafia type that avoids striking offences like murders and/or slaughters.[9] It is interesting, in this respect, as remarked by DNA [2015] a deep and irreversible mutation of the ways in which the mafia intimidation is rooted in the territory.[10] This mutation to silent mafia implies that organised crime looks like an inertial phenomenon in the northern area when it is described by previous indexes. Instead, changes in the mafia's presence at the province level were *de facto* captured by hundreds of conviction sentences based on both concepts of the unitary nature of the mafia association and *silent mafia*, sentences that are leading to millennia of prison years.

Accordingly, a natural and effective way to construct an index that accounts for *silent mafia* 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, and that turned out to be very effective to convict criminals belonging to or colluding with the clans in the North. We thus focus on the same set of crimes that are currently considered most revealing by these institutions to detect organised crime (see the Appendix). We think that this approach offers a substantial innovation in crafting mafia-type indexes. Following this approach, we gathered 14 observed variables which provide tracks of a latent variable, organised crime, and tend to be correlated. It was therefore possible to describe their variability with one index using factor

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

[8]*Infinito*, the main inquiry on 'ndrangheta in northern Italy, was run by the Milan DDA and is an historical step in the knowledge of organised crime as it shows that 'ndrangheta rules in northern Italy with a unitary structure.

[9]For a definition of 'silent mafia' as a particular expression of the intimidation method characterising mafias, see sentence n. 15412/2015 delivered by the Court of Cassation as to the *Minotauro* trial. Sparagna [2015] offers an interesting discussion of the jurisprudence of the Court of Cassation on silent mafia and the mafia method.

[10]For example, the thousands of murders in Calabria throughout the decades to consolidate the force of intimidation were unnecessary in nortern Italy as a few violent actions such as damage and arson quickly caused intimidation due to the criminal reputation of the organisation.

analysis (see the Appendix).

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] and carries useful information on the efficiency of both employees and fixed capital stock in generating quality products. The latter measures wealth, and it is well known that mafias prefer to colonise areas which produce more wealth [Gratteri and Nicaso, 2016, p. 133]. Deposits also capture the funds availability 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 requires a track record and success in innovation.[11]

Furthermore we control for migration. As noted by Buonanno and Pazzona [2014], several prominent sources agree that massive migration from southern Italy to the northern provinces along with forced resettlement of mafia bosses favored mafia transplantation. Buonanno and Pazzona [2014], indeed, find that the interaction between forced resettlement and migration was key to favor the transplantation of criminal organizations. For this reason, we also control for migration to the North from Sicily, Campania and Calabria which stand out for developing mafias as of the first half of the 19th century and provided an important migration of workers to 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; 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

[11] 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].

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 capture with a dummy. Table 1 reports the cross-province summary statistics of the aforementioned variables and indexes.

IV 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.[12] 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, mafia data 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 availability[13], 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 organised 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.

Having eliminated the mismatch of the datasets, we examined the impact of mafia on technology using aggregate data, and adopted the Fractional Probit model to account for the fractional nature of the dependent variable. The choice of this model is important as with standard linear models it is difficult to impose a positive yet bounded effect of explanatory variables on the dependent variable. Using this modelling strategy, we estimated the following cross-sectional model

$$E\left(T_i \mid \boldsymbol{X}_i, M_i, \epsilon_i\right) = \Phi\left(\boldsymbol{X}_i\boldsymbol{\beta} + \gamma M_i + \epsilon_i\right), \tag{1}$$

[12] Each of these provinces was created by reorganizing one or more of the existing northern provinces.
[13] In Italy, small firms are key and their data are only available from the Orbis data-set and since 2005.

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 (1) is the structural equation and γ is the coefficient of interest: the impact of mafia on technology. Before turning to the results, we present how we dealt with the potential endogeneity between mafia and technology.

A Identification Strategy

In examining the relationship between organised crime and technology, we paid special attention to the estimates obtained from the control function methodology. This approach was important in a study such as ours where the endogeneity problem may affect the results. In implementing a probit model, an appealing way to account for endogeneity is provided by Rivers and Vuong [1988] who developed a control function approach when the explanatory endogenous variables are continuous. This approach which is, inherently, an instrumental variables method, is discussed for example in Wooldrige [2010]. Accordingly, we add an equation to model the potential explicative endogenous variable in equation (1) as a linear function of the exogenous variables $\boldsymbol{X}$, and at least one additional exogenous variable that causes variations in T not appearing in $\boldsymbol{X}$

$$M_i = \boldsymbol{\alpha}\boldsymbol{X}_i + \delta B_i + \upsilon_i, \tag{2}$$

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 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 organised crime variable. 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 2, Panel A plots the technology index against standardised 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 organised 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.[14]

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 mafia 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 organised 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 mafia in northern Italy. Nevertheless, forced resettlement until the early 1980s was predominantly responsible among the joint causes that originated organised crime in the North as it provided a substantial exogenous flow of high-ranking bosses to the North.

But how did organised 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 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 organised crime networks on the territory.

It is worth noting that the application of forced settlement to mafia bosses 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 resettlement place. Only with the third law in

[14]Interestingly, hundreds of mafia kidnappings in the North during the 1970s were almost always close to villages where bosses had been resettled. This clearly reveals how 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].

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.[15] We also note 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.

Focusing on the relationship between forced resettlement and technology, when the boss is forced to resettle he faces two alternatives: either starts behaving honestly, or tries keeping the boss's status.[16] 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 hinders technology in the next decades. In the latter, he will adapt to the new territory his previous criminal experience to continue operating as a boss. To do so, the first step is to set up a criminal network. But why a mafia criminal network? Two incentives are at work here. First, higher chance of success: the boss is familiar with the mafia operating rules and is aware of their high effectiveness to illegally obtain profits and advantages. An intuition for the mafia effectiveness as a criminal network is provided by article 416 bis which defines the crime of 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, 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.*

This article is key to clarify what makes organised crime so powerful and its negative externalities on the local economy. The second incentive for the boss to create a mafia network is

[15] 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].

[16] *Tertium non datur* as the pathopsychological profile of the high-ranking mafia boss tends to be inconsistent with other criminal activities in which he loses the boss's prerogative.

an expected improvement of his economic status. Indeed, the resettlement place offers a virgin prairie with no competition of other bosses. The boss could therefore gain more easily a central position in the new network and, as shown by Mastrobuoni [2015] , network centrality of mafia bosses matters as it fosters their economic status. These two incentives lead to create a mafia network. Within that new network the boss can run criminal activities in the virgin territory which, ultimately, will hamper the industrial fabric of that territory and therefore its technology level. For this reason, we think 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 Empirical Results: Organised Crime and the Technological Fabric

In estimating equation (1), we first assumed that the explanatory variables are exogenous. We, then, allowed for the possibility that the mafia index could be endogenous and addressed this potential problem 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 mafia 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. 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 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.[17] As a result the technology index for that province will fall by 1.6%. One

[17]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 the mafia index. But

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 organised crime. Using continuous compounding we can show that that society will experience 7.68% less technological accumulation in five 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 organised 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 mafia and technology, the following section addresses the question: How does the mafia harm technology?

C Organised Crime and Innovation

To understand why the mafia harms technology we wondered how organised 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 measured this variable with the number of patent 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 equal to 0.5255 statistically significant at the 0.01 percent level. We thus conjectured that if organised crime negatively impacts on technology, this should occur *via* the intermediate variable innovation. A preliminary test of this conjecture is provided in Figure 2, Panel B, which plots standardised patent applications against standardised 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, organised crime stifles innovation.

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

this would imply that for the median province mafia's activities would unrealistically increase by more than 65%.

$$E\left(P_i \mid \boldsymbol{X}_i, M_i, \epsilon_i\right) = \Phi\left(\boldsymbol{X}_i\boldsymbol{\beta} + \gamma M_i + \epsilon_i\right), \tag{3}$$

where P indicates standardised patent applications. As to the potential explicative endogenous variable, we account for it like in the previous analysis and use equation (2) to obtain the control functions. Table 3 reports the coefficient estimates: The first two columns show the results when mafia is considered to be exogenous, while the last four when it is considered to be endogenous. In both cases, the findings provide evidence that organised 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, standardised patent applications for that province will fall by about 9% which is a sizeable effect.

In this section we have shown that organised crime affects negatively innovation. Since innovation is a flow that adds to the technology stock we can turn our attention on how mafias harm 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

This part runs 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 provinces, 3. the credibility of the instrument, 4. the robustness of the results with respect to potential outliers.

As to the first aspect, the interest on the relationship between organised 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 organised crime on the number of patents per province population, we directly examined the relation between organised crime and the number of patents. In this model, to capture size-effects we added a dummy equal to one if the province is also the capital of the region in which it is located. Corroborating the previous

findings, Figure 2, Panel C, plots patents against forced resettlement and shows a negative relationship between these variables. Moreover, Table 4 reports that the effect of mafia on patents is negative and significant and, similar to the previous results, it is increasing when we consider the presence of endogeneity.

Regarding the exclusion of the synthetic provinces, Tables 5, 6, 7, duplicate the regressions undertaken in Tables 2, 3, 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 standardised exiled bosses and standardised patent applications at the beginning of the forced resettlement period.[18] Our results suggest that the forced resettlement of mafia bosses in the northern provinces was not based on some technological feature of those provinces (see Table 1 in the Appendix). We also provide further evidence concerning the credibility of our instrument running the reduced-form regressions as in Angrist and Krueger [2001]. Our findings show that all the coefficients of exiled bosses are negatively significant (see Table 2 in the Appendix).

We finally investigated the residual plot against fitted values for the first stage of our regression to examine the robustness of the results in relation to potential outliers (see Figure 1 in the Appendix). The outcome shows that all of the residuals are distributed around zero and there is no obvious candidate as an outlier.

V Organised Crime, Natural Selection, and Technology

Having shown that the mafia stifles innovation, the first step to understand why we find this relationship was focusing on how organised crime relates with entrepreneurs and politicians and searching for commonalities. This step led us to observe that mafias, generally, introduce a friction in competition and, sometimes, an infringement of property rights; both effects, in turn, cause a brake on the agents' incentives to innovate. The premise to explain why this happens is that without organised crime, natural selection uses the ability to innovate for selecting who survives or prospers. When organised crime is present, however, its mere capacity to undermine property rights and eliminate or attenuate competition delivers another strategy, alternative to innovation hereafter (I), which is captured by two behaviours: 1. Adaptation, i.e., not resisting

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

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 the mafia*, hereafter (R). Strategies (I) and (R) are selected by Nature according to their fitness, namely their replication rate. Strategies' fitness is not constant but depends on their frequency which, in turn, depends on the presence of organised crime. The next step of our analysis then studies how the mafia presence generated the strategy's mutation and how it is related to the fitness of these strategies.

A Mafia and Strategies' Fitness

To discuss how mafia and strategies' fitness are interrelated we focus on some main channels through which the interaction between mafias and society occurs. While these channels are entangled and we will consider their interrelations,, it is convenient to present them separately.

A.1 Money Laundering and Credit Availability: an Inter- and Intra-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. This generates a strategy consisting in colluding with mafias. For example, commercial centers or restaurants, which are low-tech and in the key sectors controlled by organised crime, can grow faster due to easy access to illegal funds.[19] Instead, high-tech startups are generally required to follow strict procedures to obtain finance due to the presence of asymmetric information. Consequently, especially in the absence of a track record or collateral, innovative startups experience difficulties in raising funds and lag behind. 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 mafias rather than other sectors so as to attempt a cooperation with mafias to obtain finance and, therefore, survive and/or grow faster. Since the industrial sectors more connected with the mafia are low-tech, such a channel directly reduces the technological level of the industrial structure of the territory.

But money laundering also distorts intra-sector competition. For example, a new restaurant that colludes with the mafia recycling illegal funds or an unprofitable incumbent restaurant

[19] 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).

which avoids a default by the mafia acquisition tend to crowd out restaurants in the same area not relating with the mafia. This causes a fall in competition which tends to lead to a fall in innovation.[20] Thus, money laundering stifles innovation even within low-tech sectors.

Finally, money laundering indirectly hamper innovation by providing funds for corruption and for financing political campaign which, respectively, matter for the public procurement channel and the political elections channel discussed in section V. A. A.3 and V. A. A.4 respectively.

How does the presence of organised 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 commercial centers increase, then organised 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 organised crime, in turn, implies that the (R) strategy becomes more successful, in other words its fitness continues to rise. We thus face a vicious cycle.

We can now turn to the fitness of (I). Will it be affected by the mafia presence? Bonaccorsi di Patti [2009] found that in the Italian provinces where organised 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 attempts to resist subjugation, the default likelihood is higher. Thus, the asymmetric information problem becomes exacerbated in the presence of organised crime leading to higher interest rates and less access to credit. This implies that the financing costs of (I) increase, and (I)'s fitness falls when the presence of organised crime increases.

A.2 Private Protection: an Intra-Sector Channel

A second channel in which the mutation of strategy (I) into (R) takes place works through the *imposition* or *offer* of private protection in a broad sense, which occurs *via* mafia illegal services.[21] In the former case firms simply accept subjugation, while in the latter they cooperate with mafias; in both, fitness and frequency of the two strategies evolve according to the mafia presence.

[20] Regarding the causal impact of competition on innovation see Aghion et al. [2018] and the references therein.
[21] See Gambetta [1996] for a characterization of organised crime as the business of private protection.

Considering the *imposition* of illegal services, choosing strategy (R) means not resisting subjugation to the mafia in order to avoid risks to own life and firm. Examples include various types of extortion as imposition of security services, workforce,[22] suppliers.[23] These crimes infringe the property right of the agent that chooses (R), in particular the right to freely run his own firm and to earn income from it.[24] Importantly, as it will be explained in section V. A. A.5, these crimes make the (R) strategy counter innovation. Agents who choose (I), instead, reject the imposition of illegal services and are victim of felonies as threat, aggression, murder, as well as arson and damage. These felonies generate extra costs by eroding the human and physical capital of the firm, and such costs lead to losses and often defaults reducing the funds to invest in innovation. They also jeopardise the right to life and the property rights of the agent so that the potential benefits from the innovation are at risk since the agent might never enjoy them. It is this risk, then, that further depresses the incentive to innovate. As a result the fitness of (I) decreases. Instead, agents who choose (R) and accept subjugation can survive; otherwise, the illegal payments' flow from their firms to the mafia stops. Overall, the mafia's imposition of services is a burden for the firm as it can no longer count on basic rights and fairly compete with its peers.

Considering the *offer* of illegal services, often in exchange of other services/favours instead of money, firms that follow strategy (R) and demand services such as illegal workforce[25], illegal disposal of toxic waste[26], elimination of competitors, bogus invoices, and suppliers' imposition, unfairly compete with their peers. Indeed, they have an advantage consisting of lower costs or extra revenues.[27] Now, the larger the advantage, the more honest competitors choosing (I) will be crowded out unless their ability to innovate more than offsets the (R)'s advantages. 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 reces-

[22] Preventing the firm from choosing workforce that best suits its production activity negatively affects its profits.

[23] Firms unable to choose their suppliers incur a cost, but the firm imposing its products to others is a monopolist. As argued by Gratteri [2016, p. 54] " 'ndrangheta is everywhere in the industry but it is mostly present in the supply industry. If 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."

[24] See [Besley, 1995] and [Acemoglu and Johnson, 2005] as to the positive relationship between property rights protection and investment.

[25] Illegal workers are exploited for their under paid labour without labour rights protection.

[26] E.g. the *Star Wars* investigation, background of the *Infinito* investigation, revealed 178 thousand cubic meters of toxic and hazardous waste illegally disposed of over 65 thousand square meters of Lombardy agricultural land.

[27] See Varese [2006] and Dalla Chiesa [2017] along with the references therein for evidence on the following further illegal services: intimidation of customers, workers, and trade unionists for the benefit of employers, intimidation of lawful right-holders, debt recovery, false experts' reports.

sion.[28] Consequently, with mafias offering illegal services, 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 tend to lead to a decrease in innovation [Aghion et al., 2018]. 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. 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], with mafias the opposite happens: illegal services act as a subsidy preventing the replacement of low productive firms by new more productive ones. Indeed, resource 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 through which the mafia presence affects the fitness of strategy (I) and (R). Firstly, mafias, by interacting with administrators/politicians distort the competition between alternative public projects. This happens because choosing projects according to organised crime preferences rather than society preferences is a strategy that allows consolidation of the politician's power the more organised 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.[29] 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.[30] Nevertheless, if a politician follows this strategy he/she can lose power and easily be victim of mafia threats and violence. Hence strategy (I) has lower fitness the more the mafia is entrenched in the territory. The opposite happens with strategy (R). What are the implications of (R) in this context? Since mafias are biased for projects in traditional low-tech sectors, this automatically fosters low-tech sectors to the detriment of others and, thus, slows down innovation.

[28] 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 organised crime. In many cases they chose the second way".

[29] Italian municipalities infiltrated by mafias experience a 14% increase in the share of total investments in construction and waste management but a 29% fall in police force investment [Di Cataldo and Mastrorocco, 2018].

[30] 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.

Secondly, favoring entrepreneurs close to the mafia, politicians/administrators distort the competition between bidding firms. For a firm that wants to enter into the industrial sectors involved in public procurement, it is key to establish a relationship with local mafias. Thus, a larger presence of organised crime results in a larger incentive to choose (R) rather than (I).

A.4 Public Elections: an Indirect Channel

Altering public elections is a further channel through which organised crime disfavors technological progress.[31] *Via* this channel, mafias damage competition between candidates. Specifically, it establishes a convenient partnership with the winners elected thanks to the clan's votes and financial support in exchange of strategic services favoring the mafia. These include laws and influence on courts to secure judicial protection as well as decisions that allow the mafia's control of public resources or the access to financial circuits [Di Matteo and Palazzolo, 2015, p. 154]. Clearly, this channel is interrelated with the previous ones and amplifies their scope.

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, organised 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. Both intimidating and corruptive powers then make this institution extremely effective in reducing the enforcement of law and distorting public choices.

Summing up, with the natural selection mechanism at work, the presence of organised crime stifles innovation through all the channels we have described. By eliminating or attenuating competition and infringing property rights, mafias 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 as they opt to establish looser or tighter partnerships with the mafia to increase profits or reach other personal goals. Thus, agents including entrepreneurs, public administrators, politicians that establish an exchange agreement with the mafia can benefit from that agreement, at least in the short run, to the detriment of the rest of the society.

[31] The relation between public elections and organised crime is investigated by Alesina et al. [2018], Buonanno et al. [2016], De Feo and De Luca [2017].

A.5 A Key Feature of Strategy (R): Innovation Adversity

Does strategy (R) disfavour innovation? Generally this is the case. To see why, it is convenient to recall that (R) occurs either by not resisting subjugation to the mafia or by attempting to cooperate with the mafia at various levels. Now, when (R) consists of the first behaviour, resources for innovation easily become exhausted so that the incentive to compete trough innovation slows down or stops. We can clearly observe this with the private protection channel. Indeed, firms subject to the mafia extortion, for example the imposition of suppliers, 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 be harvested by the mafia. 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 profits imply a higher risk associated with innovation and thus less innovation. In all these cases, what hampers innovation is the insecurity of property rights, in particular the rights to freely manage the firm and to earn income from the firm.

Regarding strategy (R) as cooperation with the mafia, condensing this behaviour, it generally allows buying out protection from competition. This happens at various dimensions: Entrepreneurs involved in money laundering that do not need to compete to obtain finance, or that demand illegal services to increase revenue or reduce costs or, finally, that join competition in public procurement and win for being sponsored by organised crime. In all these cases, such an agent is not fairly competing with peers. Now, a fall in competition by itself tends to reduce innovation [Aghion et al., 2018]. Similarly, a politician elected with mafia's votes, on the one hand, is not competing fairly. On the other hand, once elected he is not free to support (I) agents for example promoting competition policies and anti-mafia/anti-corruption policies otherwise this would contrast with the mafia's preferences and, thus, violate the binding constraint established with them before the elections. Thus his behaviour has to support, more or less directly, (R) strategy's replication. Summing up, strategy (R) counters innovation as it is associated with damaging property rights and competition which matter for innovation.

B Mafia and Technology in an Evolutionary Game Theory Framework

To model the mechanics that relate organised crime to technology through innovation we use evolutionary game theory.[32] In the presence of organised crime Nature faces two strategies to select: Innovation, (I), and Relation with organised crime, (R). The frequency of (I) and (R)

[32] See Nowak [2006] for a general treatment of Evolutionary Dynamics.

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. 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 a common denominator in the four channels described earlier with the following hypothesis: the frequency of (R) is directly proportional to the mafia presence.

B.1 Payoffs in the Subjugation and Cooperation Cases

We first consider the case in which (R) consists of not resisting subjugation to organised crime and let the expected payoff matrix be

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

where b and $b/2$ are, respectively, the aggregate normal payoff and the individual normal payoff when the mafia is absent. However, in the mafia presence for (R) there is a payoff loss, c, due to subjugation, and a sanction, s, which is incurred if the police detects that (R) has not denounced the subjugation attempts.

Starting with the payoff for strategy (R), entry $(1, 1)$ reports the payoff for (R) when (R) meets (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 organised 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 organised crime, this because the more mafia spreads, the larger its intimidation power. Thus, (I) has an incentive in signalling to security forces (R) strategies followed by neighbours in its area, unless the presence of organised crime is not sufficiently large to expose (I) to major risks. This assumption is consistent with the fact that in areas where extortion is high almost nobody denounces organised crime to the security forces and (I) strategies turn more and more into (R) strategies. Put it differently, the larger x, the larger the pressure to abandon (I) for (R) and not denouncing due to aggression risks. The

term $(1-x)s$ models this assumption.[33]

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 mafia presence, the more it will undergo subjugation attempts by means of increasing threats, personal aggression and property crime. Clearly, these felonies against (I) imply not only immediate extra costs but also less future revenues due to insecure property rights that prevent from enjoying the benefits of the innovation. We model the resulting fall in profits by reducing the normal payoff by $xb/2$. In this way, we account for the fact that when organised 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 and the mafia is absent, the aggregate payoff is split equally and each strategy receives $b/2$.

We next consider the case in which playing (R) consists in cooperating with organised crime. Now the payoff matrix becomes

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

where c in this case is the extra payoff stemming from cooperation.

When (R) meets (R), the payoff is split between the two strategies as they are identical. 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 organised crime. Furthermore, the term $-xs$ captures the assumption that the larger the mafia presence, the higher the likelihood that (R) be detected by the police and pay the sanction. Here we have a difference with the subjugation case. Indeed, in the cooperation case (R) spontaneously go to the mafia to obtain illegal services, while in the subjugation case it is the mafia that goes to (I) to impose illegal services, and that pushes the (I) strategy to mutate into the (R) strategy for the risk of aggression. As a result, under cooperation there is no risk of aggression for (I) as under subjugation that disincentivises (I) to denounce when the presence of mafias is large. Yet, there is the risk of default for (I) as the playing field is no longer level in presence of (R) strategies. This incentives (I) to denounce (R) the larger

[33] It could sound counterintuitive that (R), victim of subjugation, also incurs a sanction by not denouncing subjugation. The rationale of a sanction is twofold: to avoid mafia abetting and protecting (I) type strategies. The Palermo Court (sentence 1380/2007), for example, convicted a victim of extortion to 6-month prison for abetting, and also convicted such a victim to compensate four civil parties with Euros 5000 each for the suffered damages. Furthermore, Confindustria, the Italian industrial association, introduced a norm in its code of ethics to expel members that do not denounce subjugation attempts by organised crime. Such a punishment is another possible form that the sanction s can take.

the default risk, which is increasing in x.

But the extra payoff c for (R), unfairly favored in the competition by colluding with organised crime, implies a loss for (I). 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 assumption that the loss incurred by (I) - due to unfair competition - is less than the extra payoff accrued to (R). The motivation is that (R) can obtain illegal services that increase only its payoff, like illegal disposal of toxic wastes or money laundering finance, and/or can obtain services that simultaneously increase its payoff to the detriment of (I)'s, like illegal imposition of suppliers, elimination of competitors in public procurement, support in political elections.

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

B.2 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

$$F_R(x) = xP_{11} + (1-x)P_{12}, \tag{4}$$

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

$$F_I(x) = xP_{21} + (1-x)P_{22}. \tag{5}$$

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

$$\dot{x} = x(1-x)[F_R(x) - F_I(x)], \tag{6}$$

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 (6) 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 stability of the equilibrium.

Calibration

For 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; in the construction sector, for example, anecdotal evidence points to a loss around half of the profits. Next, we set the value of the sanction parameter s equal to c to obtain a corresponding sanction in the range $(0 - 10)$ percent of the individual normal payoff. We consider this value as a benchmark for policy analysis carried out next.

For 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), and it is equal to the 20 percent of the individual normal payoff when (R) meets (I), for in this case (R) does not have to split the extra payoff with (R). We then set the value of the sanction parameter s equal to $0.8b/2$ so that the corresponding sanction will be in the range $(0 - 80)$ percent of the individual normal payoff. Also in this case such a value is considered as a benchmark for the policy analysis that we perform next. It is worth to note that assuming a smaller sanction under subjugation than under cooperation reflects the fact that in the former (R) is committing a less severe crime. Specifically, (R) does not denounce the subjugation attempts, which may constitute the criminal offence of mafia abetting, and certainly damages (I) as civil party. In the cooperation case, instead, (R) deliberately looks for mafia to illegally increase its payoff and, as shown by leading mafia processes in north Italy, this can constitute the grave felonies of complicity in conspiracy with mafias, or electoral exchange between politicians and mafias, or even mafia association.

Finally, in both the subjugation and cooperation cases, b does not need to be discussed as it can be factorised out of the strategies' fitness, for c and s have been calibrated in terms of b.

Results

The first and second column of Figure 3 portrays the evolutionary dynamics of the strategies' population in the subjugation and in the cooperation case, respectively. In each panel, the red circle denotes a stable equilibrium while the white circle an unstable equilibrium. Starting with the first column, where (R) consists of not resisting subjugation to organised crime, in each panel along with the two stable corner equilibria, there is an interior unstable equilibrium. Focusing on Panel A, where $s = c$, for values of x below the value at the interior equilibrium, 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 mafia-free province where 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, organised crime will become more and 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 organised crime[34], 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 $s = 2c$ respectively, where the latter implies a sanction for the victims of mafia subjugation that do not denounce in the $(0 - 20)$ percent range of the individual normal payoff. Comparing the position of the interior equilibrium in Panels B and C we notice that the sanction can mitigate but is far from solving the problem.

Does the model suggest the use of any other instrument? Yes, a compensation to (I) for the loss incurred due to organised 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 shows that if the indemnity is sufficiently large, then natural selection will guarantee that with respect to imposing illegal services mafias will not root. Ultimately, this signals that indemnity can be a key instrument in the integrated contrast to organised crime under subjugation.

We next turn to the case in which (R) consists of cooperating with organised crime, second column. In Panel A, where $s = 4c$, we still have three equilibria as in the first column, but now the stability property of the extremes are inverted, while the stability property of the internal equilibrium is twofold: stable from right and unstable from left. We consider this case as

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

a benchmark in that for $s < 4c$ there will be no internal equilibrium, so no strategy (I) at all, as shown in Panel B. Instead, for $s > 4c$ there will be two internal equilibria, the first stable and the second unstable as shown in Panel C. Panel C, computed for $s = b/2 + c$, shows that the economy can easily end up in the first internal equilibrium, difficult to uphold, where a substantial share of the strategies are (R). It also shows that there exists a value of x, corresponding to the second internal equilibrium, such that any arbitrarily small increase in x leads to the extinction of (I) strategies.

At this point, it is worth noting that under cooperation, it is impossible to increase the incentive to choose (I) with an indemnity as in the subjugation case since now (I) strategies do not receive direct aggression. The only policy instrument available thus is s. In this respect, comparing Panels C with A we notice that the smaller the sanction, i. the larger the share of (R) corresponding to the internal stable equilibrium, and ii. the smaller the distance between the two internal equilibria, the latter relevant as it affects the likelihood that the unstable internal equilibrium can be overcome leading to all (R) strategies. This shows that s is an important policy tool, but this tool cannot extinguish (R). This because when x is close to zero the reduction in competition is limited, as few (R) are around, and therefore (I) has little incentive to denounce (R) to the police. On the other hand, when x is close to one, most of the population is (R) and therefore there will be few (I) around to denounce (R) to the police. Consequently, close to the population extremes, there will always be an incentive to play (R). What is the implication for a policymaker that has to choose s? Panel D addresses this question showing all the values of s that eliminate the incentive to play (R) when one abstracts for the population extremes featuring a discontinuity in the value of s. Panel D clearly shows that s should be set as high as possible when x is close to zero or one. Since, realistically, the value of s has to be unique, that is the same for any x, we argue that it should be always set as high as possible. This is feasible as sanctions can be both pecuniary and custodial. Our model then suggests that the best that can be done to minimize the incentive to play (R) initially, and therefore the rooting of mafias later on, is adopting for (R) a pecuniary sanction equal to the normal individual payoff, and a custodial sanction not less than the punishment assigned for the crime of mafia association. In this respect, our results offer an evolutionary perspective to be included in the choice of the proper sanction for mafia crimes as electoral exchanges between politicians and mafias, and complicity in conspiracy with mafias.[35] A perspective shedding light on a key damage incurred by the society: the disincentive to innovate captured by preferring (R) to (I).

[35]There is a far-reaching debate on the appropriate sanction for mafia crimes, see for example Di Matteo and Palazzolo [2015, p. 53 and 157-158].

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.

VI Conclusions

The empirical results presented in this paper consistently support the view that an increasing mafia presence in a province leads to a fall of the technological level of that province. We document with fairly robust evidence that this occurs through a negative impact of organised 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 incur a 9% loss in the number of patents per capita.

To explain the empirical findings and investigate their implications, we built an evolutionary game theory model that captures the replicating ability of two strategies, innovation (I) and relating with the mafia (R). Our model shows the importance to distinguish the two cases in which the relating strategy (R) can occur: 1. subjugation to organised crime and 2. cooperation with organised crime. Indeed, it shows that in the former there is a level of mafia beyond which all the agents tend to be subjugated by the mafia and give up innovation, whereas in the latter there is a level of mafia, difficult to uphold, where a substantial part of the agents collude with the mafia to the detriment of the others and tend not to innovate. The model also shows that under subjugation, a sanction can only mitigate the problem, while providing a proper indemnity to the mafia's victims is key to solving the problem. In contrast, under cooperation, the sanction can be effective but should be set not less than the sanction for the mafia association crime.

We argue that these results stem from the fact that the strategy to relate with mafias undermines property rights and, mostly, introduces a friction in competition. Such an argument is consistent with the idea proposed by Schelling [1971, p. 73] that the mafia's specialty is "*exclusivity*, or, to use a more focused term *monopoly*. From all accounts [the Nobel laureate continues] organised crime does not merely extend itself broadly, but brooks no competition."

Our empirical finding that mafias disfavor technology contributes to show that the damage caused by mafias is not limited to criminal offences harming individual victims. Indeed, by imposing a burden on the technological progress, mafias put a brake on economic growth and, therefore, damages each member of the society in addition to the direct victims of its violence.

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, 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 organised 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.

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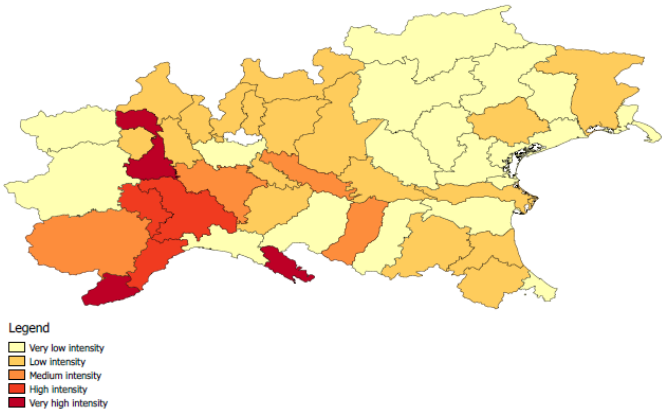
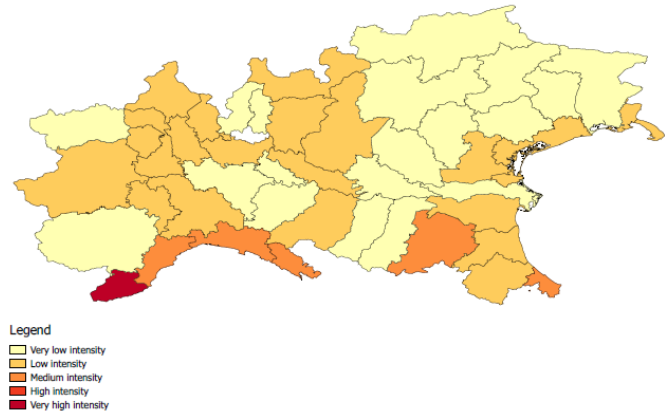
Table 1: Descriptive Statistics

	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
Standardised patents application	46	0.00011	0.00006	0.00009	0.000023	0.00035
Standardised 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
Standardised migration	46	0.062	0.056	0.04	0	0.21
Houshold deposit per capita	46	11	1.76	10.9	8.7	18

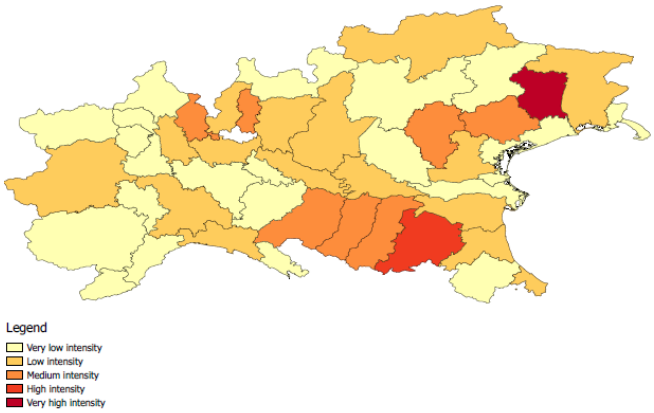
Figure 1: From Forced Resettlement to Mafia to Innovation



Panel A: Prevalence of Forced Resettlement (Standardized Exiled Bosses); stock in 1974



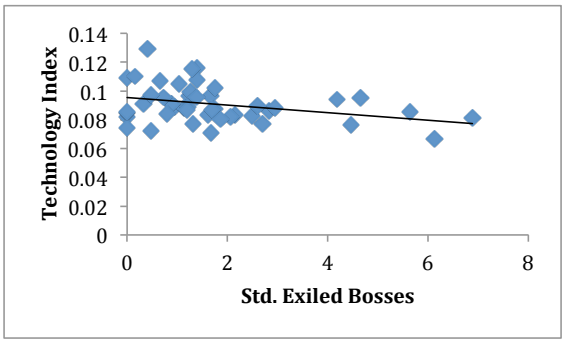
Panel B: Prevalence of Mafia (Organized Crime Index); period 2005-2012



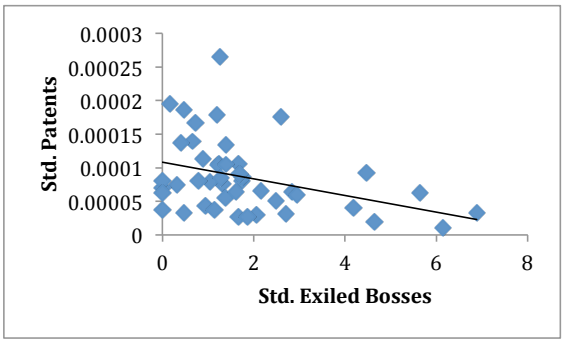
Panel C: Prevalence of Innovation (Standardized Patent Applications); period 2005-2012

Figure 2: Reduced-form Relationships between Technology/Innovation Measures and Standardised 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

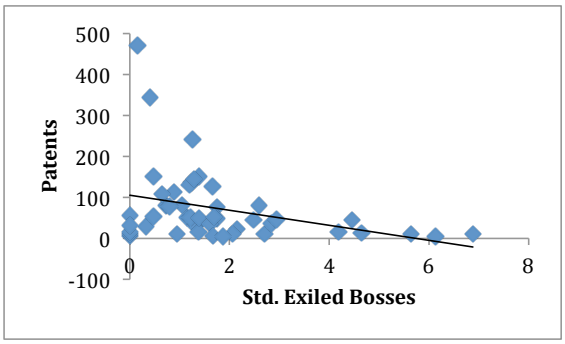
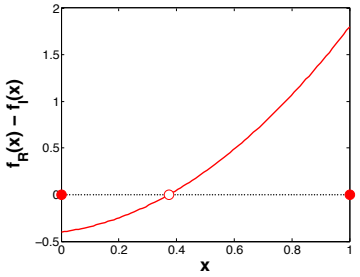
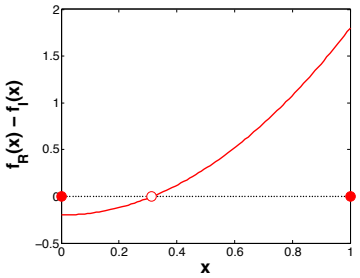


Figure 3: Evolutionary Dynamics of Strategies (R) and (I)

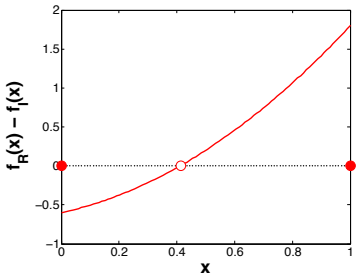
Subjugation case



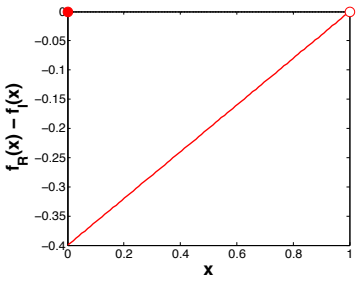
Panel A. $c = 0.1\frac{b}{2}$; $s = 0.1\frac{b}{2}$.



Panel B. $c = 0.1\frac{b}{2}$; $s = 0$.



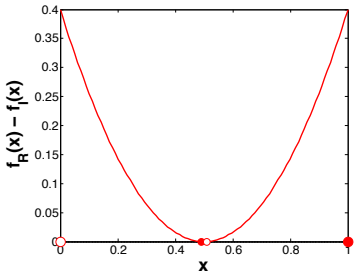
Panel C. $c = 0.1\frac{b}{2}$; $s = 0.2\frac{b}{2}$.



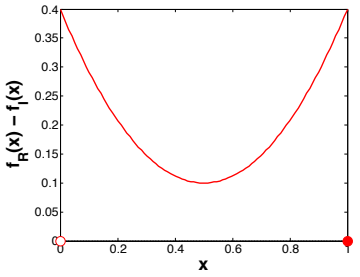
Panel D. $c = 0.1\frac{b}{2}$; $s = 0.1\frac{b}{2}$

indemnity $= x\left(\frac{b}{2} - 0.1\frac{b}{2}\right)$.

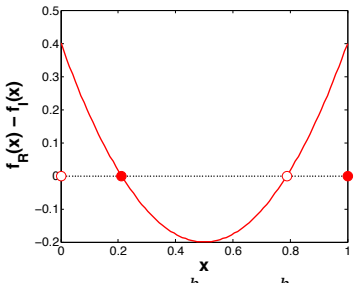
Cooperation case



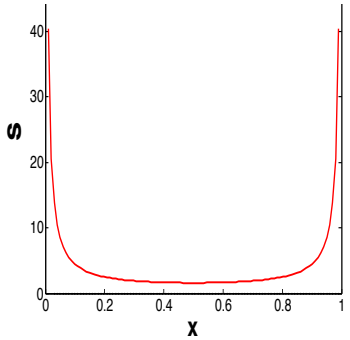
Panel A. $c = 0.2\frac{b}{2}$; $s = 0.8\frac{b}{2}$.



Panel B. $c = 0.2\frac{b}{2}$; $s = 0.6\frac{b}{2}$.



Panel C. $c = 0.2\frac{b}{2}$; $s = \frac{b}{2} + 0.2$.



Panel D. s: $f_R(x) = f_I(x)$, $x \in (0,1)$.

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

Note 1: 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.

Note 2: $\hat{v}$ is the control function. The data for forced resettlement consist 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, migration from Sicily, Campania and Calabria, and the size of the provinces (i.e. dummy is equal to one if the province 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. Also see Note 2 in Table 2.

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	46	45	46	46	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 Poisson estimates of the impact of mafia on innovation without and with controls, respectively. Also see Note 2 in Table 2.

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	-0.051***		-0.16***		-0.16**
	(0.02)	(0.018)		(0.05)		(0.07)
APE Mafia index	-0.004***	-0.0069***		-0.026***		-0.02***
	(0)	(0.003)		(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. Also see Note 2 in Table 2.

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**	-0.09**		-0.31***		-0.34***
	(0.04)	(0.04)		(0.11)		(0.12)
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. Also see Note 2 in Table 2.

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	41	40	41	41	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 Poisson estimates of the impact of mafia on innovation without and with controls, respectively. Also see Note 2 in Table 2.