

Anagraphical relationships and crime specialization within Cosa Nostra

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(Dated: October 20, 2020)

The aim of the present work is to investigate the relationships established within Cosa Nostra, by making use of networks and complex-systems methods. The analysis is performed at three different levels, that is, individuals, groups within mafia syndicates, and relationships amongst mafia syndicates.

The reported empirical analysis is based on the criminal records of 632 affiliates to Cosa Nostra selected from a set of 125 judgements emitted by the Palermo courts from 2000 to 2014. According to the criminal records of the Palermo Prosecutor Office, such a dataset includes approximately 10% of the whole population of Cosa Nostra affiliates in western Sicily. Furthermore, the vital statistics of 235 subjects sentenced for mafia crimes and the one of their relatives complemented the database that, overall, includes about 4,000 subjects.

Our results show that mafia syndicates are not specialized in terms of criminal activity, rather they show a strong territorial attachment and are involved in heterogeneous criminal activities.

Since syndicates insist on a delimited territory, young affiliates are selected on a territorial basis according to the significance and variety of their past criminal activity. Once inside a syndicate, affiliates tend to specialize in a few criminal activities, depending on their attitudes and the needs of the organization. Finally, despite the fact that the vast majority of mafia affiliates are males, our results highlight that female subjects are crucial to form and consolidate alliances between mafia syndicates through suitable marriages.

I. INTRODUCTION

Literature on Mafia and organized crime phenomena is vast and heterogeneous. It ranges from journalistic accounts [1–7] to books written by magistrates [8–12] and academic works. Scholars have investigated Mafia from several points of view. There is certainly a large interest in understanding the historical development of Mafia [13–17], its political and juridical implications [18–20], as well as its economic origins [21] and impact on the society [22, 23]. However, Mafia has also been investigated with the aim of understanding the personality traits of mafia affiliates [24–26] and the sociological roots and features of the organization [27–33].

Mafia activities are characterized by the existence of an underlying organization providing inputs, expertise and support for committing crimes that are part of a general framework. The latter is depicted by the organization, which is based on its own criminal projects. Mafia crimes are not planned and perpetrated by isolated subjects, but by people involved in a social, albeit criminal, context characterized by specific values, a code of conduct, and a peculiar way of conceiving social relationships, and communication skills [34, 35]. Many studies in the literature on personality point out that Mafia members develop their personal identity within the family, and grew up interiorizing “values” such as honor, manhood, silence, and disdain for the State, its laws and authorities [24, 36–43].

We investigate the Cosa Nostra society at three different levels by making use of a network-based data mining technique. First, we focus our attention on the characterization of the affiliation-based communities of Cosa Nostra. Second, we consider the level of individuals belonging to mafia syndicates and study their degree of criminal specialization. Third, we investigate the determinants of the interlinkages between different mafia syndicates, with emphasis on the role of family bonds.

In the first case, we consider several attributes associated with each individual belonging to a given mafia syndicate and try to determine whether there are specific attributes that are over-expressed in a certain mafia syndicate. In principle, attributes can be of different nature. Based on our data, available attributes are i) crimes perpetrated, ii) age, and iii) residence of members. Our investigation shows that, while age and specialized criminal activity do not characterize mafia syndicates, residence of the affiliates is a characterizing feature of syndicates, which reflects a strong territorial bond of Cosa Nostra. In fact, we observe that mafia syndicates are characterized – in a statistically significant way – by specific postal codes of Palermo and the nearest suburbs. This result quantitatively reflects the fact that the main strength of mafia syndicates is a tight control of a (local and specific) territory.

When looking at the literature, this result appears to support Gambetta’s view of Cosa Nostra syndicates as “protection companies” that guarantee both legal and illegal transactions that occur among the members of a

given community and/or take place in a specific area. Along this line of thinking, indeed, a syndicate must keep control of a territory, which can be a city, a neighborhood, a rural area, etc., in order to provide “protection”. With the words of Gambetta [30]: “... *the main market for mafia services is to be found in unstable transactions in which trust is scarce and fragile. Such is the case, for instance, with illegal transactions in which no legitimate enforcement agency—in other words, the state—is available.*” According to Gambetta, the main difference between the role played by a *mafioso* in a transaction and the one of a usual intermediary is that a “mafioso” does not – or at least not only – provide information, instead he produces guarantees. In other words, he represents a parallel authority (to the legitimate one) that should be recognized by both parties in a transaction. Therefore, tight control of a local and specific territory is at the core of mafia business, that is, “protection”. In this paper, we empirically prove that such a control is attained by having syndicate members living nearby each other in a very specific area. Similar conclusions have been reached for organizations other than Cosa Nostra, namely Yakuza [45], Russian Mafia [46], and Triads in Hong Kong [47].

In the second case, we construct a network of crime types by linking two crimes according to the number of subjects condemned for both. Such a number is then tested against a null hypothesis of randomness that exactly takes into account the heterogeneity of crime types. The resulting statistically validated network is partitioned into several communities, which, therefore, gather together specific crimes on the basis of the fact that they are committed by the same criminals. Such an approach allows us to define the concept of significant “similarity” among different crime types in an unsupervised way, that is, without invoking any theory of criminal specialization. Then we look at the percentage of criminals that commit successive offenses associated with crime types that belong to the same community. Such an information allows us to track the overall tendency of criminals in our sample to specialize as long as their criminal career proceeds. We observe that criminal specialization of subjects increases, on average, as long as their criminal career proceeds inside the syndicates, thus reinforcing the idea that, since mafia syndicates are not specialized, their affiliates should develop specific criminal skills to better fit the interests of the syndicate.

Again, Gambetta argues that Mafia syndicates specialize in “protection” at the organizational level, even when the protection is guaranteed to transactions (in the broad sense) that involve as one or both parties the syndicates themselves. Such a specialization requires a multiplicity of skills at the level of affiliates, skills that may also vary over time, in order to fit societal and organizational changes, and adapt to the varying conditions under which Mafia syndicates operate [20]. In this paper, we argue that Cosa Nostra syndicates adapt and change mostly by exploiting the generalist attitude to crime displayed by young affiliates, who tend to specialize on specific criminal activities slowly during the progress of their career in the organization. In other words, the (strong) skills required by the role of “protector” played by a syndicate at the organizational level is guaranteed by “old” affiliates who specialize at the individual level on one or a few criminal activities, whereas adaptation to the changing environment, which requires a variation of the skills that syndicates can guarantee, is attained by exploiting new and yet unspecialized recruits.

In the third case, we consider the network of the parental and marriage relationships of a (large) subset of subjects condemned for mafia crimes. We augment the information reported in the network description by adding extra-nodes, besides individuals, which represent syndicates, and are linked to individuals on the basis of their affiliation. We therefore have two types of nodes in the network: nodes representing individuals, and nodes representing Cosa Nostra syndicates, and two types of links, one indicating the affiliation of a subject to a syndicate, and the other one indicating a parental or marriage relationship between subjects. The network is naturally partitioned into a large number of connected components, and our interest is in studying how two mafia syndicates connect together. Specifically, we consider all of the possible pairs of nodes representing mafia syndicates and compute the *shortest path* between the nodes of each pair. The shortest path is the minimal set of nodes that connects any two node pairs in the same connected component of the network. The striking result is that, in the large majority of cases, the nodes that allow the connection between two given mafia syndicates, according to the shortest path, correspond to women, in spite of the very small number of women in the sample—19 out of 3241. This result shows that, while parental and marriage relationships are weakly characterizing the links within communities, their role becomes extremely important when considering links between different communities. Of course, mere marriage in a family context characterized by the adherence of someone to Cosa Nostra does not necessarily imply that one or both members of the couple are also affiliated. However, marriage relationships reflect the complexity of the mafia network, being a prominent channel through which Cosa Nostra manages the cultural codes and shares social practices. Cosa Nostra exploits marriages, bends them to its own interests, making them an element of cohesion fundamental for its own survival.

The manuscript is organized as follows: in section II and section III we illustrate the data and methods used in the present investigation. In section IV, we analyze the network of affiliation of subjects to Cosa Nostra syndicates. In section V, we investigate the evolution of criminal specialization of subjects. In section VI, we analyze the network of parental and marriage relationships of subjects condemned for Mafia crimes and study their role in the interlinkages amongst mafia syndicates. Finally, in section VII, we draw our conclusions.

II. DATA

The starting point of our work has been a set of 125 judgements issued by the Judiciary of Palermo (judge for preliminary investigations, jurors courts, ...) in the time period 2000-2014. For confidentiality reasons, the list of considered judgements is available only upon request. From such judgements information about 976 subjects was extracted, that includes names, date and place of birth. Such an information allowed us to reconstruct the tax code (equivalent to the social security number in other countries) of each of the 976 subjects. Other information, such as the name of judges, public prosecutors and of defense counsel, was not used in the present study.

Through the P5 tax code, we obtained the penal records (Certificati Penali) of all 976 subjects selected above, by means of the facility CERPA, which is a software that allows to query the database containing all penal records in Italy. We used the CERPA *massive* mode, which required the creation of a single file containing all the information about the considered subjects.

Amongst all obtained records, 633 were positive, while the remaining part was either relative to subjects that are over 80 years old, or already dead or who had not reported any criminal conviction. Although the information about the subjects has been extracted from judgements issued by the Tribunal of Palermo, it is worth recalling that such judgements are not definitive, and, therefore, it is still possible that some of the condemned subjects will be discharged by any conviction after all the levels of trial have been passed.

The penal record of each subject contains the information about any conviction reported by the considered subject. Such information consists in;

- date when the judgement has been emitted,
- court that emitted the sentence,
- date when the conviction become definitive,
- the crime committed according to the Italian penal code, the Code of Criminal Procedure, Road Code, Special Legislation, ...
- the sentences details (how long, if it includes fines and economic penalties, ...)

The penal records also contain the information about the time when the crime was committed. However, depending on the nature of committed crimes, such information is reported in different ways. In some cases, there is a precise date, in other cases a period of time—which can also be very long—is reported, or the information is completely missing. Starting from this information we were then able to generate a bipartite network of 633 subjects condemned for Mafia crimes, 723 committed crimes and 5408 links. In order to have a better statistics we aggregated all the crimes that made reference to different commas of the same article of the penal code. Table V provides some descriptive statistics relative to this dataset.

A second source of data provided by the Prosecutor Office consists of the information about the mafia syndicate each subject belongs to. The information was updated to October 2018. However, the Prosecutor Office has the whole historical information about the affiliation of the subjects and therefore when it is known that a subject moved from one syndicate to another the information about both syndicates was reported. According to this information a set of 436 out of 632 subjects condemned for Mafia crimes were divided into 62 mafia syndicates that are essentially based in different neighborhoods of the Palermo municipality as well as in a few villages close to Palermo. Table VI provides some descriptive statistics relative to this second dataset.

Further, a third dataset includes anagraphical relationships amongst the considered subjects. To this end we obtained from the Registry Office of the Palermo municipality the information (*Certificato anagrafico*) about father, mother, spouse and sons of 325 out 632 condemned subjects. We also have the information about the full address of the place in which they are officially resident. The information about the remaining 278 subjects was not available due to the fact that such subjects were not residents of the Palermo municipality. With this additional information the number of subjects considered in the study raised from 978 to 3989. We did not check the penal records for the additional 3011 subjects whose name were extracted from the registry records. This is also due to the fact that for many of them (especially mother and father of the considered subject) the registry records do not report the information about date and place of birth, which makes it impossible to reconstruct their tax code. The information about the tax code is crucial for getting the correct penal record of any subject as it solves any problem due to homonymy. Table VII provides some descriptive statistics relative to this third dataset.

Finally it is worth mentioning that all the activities that requested the direct knowledge of the subjects identity were performed by personnel of the Palermo Prosecutor's Office. We collaborated with them in writing the codes for extracting the relevant information from judgements, penal records and registry records. MT and SM only had access to data already anonymized.

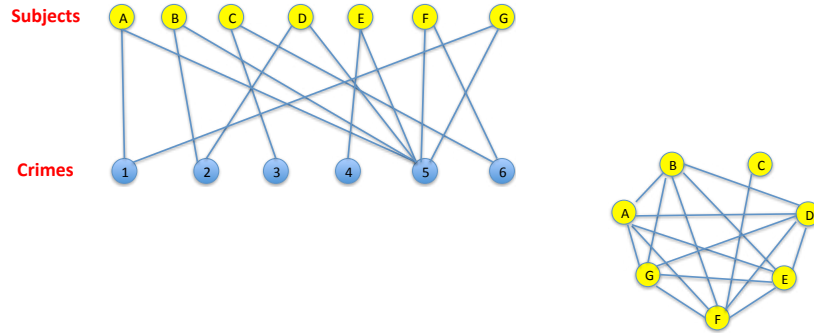


FIG. 1: The left panel shows a schematic representation of the bipartite network of subjects and their crimes. We consider a set of 7 participants and 6 crimes. The panel on the right shows a schematic representation of the resulting projected network on the side of subjects. For example, one can notice that subject C is connected only to subject F through Crimes 6, and therefore the link between C and F has weight equal to unity.

III. METHODS

A. Bipartite networks

We perform our investigations by using a network theory approach applied to the social system represented by the Cosa Nostra affiliates. The investigation of social systems by using a social network analysis is nowadays quite consolidated [48]. It has also been used in the context of mafia studies [49, 50].

A bipartite complex system is a system where one can distinguish two types of elements. The elements can be therefore gathered into two sets, namely set A and set B. Elements of set A are connected to elements of set B, but no explicit connection is present among the elements of set A and among the elements of set B. Examples include movies and actors [51–53], authors and scientific papers [54–57], email accounts and emails [58], plants and animals that pollinate them [59, 60], criminals and crimes [61], investors and trading days [62], mobile phone users and calls [63], complex systems of social importance [64, 65]. A bipartite complex system can be represented by a bipartite network, i.e. a graph where nodes are grouped in two sets, say A and B, and links can only occur between elements of set A and elements of set B, that is, connections between elements of the same set are forbidden.

A projected network of set A is obtained by linking together those elements of set A that share at least one common first-neighbour element of B in the original bipartite system. This is a weighted network, where the weight of a link between elements i and j , is the number of elements of set B that are first-neighbours of both i and j in the bipartite system. It should be noticed that the links between nodes of the projected network are virtual links induced by the projection procedure. A statistically validated projected network of set A is obtained in two steps. First, a p-value is associated with each link in the projected network, representing the probability to observe a weight larger or equal to the observed one under a null hypothesis of random pairing. Then only links with a p-value lower than a given threshold of statistical significance — for example 1% corrected for multiple hypothesis testing according to the False Discovery Rate (FDR), in the present study — are selected. The method to construct a statistically validated network is detailed in Ref. [66].

B. Community characterization

Given a network, i.e. a set of nodes (or vertices) connected by links, one can search for communities within the network. Heuristically, communities are subsets of nodes that display a higher level of connectivity among them with respect to their connectivity with other nodes in the network, see Ref. [67] for a detailed discussion. Here we will consider the Radatool [68] algorithm, which is based on the maximization of the modularity fitness function.

We characterize the resulting communities in terms of some features associated with the participants belonging to them. Specifically we use a statistical methodology illustrated in [69], which essentially consists of a repeated

construction of contingency tables and the application of Fisher’s exact test [70] to examine the significance of the association in each table.

Given the subjects in a community and some attributes, like age, crime, or postal code, associated with each participant in the system, one can answer the question: what are the attributes that are over-represented in the community, with respect to a null hypothesis of random sampling? The idea is that these attributes are those characterizing the community. It is worth recalling that such methodology does not necessarily select the most represented features in the community. Rather, the methodology selects the features that are most represented in relative terms, given the null hypothesis. Whenever the most represented feature observed in the system is also expected to be the most represented, then it is not selected by our methodology. Rather, the methodology selects features such that there is a discrepancy between empirically observed frequencies and expected frequencies according to the null hypothesis.

The null hypothesis is described by the hypergeometric distribution. Specifically, in a system including N subjects, we consider a category c (e.g., *male*) of an attribute (e.g., sex) shared, overall, by K individuals, and a community of size M . If \hat{x} is the number of subjects in the community that share category c , then the probability that a value larger or equal to \hat{x} is obtained randomly is:

$$P(x \geq X) = \sum_{x=X}^{\min(K,M)} \frac{\binom{K}{x} \binom{N-K}{M-x}}{\binom{N}{M}}. \quad (1)$$

Such probability represents the p-value of over-expression (OE) associated with the observation \hat{x} . The p-value of under-expression (UE) associated with observation X is calculated as

$$P(x \leq X) = \sum_{x=\max(0, M+K-N)}^X \frac{\binom{K}{x} \binom{N-K}{M-x}}{\binom{N}{M}} \quad (2)$$

To characterize communities, we use a 5% p-value threshold and the Bonferroni correction for multiple comparisons. If the considered attribute is a crime type, like homicide, this approach can be used to specify the criminal specialization of subjects within a given community. In this sense, our holistic and quantitative approach is different than other approaches, typically qualitative, which have been used to describe the criminal specialization of Cosa Nostra families in the past. A short review on the topic is therefore reported in Appendix A.

IV. CHARACTERIZATION OF THE COSA NOSTRA AFFILIATION-BASED COMMUNITIES

Let us consider the bipartite network given by the subjects convicted for Mafia crimes and the syndicate they are affiliated to. Since at a given time one subject can only be part of a single mafia syndicate, when projecting on the subjects side the resulting network is naturally partitioned into 62 communities that correspond to the mafia syndicates. Once again, we emphasize that the link between any two subjects is not direct. It is rather induced by the mere fact that they belong to the same Mafia syndicate. We now have a set of (natural) communities formed on the basis of the membership to a specific mafia syndicate. One might therefore ask whether they can be characterized in terms of committed crimes or other attributes as will we show below.

In fact, starting from these natural communities we can consider the community characterization methodology of section III B in order to quantitatively investigate what are the features that are over-expressed in a certain community and therefore characterize it.

In Table I we summarize the results obtained when the considered features are the crimes committed by the individuals belonging to the considered community. Since these individuals commit many different crimes, for each community we might expect more than one over-expressed crime.

The crimes we have considered are those obtained from the penal records provided by the Prosecutor Office. Such crimes are coded according to the entire body of laws existing in Italy, including the Italian penal code, the Code of Criminal Procedure, Road Code, Special Legislation, In the Italian system different articles of different codes can be joined together to form a unique crime. As an example, art. 110 (art. 110 cp) and art. 81 (art. 81 cp) of the Penal Code are usually joined with other more specific articles when the court want to emphasize that this more specific crime has been committed in collaboration with other subjects (art. 110) or that this crime has been repeated over time (art. 81). This is quite common when considering subjects condemned for mafia crimes.

Specifically, in Table I we show the committed crimes that are over-represented in the five largest natural communities corresponding to the different mafia syndicates. The first and second column show the mafia syndicate name and its size. The third and fourth column show the committed crime and its synthetic description. The fifth column gives

the number of times it is present in the whole network. The sixth column gives the number of times the committed crime is present within the community. The seventh column gives the number of elements in the network, while columns eight and nine are the p-value associated to the attribute and the p-value threshold for that community. When performing the community characterization with the methodology of section III B we set a different Bonferroni threshold t_c for each community. Specifically, we used $t_c = 0.05/A_c$, where A_c is given by the number of distinct attributes represented in the c -th community. Only a few mafia syndicates are therefore characterized by one or more committed crimes. As a matter of fact, there is therefore a weak evidence that affiliation-based communities are characterized by the type of crime committed by its affiliates.

community	M	crime	description	K	X	N	p-value OE	threshold
TOMMASO_NATALE	27	art 12 l 07/08/1992 356	Weapon and ammunition ownership	4	4	436	$1,18 \cdot 10^{-5}$	$4,24 \cdot 10^{-4}$
TOMMASO_NATALE	27	art81,110, 629cp	Blackmailing (continued and in collaboration)	57	12	436	$3,04 \cdot 10^{-5}$	$4,24 \cdot 10^{-4}$
NOCE	21	art110 cp, art4 l 18/04/1975	Carrying weapons or objects able Causing injuries (in collaboration)	33	7	436	$4,31 \cdot 10^{-5}$	$4,50 \cdot 10^{-4}$
CARINI	15	art 56,110, 635 cp	Attempted damage (in collaboration)	3	3	436	$3,31 \cdot 10^{-5}$	$6,02 \cdot 10^{-4}$
CARINI	15	art 636 cp	Introduction or abandonment of animals in others property and Unauthorized grazing	4	3	436	$1,30 \cdot 10^{-4}$	$6,02 \cdot 10^{-4}$
ACQUASANTA	7	art 110, 336 cp	Violence or threat to a public officer (in collaboration)	3	2	436	$6,59 \cdot 10^{-4}$	$1,78 \cdot 10^{-3}$
BAGHERIA	6	art 81cp, art75 l 22/12/1975	Criminal association in the field of drugs and psychotropic substances (continued)	4	2	436	$9,37 \cdot 10^{-4}$	$1,72 \cdot 10^{-3}$

TABLE I: Over-expressed crimes in affiliation-based communities, according to Eq.(1).

The above results thus indicate that mafia syndicates are weakly characterized by the type of committed crimes. This means that mafia syndicates do not show specific crime specializations. We believe that this is an interesting result, as we have judicial evidences that in the past Cosa Nostra syndicates were specialized, as illustrated in appendix VII.

One further way of characterizing affiliation-based communities is that of using the information about the age of the community members. The 631 subjects condemned for mafia crimes have birth years ranging from 1936 to 1993. In order to have a level of aggregation able to give us statistically significant results, we have aggregated the subjects year birth on a decade basis. As such, we have 26 subjects that were born in the thirties, we have 90 subjects that were born in the forties, we have 110 subjects that were born in the fifties, we have 187 subjects that were born in the sixties, we have 162 subjects that were born in the seventies, we have 52 subjects that were born in the eighties, we have 4 subjects that were born in the nineties. We want to understand what is the age composition in affiliation-based communities. Our results are shown in Table II where in the upper part of Table we show the decades that are found to be over-expressed amongst the mafia syndicate affiliates. Interestingly the three mafia syndicates reported in the table are syndicates that have made the history of Cosa Nostra and in fact the over-expressed decades are the among the oldest in our dataset. On the same footing, the SAN LORENZO mafia syndicate, which is relatively new within Cosa Nostra, shows an under-expression for the 1960 decade, i.e. for people that are nowadays in their fifties, as shown in the lower part of the table.

community	size M	decade	K	X	N	p-value OE	p-value UE	threshold
SANTA_MARIA_DI_GESU'	26	1930	14	4	436	$6.65 \cdot 10^{-3}$	1.00	$8.33 \cdot 10^{-3}$
CORSO_DEI_MILLE	24	1960	140	14	436	$5.82 \cdot 10^{-3}$	1.00	$8.33 \cdot 10^{-3}$
UDITORE	8	1940	63	6	436	$1.62 \cdot 10^{-4}$	1.00	$1.67 \cdot 10^{-2}$
SAN_LORENZO	20	1960	140	1	436	1.00	$3.88 \cdot 10^{-3}$	$8.33 \cdot 10^{-3}$

TABLE II: Over-expressed and under-expressed decades in affiliation-based communities, according to Eq.(1) and (2), respectively.

The above results, although very suggestive, are however limited to a few mafia syndicates and therefore seem to have not the necessary power to elucidate the general mechanism that lead to the aggregation of criminals within syndicates. Indeed, mafia syndicates are often organized on a clear geographical basis that finds its justification in the fact that their activities are based on a strict control of the activities present in the territory where they insist on. Based on that, we have tried to verify this assumption by trying to see whether the postal codes of the Palermo municipality, see Fig. 2, are a distinctive feature of the mafia syndicates. In order to reduce the bias due to the fact we only have the vital statistics and anagraphical relationships for the subjects resident in Palermo, we decided to restrict our analysis to the 12 largest mafia syndicates operating in the Palermo municipality. Therefore we restrict ourselves to a set of 305 subjects. Notwithstanding this restriction, the information about the postal code is only available for a subset of 201 subjects. As shown in Table III, the vast majority of the considered mafia syndicates has at least one over-expression of postal codes. These correspond to a neighborhood of the Palermo municipality which is close or it is included in the territory where where the mafia syndicate operates.

community	size M	postal code	K	X	N	p-value OE	p-value UE	threshold
TOMMASO_NATALE	27	90147	21	7	305	$9.63 \cdot 10^{-4}$	1.00	$8.33 \cdot 10^{-3}$
BRANCACCIO.	25	90123	21	6	305	$3.86 \cdot 10^{-3}$	1.00	$5.56 \cdot 10^{-3}$
CORSO_DEI_MILLE	24	90123	21	9	305	$3.90 \cdot 10^{-6}$	1.00	$1.67 \cdot 10^{-2}$
NOCE	21	90138	4	3	305	$1.08 \cdot 10^{-3}$	1.00	$5.00 \cdot 10^{-3}$
SAN_LORENZO	20	90147	21	5	305	$7.44 \cdot 10^{-3}$	1.00	$1.67 \cdot 10^{-2}$
PARTANNA_MONDELLO	17	90151	4	3	305	$5.61 \cdot 10^{-4}$	1.00	$1.00 \cdot 10^{-2}$
BORGO_VECCHIO.	17	90133	2	2	305	$2.93 \cdot 10^{-3}$	1.00	$5.00 \cdot 10^{-3}$
BORGO_VECCHIO.	17	90139	10	4	305	$1.14 \cdot 10^{-3}$	1.00	$5.00 \cdot 10^{-3}$
ZEN	16	90146	39	9	305	$2.21 \cdot 10^{-5}$	1.00	$1.67 \cdot 10^{-2}$
PAGLIARELLI	13	90129	6	3	305	$1.13 \cdot 10^{-3}$	1.00	$1.00 \cdot 10^{-2}$
ACQUASANTA	7	90142	9	4	305	$1.19 \cdot 10^{-5}$	1.00	$2.50 \cdot 10^{-2}$
VILLAGRAZIA	6	90126	10	4	305	$8.62 \cdot 10^{-6}$	1.00	$2.50 \cdot 10^{-2}$
PALERMO_CENTRO	5	90127	8	2	305	$5.80 \cdot 10^{-3}$	1.00	$1.25 \cdot 10^{-2}$

TABLE III: Over-expressed postal codes in affiliation-based communities, according to Eq.(1)

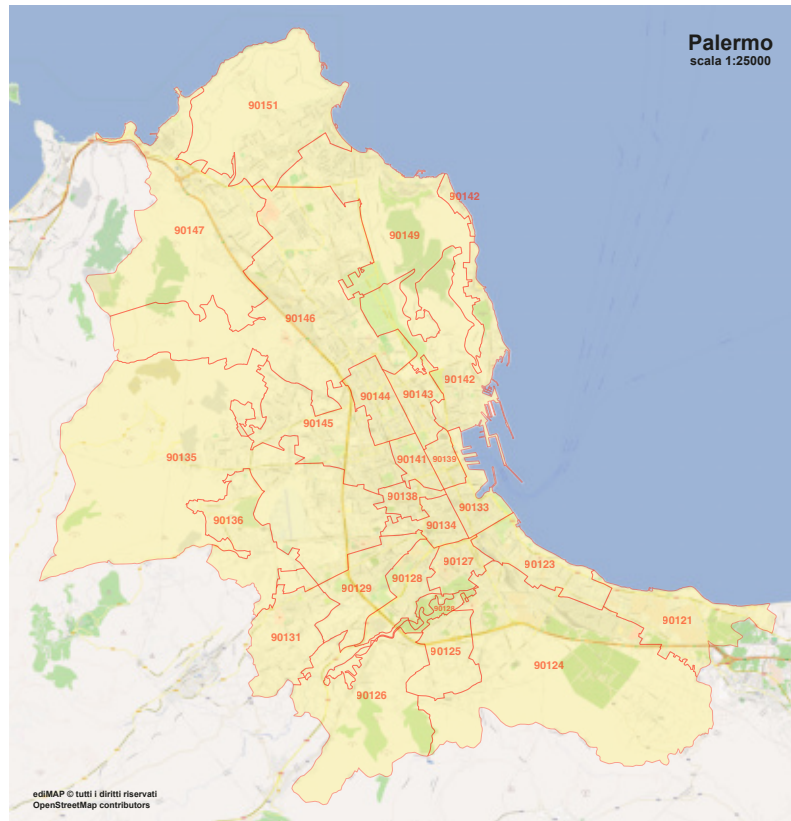


FIG. 2: Map of the Palermo municipality with the indication of postal codes.

By summarizing, we have given evidence that in some case the affiliation-based communities can be characterized in terms of committed crimes or decades. However, the feature that by far seems predominant in characterizing the affiliation-based communities is the postal code. This indicates that mafia syndicates mainly emerge on a local territorial basis, i.e. from the aggregation of people belonging to a certain delimited territory, thus reinforcing the idea that mafia syndicates exist in order to control the territory where they insist on.

We believe that postal codes might not be the most appropriate geographical units able to show the local territorial basis of affiliation-based communities. In fact, there are postal codes over-expressed for different Mafia syndicates as well as mafia syndicates covering more than one postal code. It is worth noticing that when more postal codes are over-expressed for a commiunitiy, they are relative to geographical zones that are contiguous, as indicated in Fig. 2. In any case, we strongly support the use of postal codes as this is a piece of information which is relatively easily accessible to researchers. In fact, it must be noticed that the Prosecutors Office has other types of information that is not publishable and was therefore not used in this analysis. Furthermore, it must also be considered that our study covers a time-span of more that 10 years. In this time period the influence of Mafia syndicates in the different territories of the Palermo municipality has changed, in connection to the time evolution of the strength of the Mafia syndicate itself. To give an example, during the seventies and the eighties of the last century the SANTA_MARIA_DL_GESU syndicate ruled by Stefano Bontate extended its influence from the Palermo area with postal code 90124 up to the central Palermo area with postal code 90141, a huge portion of the Palermo municipality. After the 1981 second

mafia war and the consequent defeat of the Bontate group, the influence of the SANTA_MARIA_DI_GESU syndicate diminished until it was limited to the mere Palermo area with postal code 90124.

As mentioned in the introduction, our result may support Gambetta’s view of Cosa Nostra syndicates as “protection companies” that guarantee both legal and illegal transactions that occur among members of a given community and/or take place in a specific area. Along this line of thinking, indeed, a syndicate must keep control of a territory, which can be a city, a neighbourhood, a rural area, etc., in order to provide “protection”. Gambetta’s theory has been reconsidered in [81, 82] where the role of Cosa Nostra as a “protection company” is strictly linked to its intimidatory power associated to the capacity of imposing its rules with violence. In this context, the offer of protection by Cosa Nostra would not only inevitably be linked to reputation, but would also be related to the position and the fact that it has control of a specific territory. “*Violence and protection*” – notes Sciarrone [82] – “are therefore closely connected and it is precisely for this reason that Catanzaro prefers to connote the activity of the mafia with the term *protection-extortion*”.

Other authors are however inclined to privilege the adoption of an interpretative paradigm that enhances complexity and that does not claim to be exhaustive. Rather than constructing a *general theory of mafia crime* [83], they underline how important it is never to lose sight of the complex articulation of the mafia phenomenon, which we know today to be embedded [84] in the social context, of which it reflects the transformations, its changing expressive and relational forms, communicative styles and organizational models, that change and reproduce always differently over time.

Judge Giovanni Falcone spurred on the search for the many profound characteristics of the mafia phenomenon, explaining how important it was to identify similarities and similarities of “method” between Cosa Nostra and other national and international mafia organizations because the “method” represented the link which made them similar and capable of acting in coordination with each other.

V. CHARACTERIZATION OF THE COSA NOSTRA AFFILIATES

We now turn our investigations towards the individuals committing mafia crimes. We are in fact interested in understanding whether they have specific skills or rather they gain criminal cleverness by the experience gained within the syndicate. In Fig. 3 we show the probability of performing crimes of the same type as the number of committed crimes increases. As a proxy of the criminal career progression, we consider the number of types of crimes committed by any subject in the past. The level of specialization is calculated as the percentage of subjects, at a given level t of career progression, who explore, when committing a crime at level $t + 1$, the same community they explored when committing the crime at level t . The communities of crimes are determined starting from the bipartite network of subjects condemned for Mafia crimes and committed crimes. In fact, as mentioned above, starting from the information about the penal records, we obtain a bipartite network of $n_{ADJ} = 631$ subjects condemned for Mafia crimes, $n_{crimes} = 723$ committed crimes and $l_{bip} = 5408$ links. In order to have a better statistics we aggregated all the crimes that made reference to different commas of the same code article. This bipartite network is then projected on the side of crimes thus giving a network with 717 nodes and 11761 links. However, we also decided to construct the statistically validated projected network by using the procedure of section III A. We considered a False Discovery Rate multiple test correction and an univariate threshold of 5 %. This leads to a validated network, that we call FDR-network, of $n_{FDR} = 180$ nodes and $l_{FDR} = 448$ links. The FDR-network has been partitioned by using the radatool algorithm [68, 86]. As a result we get a partitioned network with $n_{FDR,part} = 180$ nodes and $l_{FDR,part} = 374$ links. Nodes are distributed into 25 communities of size: 37, 31, 21, 17, 12, 5 (2 communities), 4 (2 communities), 3 (5 communities), 2 (11 communities).

In order to have a meaningful interpretation of our results, we can compare the figure with Fig. S3 [87] in the Supplementary Material of Ref. [61]. It is worth noting that in the mafia case the intercept with the vertical axis is much smaller than in the Stockholm case. However the slope of the fitting line is one order of magnitude larger in the mafia case with respect to the Stockholm case. This suggests that individuals recruited in the syndicates do not have a criminal specialization at the beginning of their criminal life. However, they gain such specialization very soon.

We therefore have criminal specialization at the level of individuals, while this is not observed at the level of mafia syndicates. Such result seem to be coherent with the idea that mafia syndicates are organized on a territorial basis and therefore the criminals they can recruit have a quite general criminal profile. However, as we have proved in the previous section, the criminal activities of a mafia syndicate are usually heterogeneous. As such, in each syndicate we may find criminals that are in charge of specific criminal activities within the syndicate and therefore get specialized in that specific criminal activity.

The above results support the idea of mafia syndicates as small structured communities within the Cosa Nostra society. Each community seems to be self-contained and independent. As we mentioned above, such situation is different from what Judiciary observed by investigating the mafia syndicates during the eighties of the last century. One might ask what triggered such change and a possible answer might be found in the activities carried out by

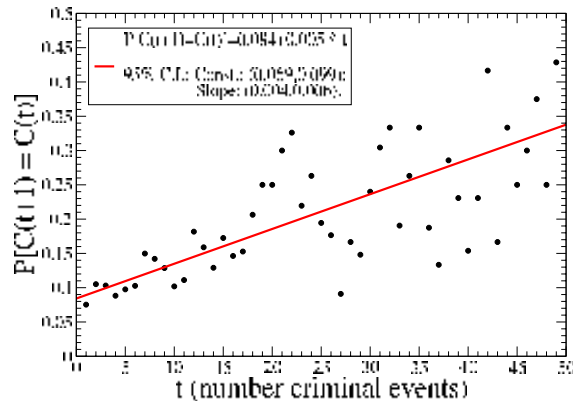


FIG. 3: Criminal specialization as a function of criminal career progression. In the horizontal axis we show the number of crimes committed by any subject in the past. In the vertical axis we show the percentage of subjects, at a given level t of career progression, who explore, when committing a crime at level $t + 1$, the same community they explored when committing the crime at level t .

Judiciary and law enforcement agencies. As it is nowadays unanimously recognized, in the nineties of the last century the so-called Cosa Nostra Cupola was destructured by the arrests of its main components. As such, mafia syndicates experienced the disappearance of the main organism where all potential controversies, conflicts and competitions had been mediated so far. Having lost their guidance, it is possible to hypothesise that mafia syndicates might have found that a strict observance of the territoriality policy was an efficient strategy in order to minimize conflicts. Each syndicate operates in its own territory and therefore need to be independent and to form inside itself all criminal skills. Finally, this might explain why each syndicate can not be specialized in committing specific crimes while its affiliates might be so.

As recalled in the introduction, the above results are compatible with Gambetta’s theory of Cosa Nostra as a “protection company” due to the fact that guaranteeing protection requires a multiplicity of skills, which can also vary over time, in order to adapt to social and organizational changes and to the different conditions in which mafia groups operate. In this work, as previously mentioned, we argue that the Cosa Nostra families adapt and change by exploiting mainly their “generalist” vocation towards criminal activities. However, it is also true that this concerns the younger group of subjects affiliated with Cosa Nostra and mafia families. As previously mentioned, with the growth of the age, the career of the affiliates specializes; but this also happens outside the traditional “protection” skills. The mafia organization, in its various divisions, has undergone numerous and profound changes, also due to exogenous factors (arrests, more stringent regulations, special prison regimes). The idea of a mafia organization that follows a linear path, with a specialization in a well-identified sector, and that only through this mechanism – the offer of an articulated “protection” system – established itself as a vital component in some circuits of daily life, no longer offers sufficient explanations for the social, political, economic and macroeconomic dimension of the Cosa Nostra organization. There are “men of honor” who undertake political careers, others who carry out autonomous commercial activities crossed with relationships with foreign criminal organizations, still others - almost completely removed from the circuit of violence - carry out business activities transmigrated from illicit to lawful, disguised thanks to a wise capital conversion. Of course, there are still numerous affiliates who continue to carry out activities related to the extortion-protection circuit described by Gambetta; but these are, in general, “old” affiliates specialized at individual level, supported by young “supporters”, still not able to mature other specialties of enterprise.

VI. ROLE OF FAMILY RELATIONSHIPS IN THE INTERLINKAGES BETWEEN COMMUNITIES

The results we have shown so far indicate that mafia syndicates are mainly set up to control a certain delimited territory. However, it is known that mafia syndicates are not isolated entities. Rather they interact with each other, either making alliances or competing with each other in order to expand their influence or to get the control of the Cupola, i.e. of the organism that ruled Cosa Nostra.

We want here to investigate whether family relationships have any major role in the links that exist amongst different affiliation-based communities.

As mentioned above, the Registry Office of the Palermo municipality provided us in an anonymized form the information about the anagraphical relationships of 235 subjects condemned for mafia crimes and included in our dataset. With this additional information the number of subjects considered in the study raised to 3989. We thus constructed the network of relationships amongst these subjects. Such network contains 3424 nodes and 5061 links.

To test the role of anagraphical relationships in the links that exists amongst different affiliation-based communities of section IV, we decide to group together all nodes representing subjects belonging to the same mafia syndicate. We therefore have two type of nodes in the network: nodes representing individuals, and nodes representing mafia syndicates. A link between two nodes representing mafia syndicate is set whenever there is a link between any two subjects each affiliated to the two considered syndicates. A link between a node representing individuals and nodes representing mafia syndicates is set whenever this individual has a family relationship with any affiliated to the considered syndicate. As a result, we have a new network with 3241 nodes and 5011 links. However, the network becomes naturally partitioned into a large number of connected components. In particular we detect 200 weakly connected components of sizes 1417, 129, 89, 67, 49, 40, 38, 27, 21, 21, 18, 17, 17, 17, 17, 15, 15, 13, 13, 13, 13, 13, 13, 12, 12, 12, 11, 11, 11. The remaining 170 connected components have sizes smaller than or equal to 10 and we did not considered them.

In this way we can easily investigate how two different nodes representing mafia syndicates are connected with each other. Specifically, we consider all possible pairs between nodes representing mafia syndicates and compute the Shortest Path between them. The shortest path is the minimal set of nodes that connects any two node pairs in the same connected component of the network. We have that 17 mafia syndicates are present in the largest connected component of 1417 elements, 2 mafia syndicates are present in the second largest connected component of 129 elements, 2 mafia syndicates are present in the fifth largest connected component of 49 elements and 2 mafia syndicates are present in the eighth largest connected component of 27 elements. We have a total number of 139 out of 253 possible shortest paths connecting pairs of these 25 mafia syndicates. In the worst case, two mafia syndicates are connected with each other through a set of 14 other nodes.

In 5 out of 139 cases, we have a direct link between mafia syndicates. In fact, we observe a direct link between RESUTTANA and BORGIO_VECCHIO, RESUTTANA and BELMONTE_MEZZAGNO, RESUTTANA and BRANCACCIO, PARTANNA_MONDELLO and TOMMASO_NATALE, PAGLIARELLI and PORTA_NUOVA.

In 10 out of 139 cases we observe that two mafia syndicates are indirectly connected with each other through one more nodes. In 3 out of 10 cases the connection is realized through another mafia syndicate: BORGIO_VECCHIO and BELMONTE_MEZZAGNO, BORGIO_VECCHIO and BRANCACCIO, BELMONTE_MEZZAGNO and BRANCACCIO are all connected through the RESUTTANA mafia syndicate. However in the remaining seven cases the connection is realized through an individual who is a female in 6 out of 7 cases. In Table IV we summarize our findings. The first column indicates the number of intermediate nodes to pass in order to connect the considered pairs. the second column indicates in how many cases this situation occurs. The third column is the product of the values in the first and second column and it gives the number of involved nodes. The next three columns report information that relates to nodes that represent communities. In particular, the fourth column gives in how many cases a community node occurs. The fifth column give the total number of community nodes that connect the two considered syndicate and the sixth column gives how many of them are distinct. The next three columns report information that relates to nodes that represent female subjects. In particular, the seventh column gives in how many cases a female node occurs. The eighth column give the total number of female nodes that connect the two considered syndicate and the ninth column gives how many of them are distinct. By subtracting from the values in the third column the values in the fifth and in the eighth columns one gets the number of nodes that represent a male subject.

intermediate steps	number of paths	intermediate nodes	paths with at least one community	community nodes	distinct community nodes	paths with at least one female	female nodes	distinct female nodes
01	10	10	03	03	01	06	06	06
02	11	22	06	06	02	11	12	10
03	16	48	13	19	04	16	24	12
04	12	48	12	16	04	12	24	08
05	18	90	18	30	07	18	44	14
06	18	108	18	42	06	18	48	13
07	11	77	10	28	05	11	34	13
08	11	88	11	30	06	11	41	15
09	12	108	12	39	06	12	49	13
10	06	60	10	23	05	06	27	13
11	02	22	02	08	05	02	10	07
12	05	60	05	05	21	05	27	11
14	02	28	02	10	05	02	13	08

TABLE IV: female links

The striking result is that in the large majority of cases the nodes that allow the connection between two given mafia syndicates are representing female subjects. Moreover the total number of female subjects involved is 19, which is an incredibly small number. This clearly shows that, while anagraphical relationships are weakly characterizing the links inside the communities, their role becomes extremely important when the links between different communities are considered. As an example, in Fig. 4 we show the fifth connected component. Red nodes represent male subjects, blue nodes represent female subjects and green nodes represent affiliation-based communities. In Magenta we signal the shortest path between Community 22 and Community 25. Such path is characterized by the presence of a single node associated to a female subject.

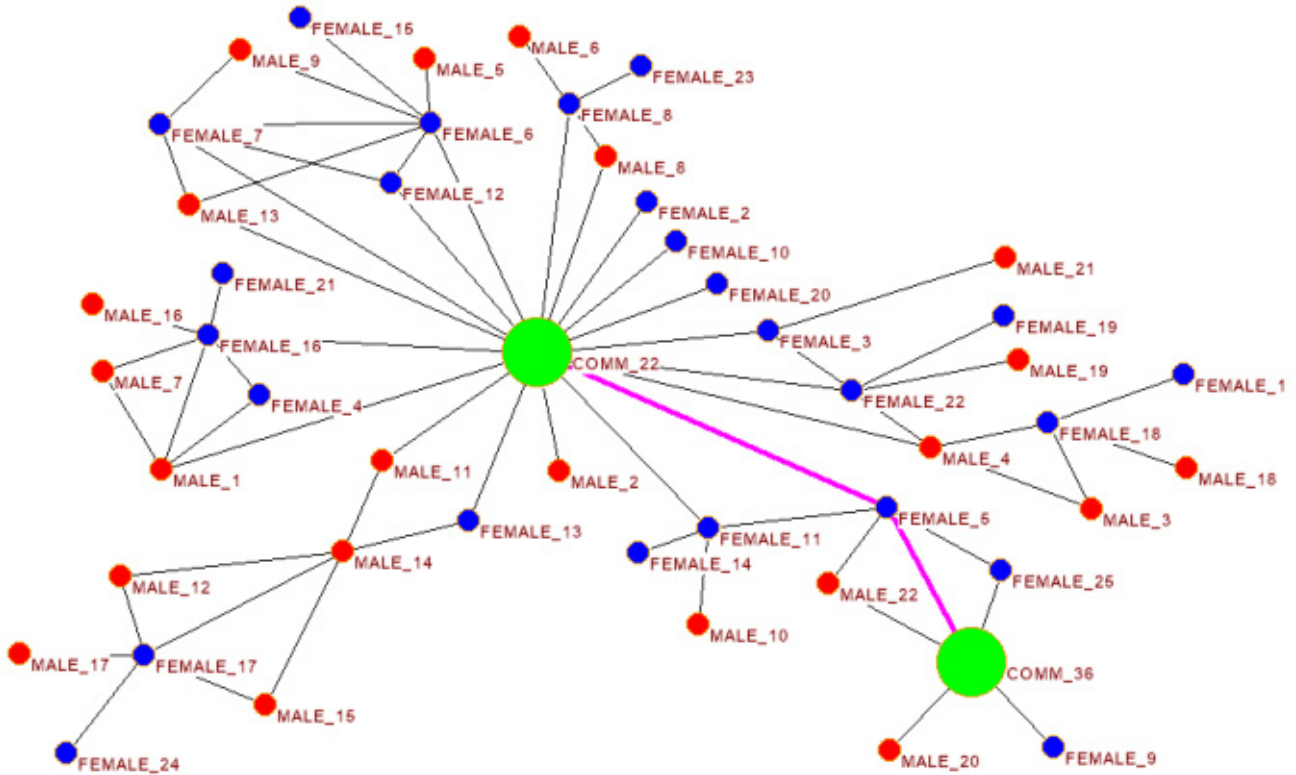


FIG. 4: We show the fifth connected component of the affiliation-based network. Red nodes represent male subjects, blue nodes represent female subjects and green nodes represent affiliation-based communities. In Magenta we signal the shortest path between Community 22 and Community 25. Such path is characterized by the presence of a single node associated to a female subject.

Already back in 1996, the Report on the phenomenon of organized crime elaborated by the Italian Chamber of Deputies (1996, p. 305-306) highlighted how ‘[...] *the emancipation of women, interrupting a continuity with the past, has rendered the free woman to become a protagonist in every sector of social life. This radical change, one can easily suppose, was not alien even in that closed and submerged world that characterizes the mafia-type criminal organizations*’.

In reality, women have always occupied a relevant space in the relational dynamics within the mafia organization, exercising explicitly criminal roles or carrying out support and assistance tasks for members of the association. Indeed, we can say that - in the light of the most recent investigative acquisitions - that exercised by women in Cosa Nostra is a leading role, since they perform very delicate functions: they educate and direct their children to (dis-) values and family traditions, decide - in fact - the future of the offspring, cultivate the memory of the deceased relatives, deal with the maintenance and sustenance of the family structure in the case in which the man can no longer do it (because taken in arrest or killed) ending up constituting the historical memory of the criminal group. Their role becomes - even - indispensable in cases where the man who guaranteed the image or the family income (the husband, the father, the brother) is forced into hiding or is arrested. In these cases, the women of the family are asked to make up for the absence, showing in public a semblance of “normality”: some become spokespersons and interpreters of the mafia tradition, taking over themselves in male roles, others even decide to show themselves in public, working to defend and support the choice of their relatives.

For these reasons, “men of honor” attach great importance to the fact of marrying a woman who is aware of her role, who shares the same cultural horizon. This role had been well reconstructed by one of the first Mafia repentants, Leonardo Messina: “*The woman has never been, nor will she ever be affiliated but has always had a fundamental role. Men like me marry the right woman: the daughter of a man like me. Cosa Nostra controls them since childhood, like us. [...] The woman never sat around the table for a meeting, but there has always been the same. Many meetings took place in my house, or that of my mother or my sister. They hear everything but can’t say anything. Women*

carry secrets [...] The heritage of a man of honor is, above all, to have a woman aware of his role. [...] I married the nephew of a mafia boss, we [...] complement each other [...] When I came home I gave her the gun or dirty clothes to throw away [...]. My wife was aware of what I was doing. I understand that this also happened in other families". In relationships with the outside world and within the blood family itself, a woman nourished and raised by the same culture as her partner, is more easily able to respond to the sudden tasks that may arise because continuity is guaranteed in the management of criminal activities.

VII. CONCLUSION

We have investigated the relations established within Cosa Nostra by making use of unconventional network-based and complex systems techniques. We have performed our investigations at three different levels: Mafia syndicates, Individuals and amongst mafia syndicates.

At the level of mafia syndicates we have given evidence of the fact that mafia syndicates are currently not specialized in specific criminal activities. This is different from what can be historically observed. The specialization strategy has been abandoned, because it is considered the "weak link" of the accumulation system. In fact, when the syndicate affiliates involved in such specific activities were struck by the offensive of the law enforcement agencies the entire cycle was penalized and irreversibly entered into crisis. Thus, starting in the 2000s, each mafia family preferred to remain generically anchored to traditional activities in the area. In fact, we also show that the vast majority of the considered mafia syndicates has at least one over-expression of postal codes. These correspond to a neighborhood of the Palermo municipality which is close or it is included in the territory where where the mafia syndicate operates.

At the level of single criminals we have given evidence of the fact that the mafia affiliates start their criminal career as generalists and end up to be specialists. In fact, since mafia syndicates are generalists, they need heterogeneous criminal skills. Moreover, they insist in a delimited territory and therefore the young affiliates are chosen merely on the basis of their territorial membership. Once inside a syndicate, being the syndicate involved in heterogeneous criminal activities, the affiliates are somehow forced to get specialized in certain criminal areas.

Finally we have given evidences that the role of females is of primary importance in setting up relationships between different mafia syndicates. This result has been obtained by unconventional network-based data mining techniques. The considered network was that of the anagraphical relationships associated to of a set of subjects condemned for mafia crimes. We augment such network of anagraphical relationships by grouping together all nodes representing subjects belonging to the same mafia syndicate. Specifically, by looking at the Shortest Path connecting any two pairs of mafia syndicates we have found that the connection between mafia syndicates are given by female subjects. Moreover the total number of female subjects involved is 19, which is an incredibly small number.

In this respect, Cosa Nostra behaves as other social systems [88] where marriages and familistic links help in setting up relationships amongst different social groups and determine alliances and splittings. The role of females in Cosa Nostra has not yet been fully recognized by the general public, although this is very well understood by law enforcement agencies and prosecutors. In an archaic type of society as Cosa Nostra, females are instrumental in setting up relationships between different mafia syndicates. Paradoxically, this makes them crucial in guaranteeing the secrecy of Cosa Nostra. Notwithstanding such role, there exist very few females that decided to become Mafia repentants, which probably tells us that historically females accepted this role with active awareness and not supinely, as one might have thought.

This issue would be worth of further investigation by making a comparative analysis of Cosa Nostra and *'Ndrangheta*, where the *'ndrine* are organized on a strong family basis and a few Mafia repentants exist.

Acknowledgements

This work is part of the activities envisaged by the "Agreement for carrying out activities of common interest" signed on 07/02/2014 (prot. DiFC n. 327/2014) between the Public Prosecutor's Office of Palermo and the DiFC and DSEAS departments of the University of Palermo.

The authors are deeply indebted with the personnel of the Ufficio Anagrafe del Comune di Palermo for their support, competence and professionalism in providing the data relative to the anagraphical relationships. Their role has been invaluable. The authors acknowledge support from the personnel of the Procura della Repubblica presso il Tribunale di Palermo for providing the penal records and their assistance for the CERPA software.

Appendix A: Focus points on the Cosa Nostra crime specialization

The investigation of the processes that, starting from the first post-war period, affected the evolution of the original forms of criminal specialization of families or groups of mafia families in Sicily is particularly complex and articulated. At its origins, Cosa Nostra manifests itself on the territory as an instrument for the protection of the interests of the latifundia and of the feud, specialized in the parasitic management of the large rustic funds owned by the notary and the Sicilian landed aristocracy [71]. If - on the one hand - the role of the Mafia leaders is to ensure the maintenance and order of the countryside through the exercise of violence on the peasants and the suppression of their rights and their freedoms [72], some families specialize in controlling the water resources and wells that guarantee the irrigation of the countryside, some others in the cultivation, commerce and export of citrus fruits, going as far as controlling the stands of the Palermo fruit and vegetable market, or - others - dedicating themselves to controlling the masses of wheat and other cereals [73]. The activities of Cosa Nostra and the specializations of mafia syndicates gradually changed in the years following the first post-war period, coinciding with the loss of relevance of the agrarian bloc and of the interests linked to the large latifundia.

Coinciding with the birth of a new, powerful bourgeoisie that looks at cities as privileged venues for new business, mafia families also move rapidly to deal with property speculation, exercising control over the drafting of land use plans, buying and selling land. and on the release of building permits. Many builders are, in reality, “men of honor” or their relatives or nominees. Through the mafia company, in its various entrepreneurial forms, Cosa Nostra is now proposed with an apparently “clean” role in the social context, starting - in fact - a process of thoroughly infiltration into the national economic and financial sector, which in the following years will produce significant side-effects. Also in this case, for example, within the mafia cycle of cement, specific specializations are manifested: some families deal mainly with excavations and soil movement; others are involved in the management of concrete production plants; others in the marketing of accessory components to the building industry (iron, bricks, ceramics). In each of these sectors, the characteristic that distinguishes these specializations consists in the monopoly regime in which these mafia entrepreneurial activities operate. The specialization in the construction and cement sector is accompanied - in a sort of virtuous criminal circuit - by the specialization of some families in the tobacco smuggling and semi-finished sector; subsequently, starting in the 1970s, specialization in the drug trafficking and refining sector [74].

Precisely in this phase (at the beginning of the Seventies) the criminal activity is developed by Cosa Nostra according to a logistical-organizational module, which enhances the specialization achieved by some criminal groups, involving distinct and autonomous operating entities, each rooted in its own territory of origin, according to an unprecedented consortium or “joint venture” scheme: a family creates and manages contacts with raw material suppliers (cigarettes, narcotics) while all the others invest in business, providing a portion of the capital required for purchases. In this way, the profits from the resale of the raw material will be distributed pro-quota at the end of the criminal distribution cycle [75]. During the first *maxi-processo* at Cosa Nostra ¹, Mafia repentant (*pentito di Mafia*) Stefano Calzetta explained that “[...] the Spadaro (Mafia family from the Kalsa district, in Palermo - Editor’s Note), dedicated in the past to cigarette smuggling, were in more recent times dedicated to the most lucrative drug trafficking, managing it in competition with other mafia families and making available to them their vast organizational network already tested in cigarette smuggling [...]” [76].

In this context, in the territory each mafia syndicate has autonomous entities that take on the characteristics of real organizational substructures, managed by a leadership in close contact with that of the criminal territorial organization of reference, from which they receive directives and summary provisions, and that deal with the distribution over the territory of the goods subject to illicit traffic. In other words, following the same logic of specialization, growth and expansion in the markets of normal commercial companies, Cosa Nostra has shown since the 1960s that it has ductile structures and an aptitude for transformation, the ability to adapt to market needs, a tendency to maximize opportunities and to minimize risks through careful planning and “entrepreneurial” planning of their illegal activities. As also shown by our results, this strategy of specialization adopted by mafia families in their illegal activities has been, more recently, abandoned, because it is considered the “weak link” of the accumulation system. In fact, when the crime specialists were struck by the offensive of the law enforcement agencies, also triggered by the raising phenomenon of mafia repentants, the entire cycle was penalized and irreversibly entered into crisis. Thus, starting in the 2000s, each mafia family preferred to remain generically anchored to traditional activities in the area, reserving the right to maintain a privileged relationship with individual “specialists” capable - from time to time - of assisting them in more complex and less usual illegal activities. In this way, the relationship between mafia families and white-collar workers at their service has become even more consolidated.

Therefore the evolution of mafia syndicates goes in the direction of a progressive generalization of their criminal

¹ P5 Jurors Court of Palermo - I Section - Judgment against Abbate Giovanni + 459, 10th February 1986-10th December 1990

activities, which is different from what happens in social organizations of different nature, as well as in different Italian mafia organizations. For example, the *'Ndrangheta* syndicates (*'ndrine*) are still quite specialized and this can be to the extremely strong social ties between syndicate affiliates, due to the fact that the *'ndrine* are organized on a family basis. This turns out to be a factor that mitigates the risk of behaviors as those occurring in Cosa Nostra.

Crime specialization in Cosa Nostra has also been observed at the level of individuals. In fact, another type of modern criminal “specialization” concerns the one that has allowed Cosa Nostra to speak - since the eighties - with politics, finance and white-collar workers, in the management of public spending and large contracts, for the acquisition of bribes on the implementation of major public works. In fact, there exists very few specialized mafia lobbyists who manage the operations of undue interference on public procurement mechanisms (financing of public works, drafting of tenders and awarding of works), which - once the bribe has been acquired by the awarded companies - directly distribute the relative amounts of dirty money to politicians, public administrators, and family representatives of the place where the works are to be carried out [77]. A portion of the bribes is generally intended also for the Cosa Nostra Commission, to meet the organization’s general expenses (costs for the trials, for the purchase of weapons, etc.) [78]. The authentic mafia face of this mechanism emerges unequivocally in moments of crisis, that is in the cases in which entrepreneurs who do not adapt to the demands of the mafia organization must be brought back to the respect of the “rules”, because not aware of the specific Cosa Nostra’s interests in certain tenders. In such cases the local representative of the mafia family intervenes directly, using the tools of violent and intimidating persuasion to obtain the desired result. The control system described above also includes the execution phase of the works, in which the interests of the Cosa Nostra representatives are protected in the area where the works are carried out, by subcontracting to mafia companies and the purchase of supplies from the same [79].

Another type of specialization that we would like to mention, has characteristics of full criminal visibility and regards the Cosa Nostra killers or firing groups. These are real military structures, made up of killers cleverly selected by the top management of the Cosa Nostra, who after a period of training in the execution of less serious crimes (damage, extortion) and careful observation of the demonstrated operational capabilities, they assign the most skilled to the execution of murders. These subjects specialized in the execution of the facts of blood, occupy a privileged position within the mafia environment. A circle of other characters of trust and proven ability able to provide support, help and logistic support revolves around a small fire commando [80]. Mafia repentant Salvatore Grigoli, said - for example - that the firing group of the Brancaccio district of which he was a member, was to carry out the “more delicate, more reserved” murders, without other Mafiosi knowing about it. In his own words: “[...] we were the army of the devil [...]”

Appendix B: Examples of family relationships highlighted during a trial

The following piece gives an example of the judicial evidence that support the hypothesis that family relationships play a major role in the setting up of interlinkages amongst mafia members and mafia syndicates.

The excerpt is taken from the judgement issued at the end of the appeal trial that followed the *mazi-processo* against Cosa Nostra that started on 10th February 1986 ²

[...] *“in the case of the organization in question, the starting point is the “family” in a naturalistic sense, to which a strong aggregating and solidarity force is traditionally attributed. If we consider that, with a shrewd policy of marriages between “families” of mafia, the constraints and connections are increasingly expanding to form a network and an inextricable network of relationships, we will understand how important this element is for the understanding of the mafia phenomenon. And, in fact, Calzetta Stefano (vol.11 f. 402881), specifies that the members of the “families” of the mafia, almost without exception, always prefer to marry each other, as well as contour insists very much on the family ties of his adversaries and uses them for identification purposes. By way of example, we can list the crossed family relationships existing between Zanca Carmelo and other men of honor.*

The aforesaid, in fact, through his wife (Buffa), is the brother-in-law of Buffa Vincenzo (Ciaculli), Pace Stefano (Ciaculli), Pullarà Ignazio (Santa Maria di Gesù), Marciandò Francesco Paolo (Santa Maria di Gesù), Lombardo Giovanni (Ciaculli) and forms a unique group with his brothers in law.

Zanca Carmelo, then, is brother-in-law of Tinnirello Lorenzo, who married Zanca Maria, and of Tinnirello Giuseppe, who married Zanca Ninfa, and through another brother of them, Tinnirello Benedetto, married to Marchese Caterina, sister of Marchese Filippo and Marchese Vincenzo, is also connected with the “family” of Corso dei Mille.

As you can see, with this series of affinities and relationships, Zanca Carmelo can count on the solidarity of three “families”, this time understood in the mafia jargon.

Zanca Carmelo, in fact, is also a cousin of Gambino Giuseppe, arrested during the Villagrazia blitz and condemned as the author of the murder committed in prison, by Marchese Pietro.

² P5 Jurors Court of Palermo - I Section - Judgment against Abbate Giovanni + 459, 10th February 1986 - 10th December 1990

Vernengo Pietro is the son-in-law of Aglieri Giorgio and father-in-law of Urso Giuseppe.

Vernengo's father Pietro married his second wife, Di Miceli Maria, sister of Di Miceli Giuseppe, from Corleone, arrested during the Villagrazia blitz.

Tinnirello Gaetano, owner of the Edil-ceramica, is the brother of Tinnirello Vincenzo, who is in turn the brother-in-law of Oliveri Giovanni, who married the daughter of Virzì Paolo, brother of Virzì Salvatore.

Scaduto Giovanni is the son-in-law of Greco Salvatore known as "the senator", brother of Greco Michele (Ciaculli).

Lo Iacono Antonino, son of Andrea and grandson of Lo Iacono Pietro married Di Maggio Giuseppe's daughter, indicated as head of the "family" of Brancaccio and uncle of the Mafara brothers.

Spadaro Antonino, son of Giuseppe and nephew of Spadaro Tommaso, is son-in-law of Scavone Gaetano for having married his daughter Anna.

Marino Mannoia Francesco, understood as "mozzarella", is the son-in-law of Vernengo Giuseppe.

Prestifilippo Nicola is a cousin of Fici Giovanni and brother-in-law of Pino Greco known as "scarpazzedda", who in turn are cousins.

Capizzi Benedetto is brother-in-law of the Di Carlo brothers of Altofonte.

Marchese Vincenza, daughter of Vincenzo and nephew of Marchese Filippo, is engaged to Bagarella Leoluca.

Montalto Giuseppe, son of Salvatore, is the son-in-law of Di Maggio Calogero.

Ercolano Salvatore, the Ferrera brothers Giuseppe and Antonino and Santapaola Benedetto are all cousins ??among them.

Savoca Vincenzo di Rosolino, grandson of Savoca Giuseppe, indicated as "representative" of the "family" of Brancaccio after the killing of Di Maggio Giuseppe, married Di Pieri Pietro's daughter .

Anselmo Rosario is Spina Raffaele's brother-in-law for having married his sister.

Gambino Giacomo Giuseppe is Pilo Giovanni's brother-in-law.

Alfano Paolo married Lo Cascio Maria, nephew of Lo Cascio Giovanni; and it could go on forever.

The cases referred to above, listed purely by way of example, therefore confirm the thesis of those who, even in the current phase of gangster transformation of the mafia organization, believe they can nevertheless identify in it certain characteristics that constitute the "specific" of "Cosa Nostra" compared to other delinquent organizations.

One of the peculiar connotations is therefore the "familismo", of which several mafia "families" have been found intertwined, while we have seen that, in addition to it, they characterize the organization the hierarchical-federal structure, and the territorial sovereignty, of which will be dealt with later ." [· · ·]

We deem useful to emphasize how a network representation of the long listing reported above would allow for an easier reading and understanding of these relationships and might help in extracting the information carried out by this data. This is at the roots of the methodological approach we have pursued in this work.

Appendix C: Descriptive statistics

1. Penal Records dataset

item description	item number
number of subjects condemned for mafia crimes	633
number of male subjects condemned for mafia crimes	616
number of female subjects condemned for mafia crimes	17
number of subjects that were born in decade:	
from 1930 to 1939	26
from 1940 to 1949	90
from 1950 to 1959	110
from 1960 to 1969	187
from 1970 to 1979	163
from 1980 to 1989	53
from 1990 to 1999	4
number of distinct committed crimes	723
min number of committed crimes per subject	1
max number of committed crimes per subject	172
median number of committed crimes per subject	5
average number of committed crimes per subject	8.6
standard deviation of number of committed crimes per subject	13
max occurrence of committed crimes	352 (art. 416 bis Penal Code)
min occurrence of committed crimes	1 (art. 56 together with 515 Penal Code)
median occurrence of committed crimes	2
average occurrence of committed crimes	7.49
standard deviation of occurrence of committed crimes	21.7

TABLE V: Descriptive statistics of the Penal records dataset

2. Cosa Nostra syndicate dataset

item description	item number
number of subjects involved in syndicates	436
number of syndicates	63
number of subjects involved in specific syndicates:	
RESUTTANA	37
TOMMASO_NATALE	27
SANTA_MARIA_DI_GESU	26
BRANCACCIO	25
CORSO_DELMILLE	24
NOCE	21
SAN_LORENZO	20
PORTA_NUOVA	18
PARTANNA_MONDELLO	17
BORGO_VECCHIO	17
ZEN	16

TABLE VI: Descriptive statistics of the Cosa Nostra syndicate dataset. In the second part of the table only the syndicates with at least 15 affiliates are reported.

3. Subject dataset

item description	item number
number of subjects	3478
number of households	467
min number of households members	1
max number of households members	10
average number of households members	3.54
standard deviation of number of households members	1.67
median number of households members	3
number of distinct postcodes	24
occurrence of 10 most observed postcodes:	
90146	305
90147	193
90123	142
90145	141
90135	133
90142	79
90126	77
90124	65
90121	46
90127	45

TABLE VII: Descriptive statistics of the subject dataset

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still proceed based on common activities and experience; but tomorrow these schemes may have a meaning of their own, even if limited to our area." (Excerpt from the deposition of Col. CA Dalla Chiesa made to the Parliamentary Commission of Inquiry into the phenomenon of the mafia in Sicily in the session of 28 March 1969, All. nr 41).

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