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Mafia war: simulating conflict escalation in criminal organizations

Martin Neumann[1] · **Ulf Lotzmann**[1] · **Klaus G. Troitzsch**[1]

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Abstract The paper describes a simulation model of conflict escalation in criminal organizations, investigating conditions of stability and collapse of the organization. As a paradigmatic case, the Sicilian Cosa Nostra provides the background for the formulation of the model assumptions. Cosa Nostra faced two so-called Mafia wars. Outbreak of wars is replicated by the simulation model. Since criminal organizations operate outside the state monopoly of violence, they provide a laboratory for studying war and state in the making: Organizational stability remains dependent on the loyalty of the Mafiosi. Monte-Carlo simulation experiments reveal a constant danger of a Hobbesian war of all against all. A statistical examination of explanatory factors of the distribution of violence shows that minimal differences in the initial conditions open up pathways to the escalation of violence. Central factors for stability are economic prosperity and normative commitment to the organization. Once the economic carrying capacity of the environment is reached, normative binding forces control escalation of violence. However, stability remains precarious and is in constant danger of falling in a trap cycle of revenge. This path-dependent effect is the central mechanism for the escalation of violence.

✉ Martin Neumann
maneumann@uni-koblenz.de

Ulf Lotzmann
ulf@uni-koblenz.de

Klaus G. Troitzsch
kgt@uni-koblenz.de

[1] University of Koblenz, Koblenz, Germany

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Introduction: organized crime as state and war in the making

Charles Tilly (1985) famously described state making and war making as organized crime. Here we take the reverse perspective of studying organized crime as state and war in the making (Nozick 1974). The Sicilian Mafia, Cosa Nostra, is a paradigmatic example of a criminal organization. Nowadays many civil society organizations fight against the Mafia. However, the embedding in Sicilian society as well as power struggles within the organization is legendary. In fact, academic scholars have also described the Mafia as a Hobbesian society (Nozick 1974; Arlacchi 1993; Dickie 2007; Dickie 2013). At any time, it is likely that a war of all against all could break out. The literature describes two major so-called Mafia wars as well as numerous killings. In spite of all the infighting among the Mafiosi, Cosa Nostra as an organization has remained uncontested. This persistence can rarely be found in the criminal world: most groups fail to establish enduring structures. This makes violent conflicts and conflict resolution within Cosa Nostra a test-case for studying the evolution of social order.

In modern times, social order is secured by the state monopoly of violence (Weber 1972; Jachtenfuchs 2005). Norm-enforcement is delegated to the third party of the court. In criminal organizations, it is obviously impossible to rely on the courts for conflict resolution (Erickson 1981; Diesner and Carley 2010; Campana and Varese 2013). Since criminal organizations have to remain covert, norm enforcement cannot be delegated to a third party but has to be accomplished by some parties of the criminal organization or the underworld. A characteristic of criminal organizations is that many members have access to means of violence. This parallels early stages of the state-making process, prior to full-fledged differentiation between judiciary, executive and legislative authority. In times before the state effectively gained control over the use of violence (e.g., one might think about the time before Louis IX effectively disarmed the lords), many parties shared the right to use violence (Mann 1986). In times when the lords elected the king, such as in the Holy Roman Empire, the state had to rely on associated lords for establishing its power. Internal and external security, jurisdiction and generation of income, i.e., taxation, could not be guaranteed without the lords. On the other hand, at all times, these allies also remained the most dangerous rivals to the central authority (Tilly 1985). The lords faced tension between commitment to the central authority and promotion of individual career interest. This might eventually generate severe violence as, for instance, during the British Anarchy in the twelfth century. This situation is comparable to the problem of conflict resolution within Cosa Nostra: Cosa Nostra posses a central authority for conflict regulation, the so-called Cupola (at least for quite some time). However, obedience to the authority cannot be enforced by a monopoly of violence. Therefore, maintenance of intra-organizational peace and order remains

precarious,[1] dependent on the Mafioso's commitment to the authority of the organization. More generally, with the example of Cosa Nostra, the paper investigates a critical point in social evolution that approaches a transition toward a possible emergence of a Leviathan, which is in constant danger of collapsing in an escalation of violence. Thus, the paper will address the question under what conditions a criminal organization such as Cosa Nostra collapses in a state of violent anarchy.[2]

We will use simulation experiments to examine the distribution of violence between Mafiosi. For investigating the generative mechanisms, the model is based on a case study of the mechanisms of Mafia operations. The huge amount of virtual data that can be generated by simulation enables a statistical analysis, providing an indirect hint at social mechanisms at work (Silbertin-Blanc and Villa-Vialaneix 2015). The rest of the paper is organized as follows: First, the empirical background will be described briefly. Next, the model is described in detail, followed by the results of a statistical analysis of the model behavior. Finally, conclusions are formulated.

The empirical case

The model concentrates on internal relations within the Mafia, leaving aside the relations between the Mafia and the state and civil society.[3] The target system is a Mafia operating in an environment of a weak state and of traditional norms, fostering unquestioned obedience to such Mafia requests as quasi-taxation. Weakness of the state reflects the situation until roughly the early 1980s, when for the first time, effective Anti-Mafia legislation was implemented and Giovanni Falcone became the founder of a group of specialized Anti-Mafia prosecutors (Dickie 2007). Traditional norms had been predominant in Sicilian society even longer (Troitzsch 2015). While obviously the notion of predominance of norms in society remains blurred, roughly Falcone's assassination in 1992 can be perceived as a turning point. However, even in the mid-

[1] In terms of complex systems, this feature can be described as so-called self-organized criticality, often used for examining extreme events. Complex dynamical systems can sometimes be found in a state between stability and chaos. A prominent example is a sand pile (Bak 1996): If new sand is continuously grained on the pile, for some time the pile simply grows, but from time to time it collapses, and 'avalanches' of sand roll down the pile. These can be measured and statistically analyzed, finding that their magnitude is inversely proportional to their frequency. A number of phenomena from forest fires, earthquakes to crashes in financial markets show this property (Bak 1996). In conflict research, this approach has been used for examining the distribution of the size of wars. According to Richardson (1948), the size of wars is logarithmically proportional to their frequency. Cederman (2003) relates this empirical finding to the theory of self-organized criticality by investigating the generative mechanisms through simulation. Competitive advantages in warfare technology are identified to reproduce the empirical distribution (Cederman 2003). Like international relations, criminal organization also operates outside the state monopoly of violence. Thus, the model can be regarded as an investigation, whether within internal relations of organizations in which top-down authority remains dependent on bottom-up commitment to this authority, social norms provide the counterpart to Cederman's finding.

[2] Note that the analogy to the state is made only with respect to internal violence. It shall not be denied that Cosa Nostra even profited from the state by manipulating public bids, most famously in the construction sector. For instance, it is known that Cosa Nostra gained huge profits from erecting the so-called Sacco di Palermo, an urban settlement built in the 1950s around the old town of Palermo (Dickie 2007).

[3] See Troitzsch (2015) or Nardin et al. (2016) concentrating on the relations between the Mafia and society.

1990s, rejection of paying '*pizzo*' (the Italian word for extortion money) was an individual, heroic act, which was followed by prompt execution (e.g., Libero Grassi killed in 1991 for publicly rejecting to pay *pizzo*). Nevertheless, Falcone's assassination became an instance of collective remembrance that the Mafia is an unjust organization (La Spina 2005, Scaglione 2011, Neumann et al. forthcoming). However, it has to be kept in mind that the literature does not draw an unequivocal picture of the empirical case. Early scholars, most famously Hess (1970), described the Mafia as a cultural phenomenon in a primitive, rural environment. However, during the maxi trials (Dickie 2007), statements of Mafia dropouts, so-called pentiti such as Tommaso Buscetta, drew a picture of a highly professional, profit-maximizing organization. In the following, research on the Mafia was dominated by a perspective from organizational sciences (Arlacchi 1987, Gambetta 1994, Lupo 1996) that was skeptical of the assumption that the phenomenon of the Mafia provides a sign of underdevelopment that will disappear in the course of economic progress. Research began to highlight economic aspects, such as the damage caused by the Mafia (La Spina 2005).

Even though exact dating remains unclear, according to the literature, Cosa Nostra goes roughly back to the mid-nineteenth century (Gambetta 2000). It is presumed that a business of private protection emerged in the times of proto-industrial farming of citrus plants and sulfur mining (Dickie 2007; Buonanno et al. 2015). At the time of declining feudalism, landlords tended to live in cities on the Italian mainland. As the state was too weak to reinforce the rule of law, banditry became a common phenomenon and citrus plantations a target of attacks. Some scholars (Dickie 2007) assume that, for this reason, the landlords hired personnel for the protection of their property and trade between rural areas and the city of Palermo (Lupo 1996). While most of the bands of bandits had only a short life span, due to protection from criminal prosecution by the political contacts of the landlords, those criminals that had been hired by landlords could establish an enduring authority of violence over the territory. This is assumed to be the origin of the Mafia (Franchetti 1877; Paoli 2003; Dickie 2007; Scaglione 2011).

In the mid-twentieth century, the Mafia enlarged its business model. A lot of details remain speculation since they had not been subjects of court trials. However, it seems likely that the Mafiosi engaged in the expanding real estate business after the Second World War (in popular terms known as Sacco di Palermo) and drug trafficking in the US. This fostered a growing prosperity of the Mafia clans. However, enlarging the business field entailed organizational growth and a need for a higher degree of central planning and co-ordination, i.e., of becoming more professional (Cressey 1972). Allegedly, in 1957, a meeting of high-ranking Sicilian and US Mafiosi took place in the Grand Hotel in Palermo (Dickie 2007). It is presumed that at this meeting the establishment of a so-called 'Cupola' had been decided. The task of the Cupola was the coordination of activities and regulation of conflicts between different Mafia clans, called 'families'. Thus, the authority of jurisdiction and at least a certain degree of central planning was ascribed to the Cupola. Moreover, the Mafia further differentiated its organizational structure: In the 1970s, an interprovincial commission was established for coordinating the different regions in Sicily. It was established at the initiative of Giuseppe Calderone, who became its first secretary (Arlacchi 1993). In Palermo, an intermediate level of a so-called Mandamento has been established that regulates territorial relations between neighboring Mafia families up to now (Neumann

et al. forthcoming). In sum, Cosa Nostra underwent organizational innovations: The Mafia faced the emergence of hierarchical structures (Paoli 2003; Dickie 2007), which characterize a professional organization with complex rules and procedures and a stable, resilient structure (Weber 1972; Blok 1974; Mintzberg 1983). Mafiosi are professionals who undertake specialized tasks (Punzo 2013; Neumann et al., forthcoming). Cosa Nostra established formalizing a few positions of a hierarchy. For instance, the position of the head of the 'cupola' can be inhabitated by different persons (e.g., these include Michele Greco, Salvatore 'Toto' Riina or Bernado Provenzano). This is a step toward a differentiation between persons and positions within the organization (Blau 1977), which is a rather remarkable innovation for criminal organizations.

However, as a criminal organization, the Mafia obviously operates outside the state monopoly of violence. Mafiosi cannot refer to the courts for claiming rights or claiming the violation of organizational norms. Thus, the authority of command structures depends on commitment of the Mafiosi to organizational norms. For this reason, there is a constant tension between obedience to organizational norms (which we call *normative drive*) and personal self-interest (which we call *individual drive*) (see Nardin et al. 2016). Consequently, though norms and rules of conduct exist, they are subject to constant manipulation (Arlacchi 1993; Neumann and Cowley 2015), and the well-ordered hierarchy of the organization is in constant danger of collapsing into anarchy. The literature reports two major outbreaks of violence, known as Mafia wars, one in the early 1960s and one in the early 1980s (Dickie 2007). Likewise, numerous murders are documented, which sometimes might be interpreted as rule enforcement but often are likely to be undertaken to gain personal advantages over a competitor. The two major wars provide examples of how different mechanisms cause the collapse of hierarchical authority.

The first Mafia war broke out in 1962. In the literature, it is assumed that the trigger was a quarrel over lost drugs. One Mafioso, Calcedonia Di Pisa, was accused of stealing the drugs (Dickie 2007). Even though he had been acquitted by a Cupola decision, he was killed shortly afterward. The authority of the Cupola decision was undermined. Di Pisa was an ally of the Greco family, which was already in conflict with another Mafia family, the Barbera. Therefore, the Greco family suspected the Barbera of being responsible for the murder and decided to take revenge. This ended up in a war between the families, which could not be controlled by the Cupola any more. It took several years and eruptions of violence before the Cupola was able to re-consolidate its authority. Several years later, a third party was suspected to have commissioned the murder of Di Pisa, exactly with the intention to provoke the war between these families. The 1969 murder of the head of this third party, Michele Cavataio, can be regarded as the peace agreement between the conflicting parties. This re-established the authority of the Cupola as a conflict-regulating authority.

The second Mafia war took place mainly between 1981 and 1983, even though first shootings were reported as early as 1978, and violence prevailed for longer (Stille 1995; Dickie 2007). This war caused even more victims than the first one. It involved all Mafia families and changed the power structure of the overall organization. The second war can be described as a power struggle. This war was a deliberate takeover of the Organization. The instigator as well as the victor was the Mafia family from the town of Corleone. They succeeded by secretly forming alliances with former allies of

their enemies. Traitors in the rivaling families secretly changed to the stronger side and helped to trap and kill the rivaling capos. Finally, they subdued all other families. After winning the war, the Corleonese family controlled the Cupola in order to suppress rivaling families. Thus, they changed the role and function of the Cupola.[4]

In abstract terms, the Mafia wars can be described as collapse of the hierarchical structure of the organization. A hierarchy can be described as the ascription of the right of a superior to execute commands over a subordinate. Once the Cupola fails in acting as a conflict-resolving authority and the Mafia families take execution of violence in their own hands, the hierarchical structure dissolves. Thus, organizational stability depends on the balance between individual drive and normative drive, i.e., the commitment of the 'constituents' to the organization. As in the early days of the state the central authority has no effective control of the use of violence but has to rely on the commitment of armed allies.

Next, it will be described how pieces of the evidence summarized in this section are expressed in rules that can be executed by software agents. While empirical data is too sparse for a statistical analysis, simulation runs throughout the parameter space of the model generate the data for statistical analysis.

Model description

The model is built on the literature about the organizational structure of the Cosa Nostra (Arlacchi 1993; Paoli 2003; Dickie 2007; La Spina 2005; Scaglione 2011; Neumann et al., forthcoming). In particular, the design follows Arlacchi (1993), as this book reports interviews with a former Mafioso, Antonio Calderone, who provided detailed descriptions of the internal organization of the Mafia, in particular, about the time before the second war broke out.

Design principle

The target of the model is conflict resolution within the organization. How do Mafia authorities maintain structural stability of the organization, and when does the organization collapse into anarchy? Insofar as the model examines the behavior of individuals in hierarchical organizations, the research question has parallels to the problem of principal-agent theory (Schneeweiss 2003): The principal-agent theory[5] analyzes situations in which an agent actor, the principal, assigns a task to another agent actor. Since the principal is dependent on the agent actor, the principal has to monitor the execution of the task and take measures for the correct execution of it. Insofar as the principal-agent theory examines mutual dependencies of superior agent actors and subordinated ones in hierarchical organizations, it parallels the dilemma that the Cupola has to rely on the obedience of the subordinated capos. The difference, however, is that the primary task of the Cupola is resolving conflicts *between* the subordinated Mafiosi.

[4] However, this came at the cost that nowadays the functional role as the Cupola seems to have vanished (Militello et al. 2014).

[5] When speaking about humans, we use the word 'actor' and reserve 'agent' for software agent; but principal-agent theory uses the word 'agent' also (and mainly) for human actors in a special role.

This is the classical problem of Hobbes parable of the Leviathan (Sofsky 1996). The contrast to the Hobbesian question is that the research question is not about the emergence of social order from a state of anarchy but the converse problem: When does social order collapse into anarchy?

Entities and attributes

The simulated organization operates in a world scattered with shops that provide the revenues for the organization. Soldiers walk randomly around the world in order to search for shops to extort. The world is divided in territories of different 'families'. This simply represents the core business of extortion and the fact that extortion is territorially organized by Cosa Nostra, meaning that different territories are assigned to different families.

The simulated Mafia has a hierarchical structure: The bottom level of a family of the Mafia consists of soldiers that[6] extort the shops. A family is directed by a 'Capo di famiglia', the boss. The capo knows the norm of not extorting outside the borders of his territory, but the soldiers do not know the borders. This is an abstraction: In reality, certainly also the soldiers know the borders of the territory. However, the model represents the fact that obedience to territorial norms depends on the decision of the capo in a simplified manner.

Furthermore, the top hierarchy level of the overall organization is the Cupola, intended to resolve conflicts between families. A head of Cupola undertakes factual activities of the Cupola. The Cupola is a separate entity that determines the scope of actions of the agent that takes over the role of the head of Cupola. In the model, one capo is selected randomly as the boss at the top level. This agent has two roles: the role of a capo with a certain territory and the role of the head of Cupola. The modeling is motivated by the fact that, in the beginning, the Cupola was a collective board of high-ranking Mafiosi and only later became monopolized by the Corleonese family (Arlacchi 1993, Dickie 2007, Militello et al. 2014). To reduce complexity of the model, the decision process within the Cupola is not represented. For this reason, a randomly chosen single agent executes the decisions of the Cupola.

Moreover, each agent belongs to a family that is publicly known and has a private list of friends. Friendship is reciprocal and distributed beyond the families or hierarchy levels. Moreover, agents have a certain degree of aggressiveness. This is an element of the model that will become crucial for the process of conflict escalation. It is based on the description of Arlacchi (1993) that, in spite of the hierarchical relations, the members of Cosa Nostra knew each other, and (more or less) family ties did not determine sympathy.

Figure 1 visualizes the relation between the entities and agents of the model. Agents represent Mafiosi that can take on various roles, whereas the world contains territories that are populated by shops.

The entities of the model and their attributes are summarized in (Table 1):

[6] To emphasize that the model simulates actors, we speak of agents with no sexual properties (i.e., we denote them as 'it' instead of 'he' or 'she').

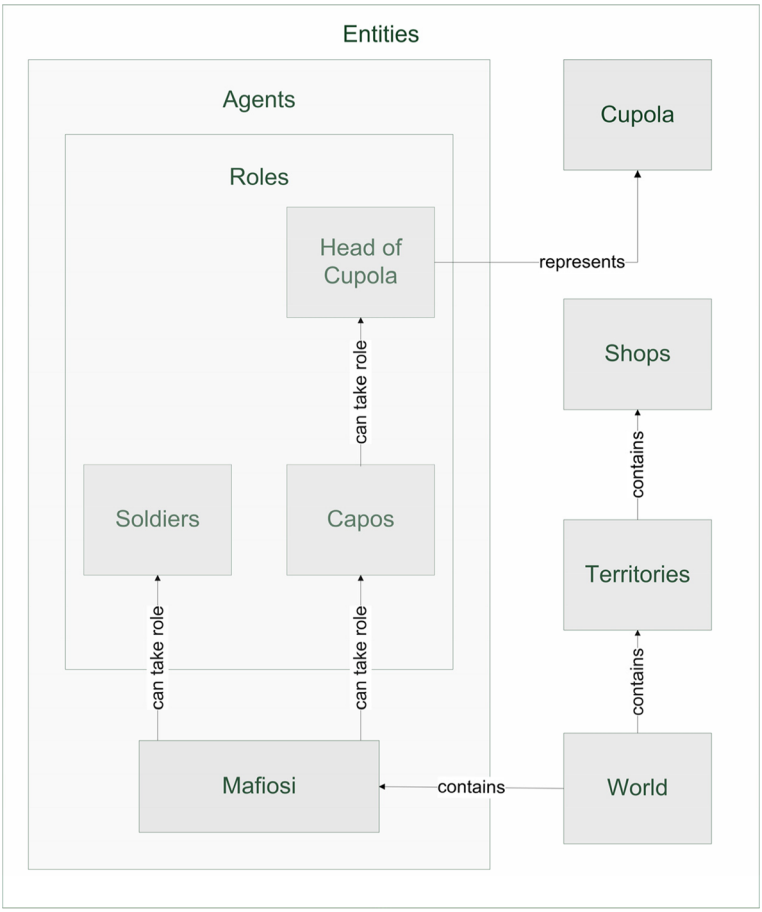

Fig. 1 Structure of the model's entities. Entities entail agents. Agents represent Mafiosi and can take on various roles in the organization. Besides agents, the model 'world' is divided into territories that contain shops. Moreover, the Cupola is represented as a separate institutional entity that is represented by a particular agent, the head of Cupola

Scheduling

The following chart presents an overview of the core features and processes of the model. A more-detailed description is provided in the following sections. Three main processes can be differentiated: ordinary business, ordinary conflict resolution and murder. The latter processes are affected by, as well as trigger the dynamics of the cognitive attributes of the agents: the loyalty of the soldiers and the authority of the Cupola. Authority of the Cupola is a relational property that depends on its reliability and its perception by the capos of the families (Fig. 2).

Sub-model 1: Ordinary business

Extortion is modeled in an abstract way: Soldiers walk randomly over the world. If they enter a patch with a shop, they extort the shop, which pays immediately without

Table 1 Summary of the entities of the model and their attributes

Agents	Attributes
Mafiosi (may be capo or soldier)	*Friendship network*: becomes effective in the case of planned murder. Plans are sent in the friendship network. Friendship is private.
	Aggressiveness: indicates severity of attacks. Determines the reputation of a family and becomes effective in the case of power struggle within a family.
	-1 < Attitude toward own family < 1: becomes effective in deciding about participating in a murder and secretly changing sides. A value of −1 represents maximum hostility, 1 represents maximum loyalty.
	- 1 < Attitude toward other family < 1: becomes effective in deciding about participating in a murder and secretly changing sides. A value of −1 represents maximum hostility, 1 represents maximum loyalty.
	Family: each Mafioso belongs to a family.
Soldiers	Gradually forget territorial norm.
	Evilness: denotes anger about norm violation by other families.
Capos	*Capos*: may take role as head of Cupola (random)
	Threshold Income level low: becomes effective in deciding to follow self-interest. The threshold represents switching to the individual drive.
	Threshold Income level high: becomes effective in deciding commitment to organization. The threshold represents switching to the normative drive.
	Response factor income high: becomes effective to increasing sanction probability.
	Response factor income low: becomes effective to decreasing sanction probability
	Number of soldiers: initial soldiers per family.
	Response factor Cupola sanction: becomes effective when reacting to Cupola sanctions. Increases probability that the capo sanctions its soldiers. Represents the degree of the normative drive.
Entities	Attributes
Cupola	0 = < Reliability = < 1. A value of 0 represents complete unreliability a value of 1 represents complete reliability.
Environment	Attributes
Territory	Space divided in territories, each family possesses fixed territory
Shops	Number of shops.

resistance. If they extort, they gain a certain amount of extortion money from the shop. The sum is fixed by a parameter (capability to pay extortion money), which is the same for all shops. Extortion money is handed over to the capo, which periodically distributes the income to its soldiers while keeping a certain amount for itself. In the initializing phase, the soldiers learn to extort only inside their territory. If a soldier extorts a shop in the territory of a different family, the capo reprimands the soldier. This decreases the probability that the soldier will extort a shop in the territory of this particular family. The action of the capo is guided by the norm ‘not to extort in foreign territories’. While the soldiers extort in the different regions (i.e., territories of the different families) in the random walk through the world, they learn the borders of the territory of their family.

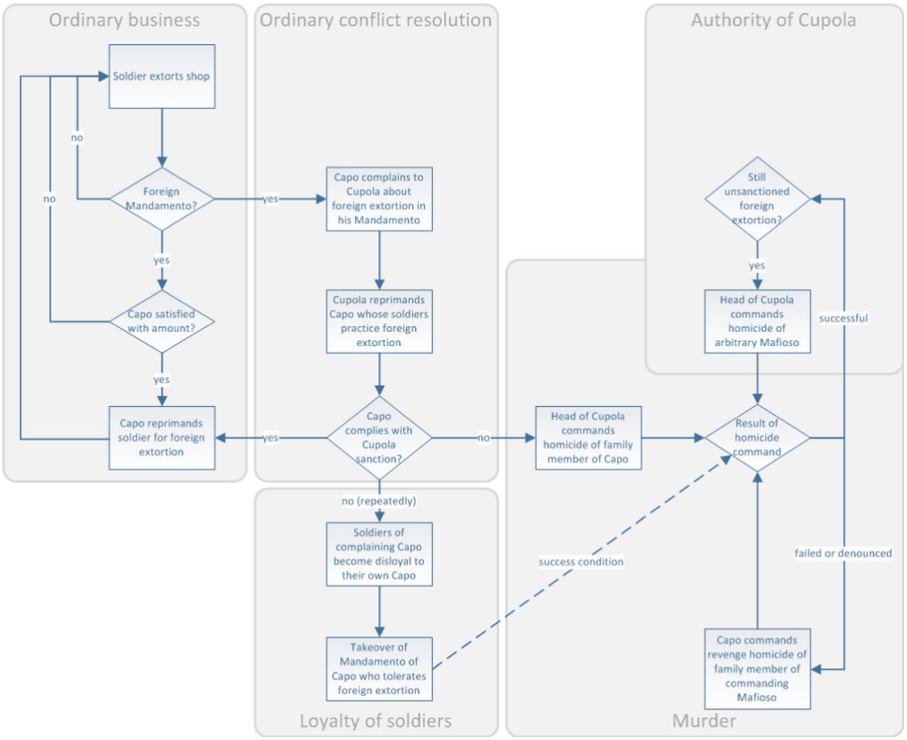

Fig. 2 Summary of core features and properties of the model. Processes start with the 'ordinary' business of extortion. Organizational differentiation is represented by 'ordinary' conflict resolution through the top level, the Cupola. If this fails, organizational stability becomes precarious: It depends on the loyalty of the bottom level of the organization, the soldiers and the authority of the top level, the Cupola

This is intentionally *not* a realistic scenario. The relation between the criminal organization and entrepreneurs, civil society and the state is studied in detail in Nardin et al. (2016) and Troitzsch (2015). In this model, extortion is a quasi-automatic process, only intended for providing a basis for income generation. The central purpose of this model is to study internal relations of the criminal organization.

However, the capo's obedience to the norm 'not to extort in foreign territories' (the normative drive) is constrained by self-interest (the individual drive): If the income falls below a capo's threshold of satisfaction, probability of penalizing decreases. In the absence of penalties, the soldiers gradually forget the norm and start again extorting in foreign territories without being penalized by their capo. This aspect of the model is motivated by the fact that families of Cosa Nostra do not blindly follow internal authorities, but high-ranking Mafiosi (represented in the model as Capos) pursue their own strategic interests (Arlacchi 1993, Dickie 2007).

Sub-model 2: Ordinary conflict resolution

At this stage, the conflict resolution by the top hierarchy level of the Cupola becomes effective. The exploited capo complains to the exploiter at the Cupola, which penalizes the deviant capo. In turn, this penalty increases the likelihood that the deviant capo will continue penalizing its soldiers. The probability is regulated by the parameter

'Response factor Cupola sanction',[7] determining the degree of the normative drive. This is the process of ordinary conflict resolution in the hierarchical organization. While details of decision-processes in concrete cases (e.g., how a case is determined to become regulated by the Cupola or how the Cupola actually reprimands deviant members) are left out, this represents the fact that successful conflict regulation by the authority of the Cupola happened (Fig. 3).

However, ordinary conflict resolution might fail. If one of the capos constantly violates the organizational norms to a much larger degree than the other capos, the head of the Cupola intensifies pressure on the deviant capo by planning an assassination. The victim will be one of its soldiers, selected randomly. This serves as a severe sign of disapproval. This element of the model is motivated by Arlacchi's (1993) description of Cosa Nostra as a Hobbesian society in which Mafiosi needed to constantly watch for and interpret signs. In fact, Arlacchi's interview partner reports many murders or attempted assassinations that served (or had been interpreted by him) as signals in the communication between families. While certainly a real selection of a target is not a random process, it has been described by Arlacchi's interview partner as quasi-random, namely as a kind of pawn-sacrifice.

Sub-model 3: Authority of the Cupola

Many of the victims had been accused of some alleged norm violations. However, Arlacchi's interview partner often had not perceived 'official' justification as trustworthy (e.g., the murder of his brother). Thus, the Cupola is perceived from inside as more or less reliable. This is represented by a value between 0 and 1. Loss of reliability might trigger unjustified violence to represent that (a) determining justice might be error prone. This is inspired by the controversial decision in the first Mafia war in the 1960s. While it remains unknown whether Di Pisa was guilty of stealing drugs, it was at least contested within the organization. Moreover, (b) it represents that the capo, which holds the role of the head of the Cupola, might manipulate its role of jurisdiction in its own interest, following the unrestrained violence of the Corleonese family, even after they took hold of Cosa Nostra after the second Mafia war. To represent the manipulation of the authority of Mafia jurisdiction, the head of the Cupola has the ability also to plan unjustified assassination. To be executed by a simulation model, a random number is generated and if the number is greater than the actual reliability of the cupola it plans an unjustified murder.

Thus, modes of conflict resolution exist but are not perfectly even handed. In case of an unjustified assassination, the authority of the Cupola is damaged. Consequently, the other capos are less likely to follow the directions of the Cupola, i.e. to react to reprimands by the Cupola. Only in the case of appropriate actions does the authority of the Cupola gradually increase again.

However, reliability of the Cupola is not constant. In harsh times with high tensions and mistrust between the Mafiosi, reliability is lower than in times of smooth operations of the organization. For instance, in the times of the outbreak of the second war,

[7] In the model the term sanction in the parameter 'Response factor cupola sanction' is used equivalent to penalty.

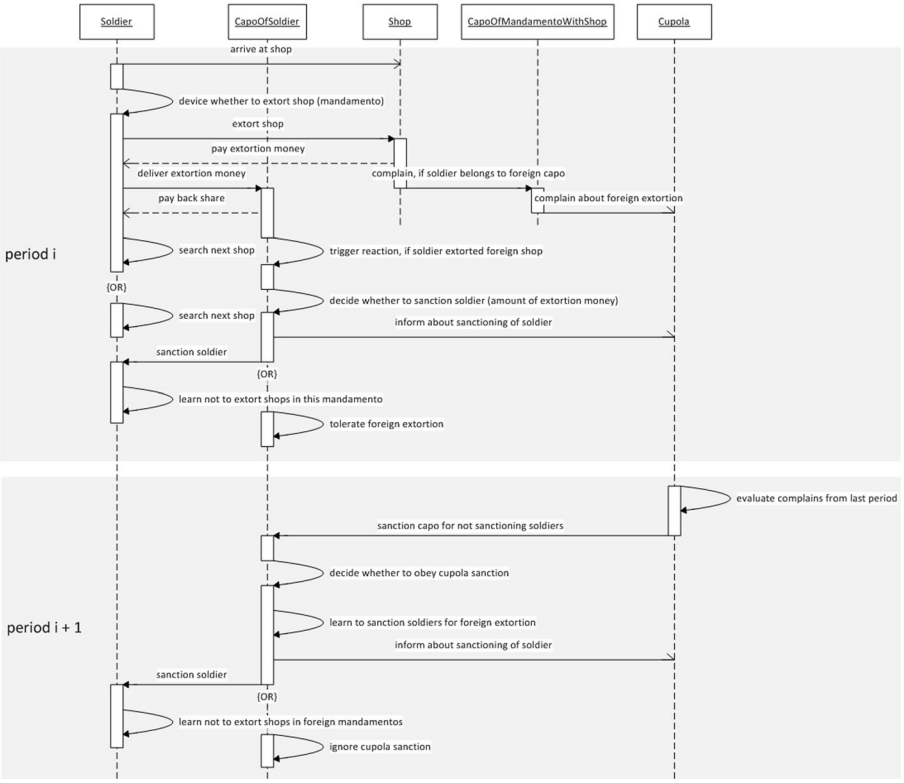

Fig. 3 Sequence diagram that summarizes the ordinary business and conflict resolution. In period i a soldier extorts a shop and delivers the extortion money to his capo, who keeps half of the amount and pays back the other half to the soldier as share. If the extorted shop is situated in a foreign mandamento, the shop owner will complain to the cupola, but at the same time the capo might punish his soldier (and reports this to the cupola, too). If the capo does not punish his soldier for foreign extortion, then in period i + 1 the cupola will rebuke the capo, possibly changing his attitude

tensions between different families caused hectic activities (Arlacchi 1993; Dickie 2007). These cannot be modeled explicitly. For this reason, tensions are simply represented as extortion in foreign territories that are not effectively suppressed by penalties. These are denoted as unsanctioned foreign extortion, which is destabilizing social order within the organization. In turn, decreasing or increasing social order decreases or increases the reliability of the Cupola. For this reason, a social order index is constructed, which determines the change of the reliability. The social order index simply measures the average unsanctioned foreign extortions over time. The objective is to represent tensions that constantly appear within Cosa Nostra and factually preceded the outbreak of the Mafia wars. Dependent on the degree of order the cupola is more or less reliable.

Sub-model 4: Loyalty of the soldiers

After discussing the behavior of the top-level management, the dynamics of the attitudes of the soldiers toward the organization will be described in closer detail. For representing that during the second war many Mafiosi secretly changed sides toward

the (perceived) more powerful Corleonese family, it is crucial to explicitly model the loyalty of the soldiers toward the Cosa Nostra families. This is a dynamic attribute, dependent on the perceived strength of the capos. Loyalty (or hostility) to a family (denoted as 'Family Attitude') can have a value between −1 (maximum hostility) and +1 (maximum loyalty).

Next, it needs to be determined how loyalty changes. Loyalty and reputation is fluid in the real world's Cosa Nostra (Arlacchi 1993). As the complexity of real actors' attitudes cannot be modeled explicitly, this is represented by a simplified abstraction: If a soldier extorts in foreign territory without being penalized by its capo and the complaints of the local capo to the Cupola were unsuccessful, soldiers of the exploited family become enraged represented by a numerical value. This is of consequence for the attitudes of the soldiers toward the Mafia families. However, the effect is two sided: If enragement remains below a threshold, the family attitude toward attacking family decreases. The soldiers are slightly angry at the attacking family. By each tick outrage gradually fades away. However, if enragement increases beyond the threshold, the dynamic of attitudes change. In this case, the own capo is perceived as too weak. Consequently, the soldiers gradually begin to change sides, as has been the case in the second Mafia war. Loyalty toward the own family decreases, whereas the attacking family becomes attractive because of being perceived as the dominant power. The own capo can only restore its reputation among its soldiers by acts of exemplary violence to demonstrate its strength.

Furthermore, since murder is an essential part of the business of Mafiosi, this is taken into account as well. This act of violence will be described in the next section. First, it shall be noted that participating in a murder is a central means for generating (or undermining) commitment (Campana and Varese 2013). It drastically increases loyalty toward the family that commanded the execution and decreases loyalty toward the victim's family.

Sub-model 5: Plan murder

As it has already been noted in the description of the sub-model of ordinary conflict resolution, the measures of the Cupola entail the command of an assassination if weaker penalties fail to maintain organizational norms. It shall be noted, however, that the Cupola does not possess an absolute monopoly of violence. Also, other capos might commission murder. However, as only the Cupola is agreed to have the right of commanding legitimate penalties in that case, revenge or even hostile take-over is motivation for murder. In the following, the mechanisms of the planning and selection of the target are explained in detail. The sequences of the process are outlined in Fig. 4.

Assassination among fellows is a common trait of the Mafia. Arlacchi reports that murders are undertaken collectively for increasing legitimacy of the aggression. However, this comes at the risk of betrayal and counter attack (see Arlacchi 1993). For representing this in the model, plans are sent within the friendship network. However, it might be the case that one of the receivers of the plan has a friendship relation to the potential victim's family, leading to a situation of conflicting loyalties. Again real world's complexity is translated into rules that represent a strategic evaluation of power relations. The capo that plans a murder selects the most loyal soldier for execution. The agent decides between two possibilities: participate in the murder or betray the

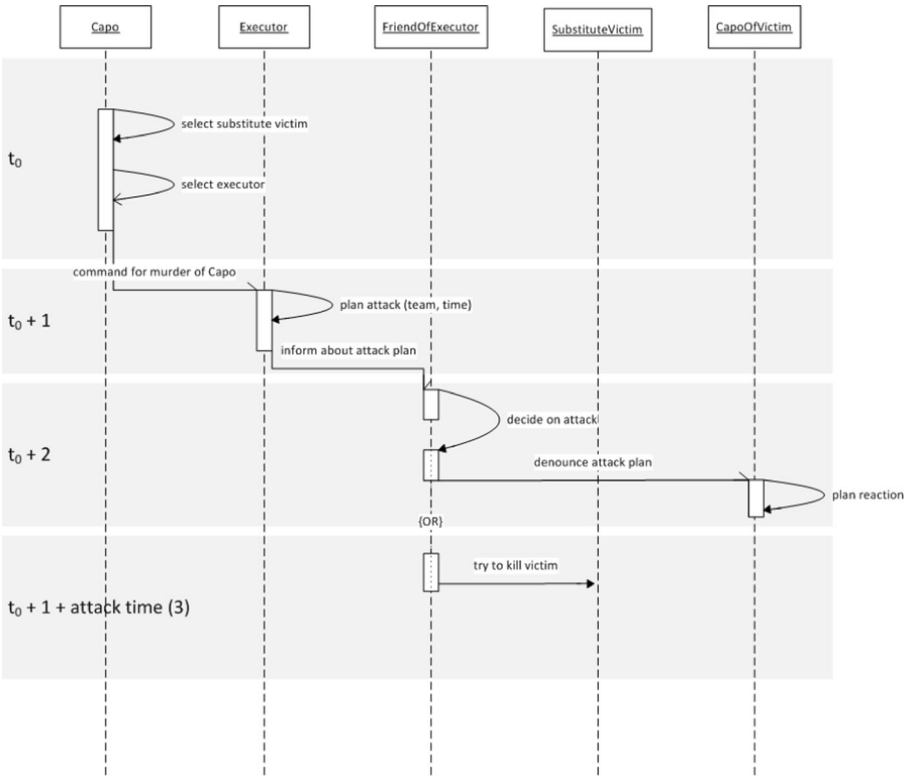

Fig. 4 Sequence diagram of the processes involved in planning an assassination. First, a capo selects a victim and an executor of the plan who chooses collaborators. All can decide to execute or denounce the plan. If a plan is denounced, a counter reaction is performed

conspirator. The resulting action is based on a two-stage decision process. First, the agent checks whether one of the families (i.e., the family of the transmitter of the plan or the family of the potential victim) is of extraordinary power. Power is calculated by the sum of the aggressiveness of the family members. If the power of one family exceeds the other significantly the agent decides in favor of the powerful family. If the power balance between the families is rather counterbalanced, the agent undertakes a comparison between the loyalty toward the family of the attacker and the family of the potential victim. A soldier accepts the plan if the soldier is more loyal towards the attacking family otherwise it betrays the plan.

If a soldier accepts a plan, the soldier contacts its friendship network and the friends decide on accepting or denouncing the plan, according to the same rule. If a plan is accepted, the assassins attempt to kill the victim: All subsequently try to kill the victim with a certain chance of success. To concentrate on the investigation of one effect, no recruitment of new Mafiosi is implemented in the model, i.e., the killed agent is taken out of the simulation and is not replaced.

However, if the potential victim gets informed, or the execution of an assassination fails, the potential victim (more precisely: the capo of the family) in turn generates a plan of murdering the conspirator in a counterattack. The threatened capo switches into a mode of revenge. This is a decisive tipping point in the organizational evolution: The

monopoly of violence is taken out of the hand of the head of the Cupola. This can be described as a collapse of the hierarchical order of the organization. The plan for a counterattack is again distributed in the friendship network of this agent, and the potential execution or denouncement is based again on the same principles.

Finally, a decision of targeting a potential victim of an assassination has to be taken: Typically, murders are undertaken as a warning for a deviant capo, i.e., the capo itself is not murdered, but one of its soldiers is. As already noted, often Mafiosi seem to have been killed as a kind of pawn-sacrifice (Arlacchi 1993). In this case, a soldier of the family of the deviant capo is selected randomly as a potential victim. However, during the wars, most high-ranking Mafiosi also became victims of assassinations (Dickie 2007). This is the hostile take-over as in the second Mafia war. Murder of a capo is preceded by a strategic evaluation motivated by evidence that, in particular, in the second war, murder of high-ranking Mafiosi was strategically planned (Arlacchi 1993, Dickie 2007): soldiers may secretly decide to change to another family (see Stille 1995; Dickie 2007). This is represented by the degree of loyalty, i.e., the family attitude. If the loyalty toward the own family is below the loyalty toward the aggressor family, the soldier has changed sides. A capo is target of an assassination if the average loyalty of the capo's soldiers towards attacking family is greater than towards their own capo.

The murder of a capo triggers a power struggle between the soldiers. The winner is either the soldier with the longest history of successful murders or, if this remains undecided, the most aggressive soldier. This is influenced by the fact that, for instance, in his early career, the later Mafia boss Bernado Provenzano gained a reputation as a brutal assassinator, known as 'the tractor' for 'mowing down people' (Dickie 2007). If a soldier that changed the sides becomes the new capo, it subordinates this family to the other family. In this case, the winning family controls the territory of the assassinated capo, and assassination as well as exploiting foreign territories is terminated. In this way, one family may take over the whole organization, as was the result of the second war. This is not completely a realistic representation of the second Mafia war. In fact, it underestimates the factual degree of violence of the Corleonese family, who eliminated not only their enemies but also their associated helpers when they were no longer useful (see Stille 1995, Dickie 2007).

Simulation results

The model is implemented in Repast Symphony, a tool specifically developed for agent-based simulation. Running the simulation model typically generates patterns in which, during most periods of the simulation, no murder or only a rather 'smooth' decline of soldiers can be observed. However, the rather 'peaceful' times are interrupted by extremely steep declines in the number of soldiers of some families. These extremely steep decreases indicate massive killing within a very short time period. Such mass killing is denoted as a war: if 15 % of soldiers or more of the overall population are killed within one period, this is defined as a war. Note that no cognitive concept of 'being in a state of war' is implemented in the Mafioso agents. Mafioso agents only know the concept 'murder'. Murder, however, can be observed both in the rather smooth decline of the number of soldiers as well as in wars. Thus, war can be described as an emergent property of the model.

Initialization and simulation experiments

The philosopher DeLanda (2015) characterizes simulation models as tools for exploring possibility spaces. The possibility space can be explored by experimenting with parameter constellations. For systematically exploring the parameter space, initialization of the model follows the strategy of a Monte-Carlo simulation. 2000 runs were undertaken (with each simulation running 600 periods). Initialization of the parameter was varied within the range plotted in Table 2 for exploring the parameter space of the model. Thereby, the Monte Carlo simulation explores the space of possibilities for answering 'what if' questions (Woodward 2003; Cooper 2005). Most interesting is an investigation of critical zones, in which the social order of a hierarchical organization collapses. The huge amount of data produced by the simulation experiments enables a statistical detection of the critical zones in the parameter space, namely what conditions foster criticality.

Statistical analysis

The first thing to note is that frequency and intensity of violence is very unevenly distributed. In the 2000 runs, the number of wars varied between 0 (in 1770 runs) and 7 (2 runs). This is shown in Table 3. The maximum number of homicides per period varied between 0 (i.e., a whole run without any murder) and 136 murders within one period. However, beyond 100 murders per period, only one run appeared with 104 murders, one run with 119, one run with 124, and one run with 136 murders within a period. In the majority of runs, the maximum number varied within the interval of 0 to 100. This is shown in Table 4. Frequencies are plotted in intervals of 5, i.e., the number of runs with 0 as the maximum number of murders per period is plotted, the number of runs with up to 5 murders, up to 10, etc.

Table 2 Range of parameter variation in the Monte Carlo simulation.

Variable	Range of variation
Number of families	9
Attitude toward own family	Normal distribution with Uniform distribution of mean (0.5. . 0.9) Standard deviation 0.05
Attitude toward other families	Normal distribution with Uniform distribution of mean (0.2. . 0.5) Standard deviation 0.1
Multiplier income low	Uniform distribution (0.2. . 0.8)
Multiplier income high	Uniform distribution (1.5. . 2.5)
Cupola sanction response factor	Uniform distribution (1.05. . 2.5)
Threshold income high	Uniform distribution (600. . 2500)
Network size	Uniform distribution (1. . 5)
Shop capability	Uniform distribution (100. . 500)
Number of shops	Uniform distribution (100. . 1500)
Number of soldiers	Uniform distribution (10. . 130)

Table 3 Distribution of the number of wars in the runs

No. of wars	Frequency of runs
0	1770
1	123
2	73
3	19
4	5
5	6
6	2
7	2

Thus, in large parts of the parameter space, the commitment of the simulated Mafiosi to the organizational authority is effective. However, certain conditions generate a strong escalation of violence. The remainder of the article will investigate the mechanisms of the maintenance of social order and its collapse. First, the conditions for stability are investigated. It shall be noted that both in circumstances of extremely prosperous economic conditions as well as in circumstances of extremely high normative commitment (and at least not too bad of economic conditions) no homicide occurs. The organization remains stable and (internally) peaceful. However, this is due to very different reasons: In the case of extremely good economic conditions, there is simply

Table 4 Distribution of max. Homicides per period in the runs

Max. homicide per period	Frequency of runs
0	1301
5	142
10	118
15	128
20	61
25	33
30	35
35	33
40	31
45	31
50	25
55	13
60	13
65	4
70	6
75	8
80	5
85	2
90	3
95	1
100	1

Table 5 Explanatory variables for the total number of penalties

Predictor	Additional contribution to variance reduction	Total variance reduction
Multiplier income low	.47	.47
Number of soldiers	.25	.72
Number of Shops	.06	.78
Capability to pay	.04	.82

no reason for violence, since everybody gains satisfactory income. In the case of extremely high normative commitment, the Mafia may even operate at the border of the economic capacity of the environment and still remain peaceful because of the high normative commitment of the capos of the families. In this case, conflict resolution by the Cupola becomes effective. This finding is highlighted by statistically examining those runs in which no homicide appears (which are 1301 runs). A multiple regression with the total number of penalties as dependent variable reveals a model with four explanatory variables with an explained variance (R^2) of .82 % (SPSS method Stepwise).[8] The predictors are displayed in Table 5.

The *multiplier income low* represents the normative component of the explanation, more precisely the individual drive of the capos: namely, how the likelihood to penalize their soldiers is reduced when faced with unsatisfactory income. Number and prosperity (capability to pay) of the extorted shops represent economic conditions of the environment, whereas a greater number of soldiers, on the one hand, provides more sources to generate income but, on the other hand, also provides more opportunities to deviate from the norms.

In fact, the relation of the number of Cupola penalties to the *multiplier income low* is negative: the stronger the individual drive (i.e., the more the probability of capo penalties is reduced), the higher the number of penalties by the Cupola. Note that in all these runs, no homicide appeared. Likewise, the higher the number and prosperity of shops, the smaller the number of Cupola penalties. Thus, this relation is also negative, whereas there is a positive relation between the number of soldiers and penalties. In fact, the normative component is of greatest explanatory value for maintaining social order: penalties keep the individual self-interest under control. The extreme case of no violence at all explores the effectiveness of mechanisms in principle. This is of theoretical interest. However, it has to be noted that it is unrealistic that these extreme conditions are empirically realized.[9] The same holds for runs with extremely high violence. Most interesting are the cases in the middle.

[8] The use of multiple regression methods is justified as it is used without any significance levels. It is acknowledged that, eventually, non-linear models may even increase explained variance. Here, only the variance explained by a linear model is used as a baseline model. As the total variance reduction is quite high a more detailed analysis of the joint distributions of predictors (input parameters) and output metrics did not seem so very important.

[9] It is speculated whether the current relative inconspicuousness of the Sicilian Cosa Nostra may be due to an exploitation of an (unknown) new business field with good economic returns, comparable to the late 1950s. However, this is currently not supported by empirical findings. On the contrary, scholars regard Cosa Nostra as an organization under pressure (Militello et al. 2014) and views that the current silence is a sign of danger (e.g., Reski 2008) are a minority position.

Thus, economic prosperity and normative commitment to the organizational authority are conditions that foster peaceful simulation runs. However, they do not determine peace. While violence is predictable in unfavorable circumstances, the reverse is not the case: Even in runs with rather prosperous economic conditions or high normative commitment, an outbreak of violence may happen. This is shown by a statistical analysis, outlined in the following: The *Cupola sanction response factor* regulates the degree by which capos react to penalties imposed by the Cupola. Thus, it indicates the normative commitment of the capos to the authority of the top level (the Cupola). The correlation of this factor with the number of periods in which homicide appeared is −.40. This correlation shows that Cupola penalties are indeed effective but do not determine peace either, as explained variance is only about one-sixth ($R^2 = .16$). The correlation between economic factors (number and capability of shops) and indicators for violence (outbreak of war, maximum number of homicides per period) is even weaker. Thus, violence cannot be explained only by these two factors.

This result suggests path dependency. The course of a simulation run is not only determined by initial conditions but also depends on events in the course of the simulation run. However, what triggers the escalation of violence? The answer is simple: The central mechanism that a simulation run enters a violent pathway is revenge. Once, by some accident, a revenge murder is undertaken, this triggers new acts of violence. The simulation enters a pathway of cycles of revenge. This mechanism is indicated by a number of statistical hints:

- The correlation between revenge murder and the maximum number of homicides per period is .76 ($R^2 = .58$). Periods with high violence are dominated by revenge.
- The correlation between revenge murder and the number of wars is .50 ($R^2 = .25$).
- The mean proportion of revenge murder in the absence of war is 13.28 % (i.e., murder is mostly undertaken by the Cupola as a strong penalty of a deviant capo), whereas the mean proportion of revenge murder in the case of war is 74.55 % (i.e., most murders are revenge murders). In sum, revenge is a central mechanism, driving violence out of control, i.e., outbreak of wars.

Revenge depends on the question of whether a planned assassination is denounced. This is again dependent on the distribution of loyalties in the friendship network, which is a dynamic attribute. Therefore, revenge is highly chance dependent and might happen, even in favorable conditions. However, once a cycle of revenge is initiated, it might develop momentum, which may no longer be controllable by the organizational mechanisms of conflict resolution and, in turn, may generate a collapse of the organizational authority. In particular, the first war in the 1960s can be regarded as an escalation of a cycle of revenge: Without going into details, the Grecos took revenge for the assassination of their ally Di Pisa, allegedly undertaken by the Barberas (e.g., one of the Barbera brothers had been killed), and the Barberas took revenge in return. Certainly an explanation of the *reason* for the outbreak of war needs to include strategic interests (e.g., conflicts between the old dynasty of the Grecos and the ambitious Barberas). However, the *mechanism* that initiated particular actions in terms of cause and effect can be described as revenge.

Nevertheless, the degree of violence is very unevenly distributed. This leads to the question of what factors are responsible for the variance. As revenge has been identified as an important mechanism, the following scattergram in Fig. 5 shows the relation

between the maximum number of homicides per period and the proportion of revenge homicides (in those simulation runs that at least generated acts of homicide) for approaching this question.

Figure 5 reveals a great variety. However, it clearly shows distinct types of simulation runs. We differentiate the following types: First, runs can be differentiated in those with and without war. Furthermore, in the case of war, we distinguished between runs with an early outbreak of war (defined as runs with the period of outbreak of first <50) and late outbreak of war (defined as runs with the period of outbreak of first >50).

1) War Type *late* is represented by the dark green dots. While these runs exhibit a great variance, and many runs only exhibit a modest degree of violence, there is a possibility of massive violence and a bias toward most murders undertaken as revenge.
2) War Type *early* is represented by the blue dots. Variance is even greater, in particular, towards even more violence. Not unsurprisingly, the most violent runs are also characterized by early outbreak of war.

Moreover, the data reveals that even in those runs without war (War Type *never*) three different types of characteristic simulation runs can be distinguished:

3) *Type 1* is displayed by the red dots at the bottom of the scattergram: While the runs are quite evenly distributed among the proportion of revenge homicides, the degree

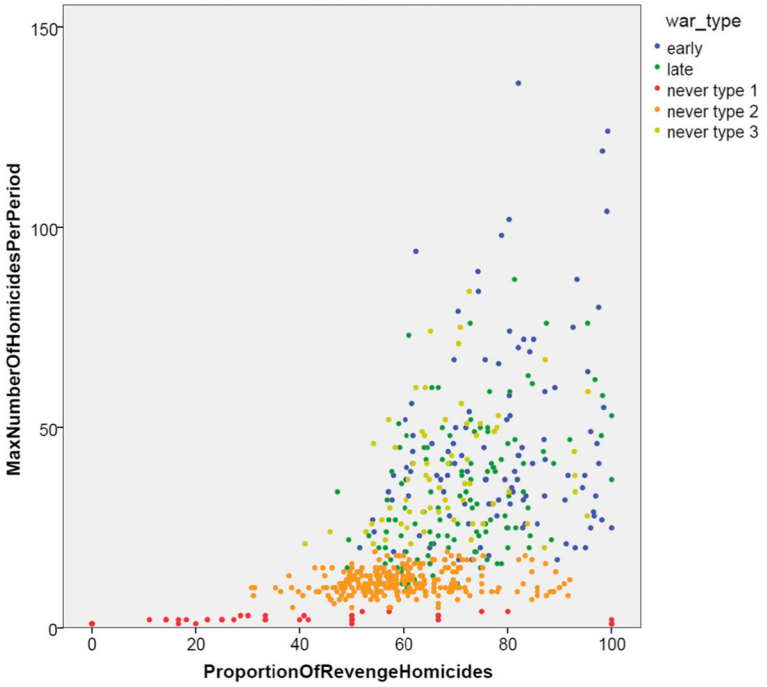

Fig. 5 Distribution of simulation runs along the dimensions of proportion of revenge homicides and intensity of violence measured by the maximum number of homicides per period

Table 6 Explanatory variables for the maximum number of homicides per period in the case of early war (Period of first war <50)

Predictor	Additional contribution to variance reduction	Total variance reduction
Number of soldiers	.618	.618
Size of friendship network	.052	.670
Attitude to other families	.016	.686

of violence (measured by the maximum number of homicides per period) remains very low.

4) *Type 2* is displayed by the orange dots, which form a cloud right above the bottom line. Also, these display a strong variance along the line of the proportion of revenge homicides. However, compared to the red dots of Type 1, they are a bit shifted to the right, i.e., more towards revenge homicides. While this type is more violent than Type 1, here the degree of violence remains under control, too.
5) *Type 3* is displayed by the light green dots: This type reveals the strongest variance among the runs without war, in particular, with regard to the degree of violence. The pattern is similar to the pattern of War Type *late* (i.e., dark green dots).

A discriminant analysis confirms that the three types of runs without wars but with murder are differentiated along the two axes of *maximum number of homicides per period* and *proportion of revenge homicides* (η^2 = .79 for the former and .50 for the latter). Now, which influence factors characterize these types and how they are differentiated was investigated. For this reason, another stepwise multiple-regression analysis was undertaken to examine which input variables explain the variance in the virtual data. We concentrate on a discussion of those correlations, where an explained variance of about .3 and more could be found.

War type early (*N* = 113)

The strong variance of violence of this type, which generates the most violent simulation runs, can be explained rather well. The maximum number of homicides can be explained with an R^2 of .686 (see Table 6). Explanatory variables are the *number of soldiers*, the *size of friendship network* and the loyalty, i.e., *attitude toward other families.* All relations are positive. Not surprisingly, the more soldiers that exist, the

Table 7 Explanatory variables for the first outbreak of war in the case of late war (Period of first war >50)

Predictor	Additional contribution to variance reduction	Total variance reduction
Number of soldiers	.244	.244
Number of Shops	.031	.275
Income high threshold	.030	.305

Table 8 Explanatory variables for the number of periods with homicide in the case of late war (Period of first war >50).

Predictor	Additional contribution to variance reduction	Total variance reduction
Number of soldiers	.232	.232
Number of shops	.178	.410
Multiplier income low	.098	.508
Cupola sanction response	.119	.627
Shop capable to pay	.042	.669
Size of friendship network	.035	.704

more that can be killed. This is due to the friendship network and the loyalty toward other families: More friends and more positive loyalty toward other families increase the likelihood of betrayal (which is more likely with the more soldiers that exist, for which all have a friendship network). Certainly, the possibility of high violence is also due to the early outbreak of wars, which make possible long episodes of violence. Empirically, this type resembles the second war in which the Corleonese family (the military arm of Cosa Nostra with fewer economic resources but strong military forces, reflected by the variable *number of soldiers*) applied a brutal strategy (even for Cosa Nostra) of intentionally escalating violence for eliminating their rivals. Even though explained variance of the variables *size of friendship network* and *attitude toward other families* is only modest, the model resembles the Corleonese's strategy for the escalation of violence by secretly winning soldiers of the rivaling families who changed to the seemingly stronger party.

War type late ($N = 117$)

If an outbreak of war is delayed, it is most interesting which factors trigger the first outbreak of war. The variance can be explained with an R^2 of .305 (see Table 7). However, there is a remarkable tension between the outbreak of war and violence in general. The latter is measured by the number of periods in which murder occurs. This

Table 9 Explanatory variables for the maximum number of homicides per period in the case of late war (Period of first war >50).

Predictor	Additional contribution to variance reduction	Total variance reduction
Number of soldiers	.246	.246
Multiplier income low	.118	.362
Size of friendship network	.049	.411
Attitude to other families	.035	.446
Cupola sanction response	.020	.466
Number of shops	.017	.487

Table 10 Explanatory variables for the number of wars in the case of late war (Period of first war >50)

Predictor	Additional contribution to variance reduction	Total variance reduction
Multiplier income low	.111	.111
Cupola sanction response	. 089	.200
Number of shops	.075	.275
Number of soldiers	.046	.321
Shop capable to pay	.025	.346

can be explained with an R^2 of even .70 (Table 8) and the maximum number of homicides with an R^2 of .49 (Table 9). First, we concentrate on explaining the first outbreak of war (Table 7).

The outbreak of the first war is later, if the number of soldiers is greater, as well as the capo's threshold to start penalizing its soldiers again (in the case of satisfactory income). Moreover, a lower number of shops delay the outbreak of war. More soldiers delay the outbreak of war, because this increases resources to generate income. However, the direction of the other variables is counterintuitive at first sight: Fewer shops imply less-favorable economic conditions, and a higher threshold to return to obedience to the organizational norms implies a stronger individual drive. Why should this *delay* the outbreak of war?

This is explained by the variables representing general violence. The variance in the number of periods in which murder occurs at all (Table 8) is positively related to the *number of soldiers* and negatively related to the number and prosperity of shops (both representing economic conditions), the *multiplier income low*, the *Cupola sanction response* factor (both representing normative commitment) and the *size of friendship network:* Less-favorable economic conditions and less-normative commitment generate constant violence, however, below the threshold of a full-fledged war. Normative and economic binding forces might reduce such small-scale violence, but at the cost of the danger of stronger escalation of violence to full-fledged wars. It leads to a concentration of violence.

This finding is confirmed by an examination of the maximum number of homicides per period (Table 9). Also, here the degree of violence is shown to intensify by stronger normative commitment (*Cupola sanction response*), a lower individual drive (*multiplier income low*) and better economic conditions (*number of shops and number of soldiers).*[10] Normative and economic binding forces lead to rare but severe outbreak of violence.

The normative and economic binding forces that lead to a concentration of violence are also in line with the variance of the number of wars (R^2 .346, see

[10] Surprisingly, the mechanisms of betrayal are different than in the case of early war. While intensity of violence is positively related to the size of the friendship network (as in the case of early war), it is negatively correlated to the attitude toward other families. This might be due to the classification: if no dampening mechanism existed, the simulation runs would not exhibit delayed wars, i.e., the runs would fall in the class of early war.

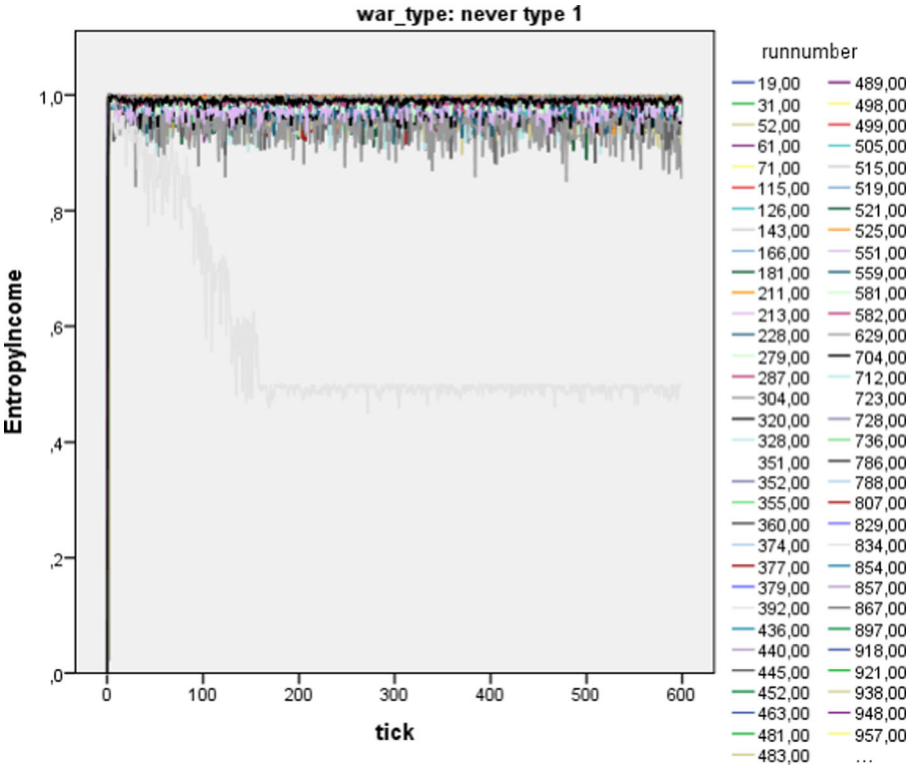

Fig. 6 Development of entropy during the simulation runs of type 1

Table 10). Lower individual drive (*mulitplicator income low*) and higher normative drive (*Cupola sanction response*) decrease the number of wars as well as favorable economic conditions (number and prosperity of shops, number of soldiers). These are runs in which the Cupola for some time is able to control violence until it finally fails to prevent an outbreak of war.

This type has more similarities with the first Mafia war, preceded by tensions between the rivaling Grecos and Barberas. While normative binding forces (which have certainly been stronger than in the 1980s) have prevented violence for some time, it was predictable for Michele Cavataio that a certain impulse (the murder of Di Pisa) would be sufficient for triggering an outbreak of violence.[11]

[11] In terms of complex systems, the tradeoff between petty violence and war found in this type provides insights into the dynamics of self-organized systems in general: That suppression of small scale violence by normative binding forces increases the danger of concentration of violence in full-fledged wars and reveals a property that can also be found in avalanches, or also in sand piles. If binding forces between individual grains of sand (or snowflakes in alpine avalanches) are reduced, they flow from the pile more easily and thus more frequently, which reduces the intensity of avalanches. In systems of self-organized criticality, too harsh of a control system reduces frequency but at the cost of increasing intensity of extreme events.

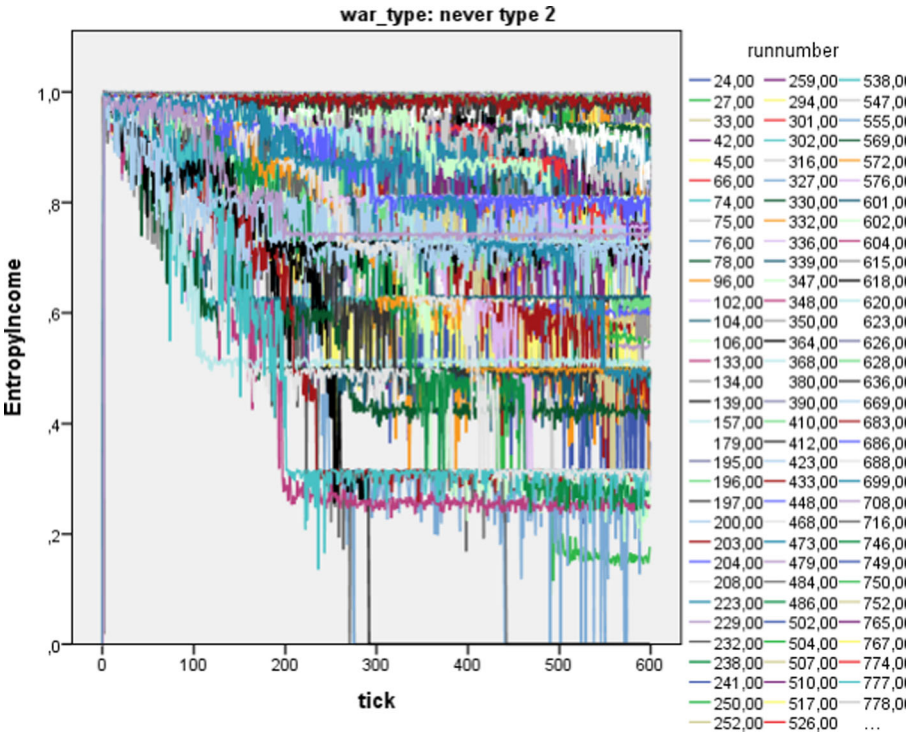

Fig. 7 Development of entropy during the simulation runs of type 2

Never war: discussion of the types

The three types of runs without wars but with homicide shed light on the path dependency in the course of a simulation run. Compared to the overall runs without wars, including those that do not exhibit any murder, all three types are characterized by slightly less-favorable but not extremely bad economic conditions. A discriminant analysis reveals that neither the *number of shops* nor their *capability to pay* extortion money is significant in determining the discriminant functions. Economy does not provide an explanation for the increasing escalation of violence (as measured by the maximum number of homicides per period). Instead, enforcement of norm compliance is necessary. The Cupola is fully stretched in keeping violence under control, not sufficiently to prevent any violence but at least able to prevent wars.

However, during the simulation runs, economic power changes significantly. The history of the different types of runs describes different political economies: A comparison of the concentration processes (i.e., hostile takeover, as the Corleonese Family did in the second war) reveals characteristic differences. To measure concentration processes the concept of entropy is utilized.[12] Very generally entropy denotes the

[12] Alternatively, the Herfindahl index could have been used, but this index has the disadvantage that its minimum value is not zero but depends on the number of groups, hence it does not lend itself to comparisons between situations with different numbers of families. For a discussion of these and other indices see Palan (2010).

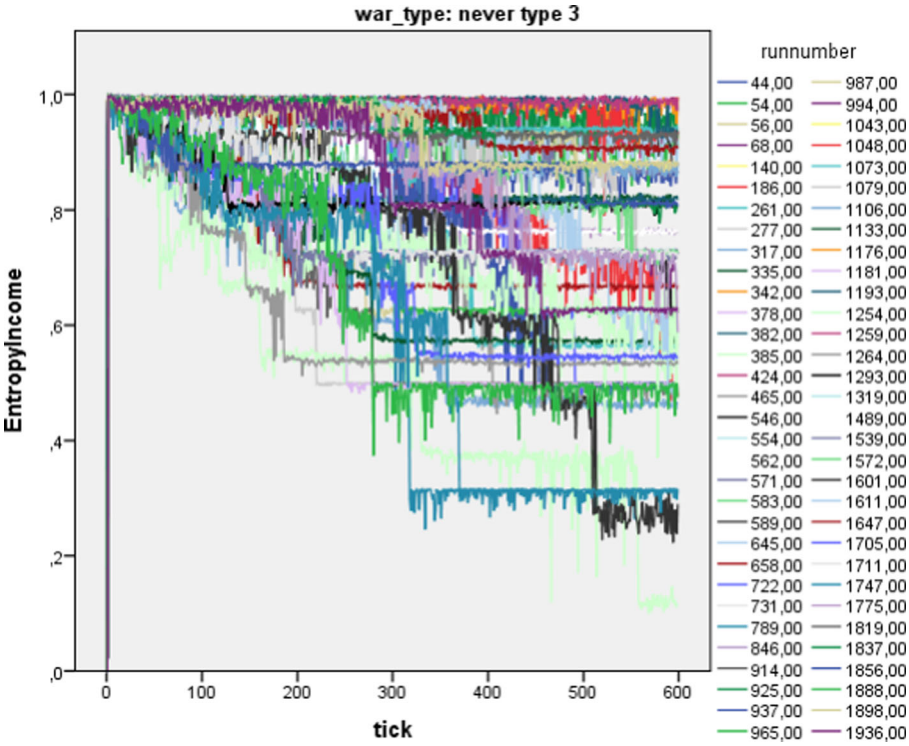

Fig. 8 Development of entropy during the simulation runs of type 3

degree of order and disorder. High entropy denotes high order. For instance if a glass of water is filled with hot water on the right and cold water on the left, the overall temperature will balance in the course of time. This is measured by increasing entropy. In our case we measure the degree of disorder in the number of soldiers per family. The more evenly the number of soldiers is distributed among the families, the higher the entropy (entropy =1 means that all families have exactly the same size, entropy =0 means that one family subdues all others). Thus, decreasing entropy indicates a more uneven distribution of the number of soldiers. This implies a concentration of the number of soldiers, and thus power, in a few families. Figures 6 through 8 show the development of the entropy in the runs of the different types.

The peaceful Type 1 consists of two typical scenarios. In nearly all runs, no concentration takes place. Only one run shows a modest concentration at the beginning. This Type is characterized by a balance of power in which rarely hostile takeover happens. The families remain co-existent. Types 2 and 3, first, are characterized by an extreme variance between the runs. This reflects the variance in the degree of violence. However, while in both types runs are possible with a rather equal power balance, strong concentration processes *can* happen and *do* so quite often, in the case of Type 2, even more pronounced than in the case of Type 3. These are the runs with a high degree of

Table 11 Characteristic values of the three types without war but with homicide.

Variable	Type 1	Type 2	Type 3
N	137	268	64
Mean max. Homicide per period	1.53	11.41	39.33
Std. deviation	.76	3,01	15,04
Mean shop capability to pay	272.73	292.42	272.20
Std. deviation	116.28	109,91	109,04
Mean number of shops	790.81	736.72	792.61
Std. deviation	406.48	390,53	416,66
Mean number of soldiers	61.31	46.44	45.75
Std. deviation	25.16	24,97	19,09
Mean Cupola penalties	63,643.74	45,352.66	30,280.97
Std. deviation	33,174.63	48,919.84	40,264.41
Mean proportion revenge murder	22.07	59.99	68.72
Std. deviation	28.66	11,90	11,51
Mean size of friendship network	2.77	2.70	3.52
Std. deviation	1.30	1,31	1,08

revenge murder. Revenge murder might induce processes of hostile takeover in which finally one or a few winning families overtake the organization. Thus, as it was the case in the second war, concentration of power is also a violent process in the model. However, which mechanisms differentiate the types? This can be answered with Table 11.

With regard to the input parameters, the types differ in two dimensions: First, Type 1 has significantly more soldiers than Type 2 and Type 3, which are comparable in this dimension. Second, Type 1 and Type 2 exhibit a comparable size of the friendship network, while Type 3 has a larger friendship network. These combinations produce different pathways to violence: More soldiers provide more capacities for resource acquisition. Consequently, the more violent Types 2 and 3 have a lower mean value of the number of soldiers. In addition, as the larger friendship network in Type 3 increases the likelihood of betrayal, Type 3 is the most violent one. During the simulation runs, this leads to constantly decreasing penalizing activities of the Cupola from Type 1 to Type 3 and increasing revenge; less penalizing implies more violence. Thus, small differences in the initial conditions may trigger very different pathways.[13]

[13] This finding might be relevant also for policy interventions: It indicates that the horizon of prediction (i.e., of possible consequences of interventions) is dependent on bifurcations and path dependency and in consequence is rather narrow. This suggests that effects of policy interventions may be barely predictable for systematic reasons.

Conclusion

As a laboratory for the investigation of the evolution of social order, the Monte-Carlo exploration of the parameter space investigates the counterfactual question of what can happen under different circumstances. Stability can be traced back to two central mechanisms: First, economic conditions provide a control variable. If the environment provides sufficient resources, the individual families collect resources on their own, and no organizational norms are needed at all. The binding forces of a normative commitment to the organization come in to play when the carrying capacity of the environment is reached. In this case, they provide a chance for persistence of the organization. However, there remains a constant danger of collapse. Effects of path dependency can trigger collapse.

Critical for the stability is the control over a monopoly of violence of the organizational top-level management, i.e., the Cupola. There is constant danger that the authority may lose control of violence. As the state had to rely on associated lords for establishing its power in early times of evolution of the state, the authority of the Cupola remains dependent on the commitment of the associated leaders of the Mafia families. However, there is a constant danger that the individual capos (comparable to the lords) take violence in their own hands, and the criminal organization falls back in a Hobbesian state of anarchy.

However, anarchy leads to an escalation of violence through the trap of cycles of revenge once the top-level authority loses its monopoly of violence. Revenge is the central mechanism of the escalation of violence. Obedience to the organizational authority, thus, has a pacifying effect. Once cycles of revenge are initiated, violence easily escalates to full-fledged wars, which are no longer controllable by the top-level authority. This is a path-dependent effect. The types War Types early and War Type late resemble the different characteristics of the first and second Mafia war. Early outbreak of war is driven by military power as the second Mafia war whereas late outbreak of war is characterized by an increase of tensions beyond control, similar to the first war. Moreover, the results in the case of absence of war but existence of assassination reveal a further social mechanism: a pacifying effect of war, by concentration of violence. Normative and economic binding forces might reduce small-scale violence, but at the cost of the danger of stronger escalation of violence to full-fledged wars.

The three types of runs with murder but no war associated with very different degrees of violence, reveal that minimal differences in the initial conditions generate strong differences in the outcome. Minimal differences open the pathway to violence.

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Compliance with ethical standards

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Conflict of interest The Authors declare that they have no conflict of interest.

Appendix: an ODD protocol including technical details of the model

In this appendix a more technical description of the model will be provided following the ODD protocol (Grimm et al. 2010; Mueller et al. 2013). In order to ease replicability, we follow the advice provided in the comments to the ODD to formulate central rules as pseudo-code that is nearly identical with the implemented code. As already the more informal description in the main body of text should give the reader an idea of the mechanisms of the model, obviously certain redundancies cannot be avoided completely.

1. Purpose

Research question is studying stability of social order in criminal organizations. Criminal organizations are selected as example since they operate outside the state monopoly of violence, which evolved in the human cultural evolution as a mechanism for securing social order. Lack of state monopoly of violence makes criminal organization a test-bed for studying emergence and collapse of social order. Cosa Nostra is a special case as it evolved some form of conflict regulating bodies, as the Cupola. For this reason, the target of the model is stylized fact representation of the conflict resolution and its failure leading to the outbreak of Mafia wars. Research question is the analysis of the mechanisms of stability and to investigate whether and when patterns of an outbreak of Mafia wars can be detected.

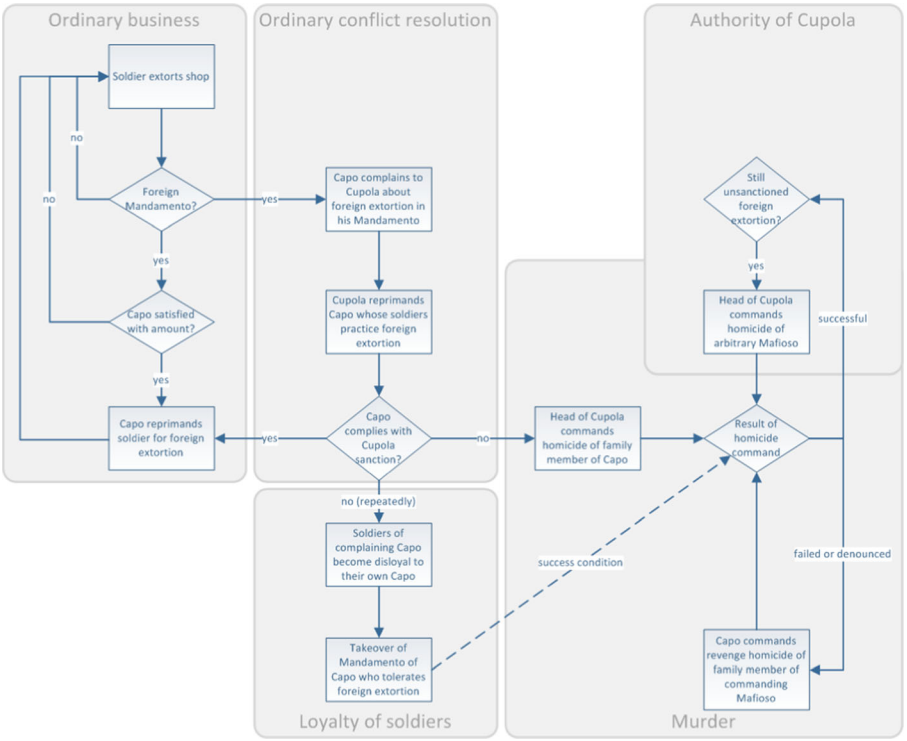
2. Entities, state variables, and scales

The entities of the model and their attributes are summarized in (Table 12):

3. Process overview and scheduling

Time is modeled tickwise. However, ticks do not represent concrete time as e.g. month or years. Moreover, ticks are structured in periods of 100 ticks. At the end of each period the cupola becomes active. The world is a rectangular composition of cells that is divided in territories of different Mafia families. Note that no recruitment of new soldiers is implemented in the model to

concentrate on the investigation of one effect, namely the outbreak of war that becomes visible by killing of Mafiosi. An overview of the scheduling is provided in Fig. 2 which is recalled here.



Ordinary business:

Soldiers:

The soldiers walk randomly in the world. If they arrive on a cell with a shop soldiers decide to extort or not. The decision is based on salience of the norm to extort only in the own territory. The salience is based on past experience of punishments (technically a message) from their own capo for extorting in foreign territory. Soldiers remember the location where they have been punished and avoid punishment. If they get punished soldiers decrease their probability to extort on that particular place. Thereby soldiers learn to extort only in their own territory, even if they don't know the territory explicitly. In the absence of sanctions they gradually forget the norm. Central action rules is the probability of extortion which is expressed in the following pseudo-code:

```
p_extort(t+1)=p_extort(t)*multiplierForgetting;
multiplierForgetting = 1.002
```

The value of the multiplierForgetting implies that in the absence of punishment each tick the probability of extortion in a foreign territory slightly increases.

Table 12 Summary of the entities of the model and their attributes

Agents	Attributes
Mafiosi (may be capo or soldier)	*Friendship network*: becomes effective in the case of planned murder. Plans are sent in the friendship network. Friendship is private.
	Aggressiveness: indicates severity of attacks. Determines the reputation of a family and becomes effective in the case of power struggle within a family.
	-1 < Attitude toward own family < 1: becomes effective in deciding about participating in a murder and secretly changing sides. A value of −1 represents maximum hostility, 1 represents maximum loyalty.
	- 1 < Attitude toward other family < 1: becomes effective in deciding about participating in a murder and secretly changing sides. A value of −1 represents maximum hostility, 1 represents maximum loyalty.
	Family: each Mafiosi belongs to a family.
Soldiers	Gradually forget territorial norm.
	Evilness: denotes anger about norm violation by other families.
Capos	*Capos*: may take role as head of Cupola (random)
	Threshold Income level low: becomes effective in deciding to follow self-interest. The threshold represents switching to the individual drive.
	Threshold income level high: becomes effective in deciding commitment to organization. The threshold represents switching to the normative drive.
	Response factor income high: becomes effective to increasing sanction probability.
	Response factor income low: becomes effective to decreasing sanction probability
	Number of soldiers: initial soldiers per family.
	Response factor Cupola sanction: becomes effective when reacting to Cupola sanctions. Increases probability that the capo sanctions its soldiers. Represents the degree of the normative drive.
Entities	Attributes
Cupola	0 = < Reliability = < 1. A value of 0 represents complete unreliability a value of 1 represents complete reliability.
Environment	Attributes
Territory	Space divided in territories, each family possesses fixed territory
Shops	Number of shops.

Capos:

Capos divide the sum of extorted money periodically equally between the capo of family and (all) the soldiers, i.e. the capo gets half of it, all soldiers the other half. Moreover, capos sanction their own soldiers who extort on foreign territory with certain probability. Sanction probability varies dependent on the satisfaction with the income and experience of sanctions from head of cupola (cupola response factor). The development of the sanction probability is calculated by the following rules. First the probability is drastically reduced in case that a threshold of satisfactory income is underscored.

```
IF income < Threshold Income level low
      THEN sanction probability = sanction
probability* responseFactorIncomeLow
```

However, if the income reaches again a threshold of satisfaction the probability increases again.

```
If income > Threshold income level high
   THEN sanction probability = sanction probability*
   responseFactorIncomeHigh
```

Moreover, capos react to punishment of the cupola by increasing their probability to punish their soldiers.

```
If capo gets sanctioned by cupola
   THEN sanction probability = sanction probability*
response factor cupola sanction
```

Ordinary conflict resolution

Capos:

If the territory of a family gets extorted by foreign soldiers the capo complaints at the cupola. More technically, the shop informs his capo about extortion by foreign soldiers. Then the capo informs cupola.

Head of cupola:

If head of cupola receives complaints it sanctions deviant capo. The sanctioned capo adapts its probability to sanction soldiers that extort in foreign territories. However, if capo constantly deviates the territorial norm and does not react to sanctions by cupola properly, the cupola can even decide to command an assassination as a severe sign of disapproval. This is determined by the following rule:

```
IF for one of the capos the number of unsanctioned foreign
extortions / mean unsanctioned extortions of all capos >= 3.5
      THEN Cupola commands purposeful homicide against this capo
```

Murder:

Capo who plans murder selects target. Typically a plan for murder is a sign for a deviant capo, i.e. a severe sanction. In that case a soldier of the family of the deviant capo is selected randomly. The case that capo is selected as potential victim is discussed in the section on hostile take-over.

Capo who plans a murder selects most loyal solder for execution (attitude towards own family). Murder is undertaken collectively. Note that this holds for the case that the head of the cupola is planning an assassination as well as for the case that a capo is planning a murder without permission of the cupola. First, the capo selects its most loyal soldier (with the highest value of family attitude: see submodel loyalty of the soldiers) as executor of the assassination. The soldier now has to decide whether they accept the plan and participate at the assassination or whether they denounce the plan. This is based on a two stage decision process: First it is checked whether one family is of extraordinary strength, measured by the sum of the aggressiveness of the soldiers. If the strength of one family exceeds that of the other by 1.5 the decision is in favor of the stronger family. If this is not the case the next step in the decision process is

based on a comparison of the loyalty towards the families of the victim and the aggressor, expressed in the following pseudo-code.

```
IF attitude toward own family > attitude toward family of
planned victim
    THEN plan is accepted.
IF attitude toward own family < attitude toward family of
planned victim
    THEN plan is denounced.
```

As murder is undertaken collectively, next the selected executor selects three soldiers in its friendship network and sends them a message to inform about the plan. The friends decide on accepting or denouncing the plan based on same rule. If a plan is accepted the murder is executed. All assassinator try subsequently to kill the victim and are successful with a probability of 0.6. If plan is denounced the Capo of the family of the targeted victim plans counterattack. This is revenge. Counterattack is based on same principles.

Hostile take-over:

Hostile take-over depends on a strategic plan, namely by calculating if a sufficient number of soldiers have secretly changed the sides. The following pseudo code reflects the calculation. The average loyalty (denoted by the family attitude) of the soldiers of the targeted victim family is calculated. Only if on average the attitude towards the attacking family is greater than towards the own family a capo is selected as potential victim of an assassination.

```
IF average family attitude toward own family < average family
attitude toward attacking family
   THEN
   select capo as target for killing
   ELSE
   select soldier randomly as target for killing
```

If capo is murdered a new capo is instantiated. The new capo results from a power struggle between the soldiers. Winner of power struggle is either the Soldier with most successful murderers. If this remains undecided most aggressive soldier is selected as new capo. If the new capo has a family attitude towards attacking family that is greater than its family attitude towards own family then new capo subordinates its family to the other family. In case that the hostile take-over is successful, no extortion of foreign territory takes place anymore.

4. Design concepts

Basic principles. Central ingredient of social order are social norm, in particular in the absence of a force that secures norm enforcement as Max Weber formulated: “An order will be called law if it is externally guaranteed by the probability that coercion (physical or psychological), to bring about conformity or avenge violation, will be applied by a staff of people holding themselves specially ready for that

purpose" (Weber 1972). Organizational stability is the indicator of social order in a world outside the state monopoly of violence which is (obviously) a highly deviant order from the perspective of the legal world. The hierarchical structure in which the cupola is responsible for norm enforcement is taken as indicator for organizational stability. Thus when capos start taking justice in their own hands, or just take advantage of opportunities the organization collapses. Mafia wars are taken as indicator for the breakdown of a normative order. Norms are implemented at the level of the capo agents. These face a trade-off between a normative drive and an individual drive, i.e. maximizing own benefit by taking advantage of norm violation. Attributes that balance the trade-off are: Threshold Income level low and Response factor income low that represent the individual drive. The threshold indicates dissatisfaction with personal income while the response factor indicates the intensity by which the dissatisfaction results in violation of the territorial norm. The normative drive becomes effective in the Threshold Income level high, Response factor income high (acting conversely to the individual drive), and Response to cupola sanctions which regulates the degree of effectiveness of cupola sanctions.

Scenarios: These can be described as the results of the Monte-Carlo simulation. Scenarios are not deliberately designed specific applications of a general model, but result of the systematic exploration of the parameter space. The search process in the parameter space reveals the possibility space of the model. The possibility space includes scenarios with early outbreak of war and late outbreak of war. It includes also scenarios without any war and even without homicide and three types of parameter constellations without war but with homicide. The different scenarios are characterized by different combinations of parameter constellations as described in the statistical analysis.

Emergence. During a simulation run often periods with no or only few murders are interrupted by extremely steep declines in the number of soldiers. These extremely steep decreases indicate massive killing. Such mass killing is denoted as a war: if 15 % of soldiers or more of the overall population are killed within one period, this is defined as a war. As no cognitive concept of 'being in a state of war' is implemented in the Mafiosi agents, wars are an emergent property of the model.

Adaptation. Soldiers adapt their loyalty or hostility to the families. If they perceive a family as aggressive they first become hostile against the aggressor. However, if the aggressor is perceived as stronger than the own family, or the capo of the own family as too weak because it is not able to counter the aggression respectively, they increase their loyalty towards the aggressor. They secretly change the sides. Capos adapt to the territorial norm by getting punished by the Cupola in case of norm violation.

Fitness. Fitness does not play a role in this model.

Learning. Soldiers learn not to extort in foreign territories by reacting to punishment in reaction to an extortion activity. The soldiers associate the location at which they have been punished with the activity. To avoid punishment the soldiers reduce their probability of extortion at the particular place (not with the activity of extortion in general). Thereby they learn to avoid extortion outside the territory of the family.

Prediction. In case of an attempt of a hostile take-over the attacker makes a prediction that after the murder of the capo the new capo will submit to the attacking family with a high probability as indicated by the prior calculation of the average values of the loyalty of the soldiers.

Sensing. Soldiers can perceive that they have been punished. Capos can perceive the family attitudes of the soldiers. While soldiers receive a message that they are now punished, which is explicitly modeled, capos are simply assumed to know the family attitudes of the soldiers. Moreover agents know their family affiliation and their friends and send and receive messages with plans about assassination within their friendship network.

Interaction. Agents send and receive plans, in particular with regard to assassination, but sanctioning is modeled as sending a message as well. Soldiers collect extortion money and hand it over to their capo. The capo distributes the money among its family. Moreover assassination is an action of one agent imposed on another one, whereas the collective activity of assassination is modeled as sequential individual acts.

Stochasticity. Stochastic processes are random walk of the soldiers, extortion, sanctioning (both sanctioning of soldiers by the capos and sanctioning of capos by the head of cupola) and murder.

Collectives. Mafiosi belong to a family. Moreover, the cupola is a separate entity, however, modeled as represented by an individual capo which takes the role of the head of the cupola. The collectives are not emergent.

Observation. Output data of the model are:

- Period of the first homicide
- Number of periods with homicide
- Mean number and the variance of homicides per period, as well as the minimal and maximal number of homicides per period
- Proportion of revenge homicides
- Number of wars
- Period of first war
- Period of last war
- mean periods between wars
- Total number of sanctions by cupola

5. Initialization

For systematically exploring the parameter space, initialization of the model follows the strategy of a Monte-Carlo simulation. 2000 runs were undertaken (with each simulation running 600 periods). Initialization of the parameter was varied within the range plotted in Table 2 for exploring the parameter space of the model. This is recapitulated here.

Variable	Range of variation
Number of families	9
Attitude toward own family	Normal distribution with Uniform distribution of mean (0.5. . 0.9) Standard deviation 0.05
Attitude toward other families	Normal distribution with Uniform distribution of mean (0.2. . 0.5) Standard deviation 0.1
Multiplier income low	Uniform distribution (0.2. . 0.8)

Variable	Range of variation
Multiplier income high	Uniform distribution (1.5. . 2.5)
Cupola sanction response factor	Uniform distribution (1.05. . 2.5)
Threshold income high	Uniform distribution (600. . 2500)
Network size	Uniform distribution (1. . 5)
Shop capability	Uniform distribution (100. . 500)
Number of shops	Uniform distribution (100. . 1500)
Number of soldiers	Uniform distribution (10. . 130)

6. Input data

The model does not use input data to represent time-varying processes. Note that 'Input data' does *not* refer to parameter values or initial values of state variables.

7. Submodels

Loyalty of soldiers

Loyalty (or hostility) to a family (denoted as 'Family Attitude') can have a value between −1 (maximum hostility) and +1 (maximum loyalty). The value changes during a simulation run. Note that further increase is cut in case that the family attitude reaches – 1 or +1. Change of loyalty is triggered by extortion of foreign soldiers in the own territory. This increases a parameter denoted as 'evilness' by 0.3, representing the outrage.

```
IF unsanctioned foreign extortion
   THEN evilness = evilness + 0.3
```

This is of consequence for the attitudes of the soldiers toward the Mafia families. However, the effect is two sided: The threshold is a degree of 'evilness' of >0.5, i.e., two or more unsuccessful complaints of their capo. If 'evilness' remains below the threshold, the family attitude toward attacking family decreases by −0.1, i.e. soldiers are slightly angry at the attacking family.

```
IF evilness =< 0.5
THEN FamilyAttitude(Attacker)=FamilyAttitude(Attacker)-0.1
```

By each tick, the 'evilness' decreases by 0.995 (i.e., the outrage gradually fades away) to represent that foreign extortion that happened long ago gets forgotten. However, if the value of the 'evilness' variable increases beyond the threshold of 0.5 the change of attitudes switches. Now the own family is perceived as too weak and the soldiers gradually sympathize with the attacker.

```
IF evilness > 0.5
THEN FamilyAttitude(Attacker)=FamilyAttitude(Attacker) +
0.1
```

Only by an act of exemplary violence the capo can resume loyalty of its soldiers.

```
IF murder (ownCapo) successful
   AND FamilyAttitude < 1
      THEN FamiliyAttitude(own) = FamilyAttitude+0.6
```

Furthermore loyalty is influenced by a history of common violence. Participating at a successful murder increases the familyAttitude of the participant soldier agent towards the family that commissioned the murder by 0.5 (until the maximum value of 1 is reached).

Authority of cupola

The authority of the cupola is reflected in the reliability of the actions undertaken by the head of the cupola. This does not reflect strategic manipulation of the role of the head of the cupola (as the Corleonese did in course of the second Mafia war). However, it does reflect that the cupola is not – at least not always – a neutral party that stands above the interests of the individual families.

```
0 =< Reliability =< 1
```

The reliability is taken into account in the execution of the sanctioning activity of the head of the cupola.

```
IF random < Reliability   THEN sanction
```

Thus only in case of reliability =1 the cupola will always sanction deviant capos. Even more, the cupola may also undertake unjustified violence.

```
IF random > Reliability
   THEN plan murder random Capo (by Cupola)
```

Thus, modes of conflict resolution exist but are not perfectly even handed. In case of an unjustified assassination, the authority of the Cupola is damaged. Consequently, the other capos are less likely to follow the directions of the Cupola, i.e., the Cupola sanction-response factor decreases. This is translated in the following rules:

```
IF plan murder random Capo
   THEN response to Cupola sanction (i+1) = response to
   Cupola sanction (i) - (response to Cupola sanction (i) -
   1)*0.5
```

Since response to Cupola sanction is a value >1, the term subtracted on the right-hand side of the equation is always greater than 1. However, since it is multiplied by 0.5 it is smaller than 'response to Cupola sanction(i)'. Thus, 'response to Cupola sanction(i + 1)' is decreasing. Only in the case of appropriate actions does the authority of the Cupola gradually increase again. This is realized in the following formula:

```
IF NOT Cupola (plan murder random Capo)
   THEN response to Cupola sanction (i + 1) = response to
   Cupola sanction (i) + initial (response to Cupola sanction
   – response to Cupola sanction (i))*0.2
```

Since the initial 'response to Cupola sanctions' is always greater or equal to its value at time i, the second term on the right-hand side of the equation approximates 0 when the authority of the Cupola is recovering. Therefore, the overall value of the response to Cupola factor approximates its initial value.

However, reliability of the Cupola is not constant. In case of tensions, it is lower than in times of smooth operations of the organization. Tensions are simply represented as extortion in foreign territories that are not effectively suppressed by sanctions. These are denoted as unsanctioned foreign extortion, which is destabilizing social order within the organization. In turn, decreasing or increasing social order decreases or increases the reliability of the Cupola. For this reason, a social order index is constructed, which determines the change of the reliability. The social order index simply measures the average unsanctioned foreign extortions over time. The complex muddle of conflicting actions and (alleged) 'signs' is represented by a mathematical abstraction.

```
SocialOrderIndex (i) := avg (unsanctionedForeignExtortion at
period (i))
SocialOrderIndex (9+1):= avg (unsanctionedForeignExtortion at
period (i+1))
```

Change of social order from period i to period i + 1 can be represented as a curve with positive or negative gradient, denoted as α, constructed by the following formula.

```
α(i+1) = SocialOrderIndex (i+1) – SocialOrderIndex (i)
```

This determines the change of the reliability of the Cupola, to represent that the Cupola is more effectively controlling the organization in more relaxed times.

```
Reliability (i+1) = Reliability (i) – tangH (α/5)
```

Note that α can be positive or negative, tangH is a normalizing factor. Thus reliability may increase or decrease. In case 0 or 1 is reached, reliability remains at this value.

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