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Can agent-based simulation models replicate organised crime?

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Abstract The aim of the paper is to discuss the possibility of using complex software agents in a simulation model in order to represent and analyse the dynamics of certain types of criminal systems via Agent Based Modelling (ABM), in particular Extortion Racket Systems (ERSs). It presents a simulation model and the results of a large number of runs to find out under which parameter constellations governing the normative behaviour of the software agents the model replicates the macro observations in a number of provinces in Southern Italy. Finally the simulation model is applied to analysing strategies and their effect on the behaviour of the agents and the system as a whole.

Keywords Extortion rackets · Norms · Deliberative agents

Introduction: simulation as a deductive approach

Simulation means deducing macrostructures from microspecifications with the help of computer programs where it is impossible or extremely difficult to do such a deduction with classical mathematics. In a way this methodological approach in sociology can be described paraphrasing a quotation from Max Planck in 1930:

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"The researcher, in confidence in the lawfulness of the *social* world, forms a system of terms and sentences, the so-called *computational sociologist's* world view, which he endows to the best of his knowledge in order that it — put in place of the real world — should send him — if ever possible — the same message as the real world would send." (Planck 1949, p. 235, my translation, the italicised words replace Planck's respective wording). The question remains how one can check whether the simulation model of an extortion racket system — "a system of terms and sentences" *in some appropriate programming language* — sends "the same message as the real world would send" in the form of, for instance, criminal statistics, police and judicial documents or surveys trying to find out more about the values and norm valuations of the society and about security and crime related attitudes of citizens or entrepreneurs in their role as potential victims of extortion.

The paper continues with a short discussion of three types of validity and validation, continues with a sort description of the underlying simulation models and of the empirical data used for both parameterising the model and comparing its output to the "message as the real world would send". The central section is devoted to this comparison, and a final section uses the simulation model to assess strategies to fight mafia-like organisation and to reduce their success.

Types of validity

With Zeigler (Zeigler 1985, p. 5) we should distinguish between three types of validity and three different stages of model validation (and development):

replicative validity: the model matches data already acquired from the real system (retrodiction),
predictive validity: the model matches data before data are acquired from the real system,
structural validity: the model "not only reproduces the observed real system behaviour, but truly reflects the way in which the real system operates to produce this behaviour."

It is obvious that stages one and two are quite easily reached: if a simulation model of a social system is used to derive theses about macrostructures from micro specifications data from the past about distributions of individual variables or about macro effects are usually available, and a fortiori this also holds for data in the future whose collection can than be guided by the simulation results. Stage three is usually more difficult to achieve as in the realms of nearly every disciplines micro data are more difficult to collect, or they are — and this is the special problem of the social sciences — not observable at all as humans are often not sure about their inner states, and if they are they are often not willing to reveal them, an effect which is particularly important for crime-related attitudes and is relevant both for victims and offenders.

Hence this paper will have to give answers to the following questions:

1. What kinds of empirical data are available to design a model of mafia micro behaviour?

2. What kinds of empirical data are available to compare simulation output to empirical macro data?
3. Can structural validity of an agent-based model be achieved at all (when even the real actor often cannot tell how he or she "operates to produce [his or her] behaviour")?
4. Can we evaluate strategies and interventions with the help of an agent-based simulation model?

Question no. 4 goes a little beyond the validity issues discussed above, as it even supposes that the model, when it is used to assess strategies, has already been validated. On the other hand, if the results of simulated interventions are in line with empirical evidence this could be an additional argument for believing that the model is valid — or, to resume Max Planck's considerations: "As far as researchers succeed [in getting messages from the model as the real world would send] they may, without having to be afraid of a matter-of-fact refutation, claim to have recognised one aspect of the real world although such a claim can, of course, never be directly proven." (Planck 1949, p. 235).

The Palermo scenario model

Structure of the model

The version of the mafia models which this paper uses for its argumentation[1] represents a fictitious region whose economy simply consists of

- a number of firms (of any kind),
- a number of people consuming the goods and services (of any kind) of these firms (and supplying these firms with goods, services and staff),
- persons who engage themselves in extortion rackets, asking the firms for extortion money (≪*pizzo*≫) and eventually punishing them when they refuse to pay,
- police officers who observe criminals whose earlier deeds were recorded and/or who were reported by their victims or by rueful accomplices (≪*pentiti*≫) and
- a court which can sentence criminals to jail terms of a number of years.

To be a little more precise: each run of the model represents such a virtual region and describes what could have happened in a real region described with the parameters and initialisations of this run.

[1] An earlier version of the NetLogo version can be found at http://ccl.northwestern.edu/netlogo/models/community/NOERS. The code which is currently used for this paper has some additional features for searching the parameter space and for outputting additional metrics as well for injecting interventions. The mechanisms for the agents are the same as in the published version. The version used in (Nardin et al. 2015) differs from the NetLogo version (which was originally designed as a rapid prototype) in so far as the former uses an event-orientation whereas the latter is period-oriented; besides there are only minor differences.

Depending on the type they belong to, agents know certain norms related to extortion, and these relate to the actions they are able to take. Actions and norms are listed in Table 1.

Agents of all types keep a memory of several types of norm invocations (separate for each norm they know) directed to themselves and others and of observations of norm compliances and violations, sanctions and punishments, where the theoretical background is derived from Cialdini's littering experiment (Cialdini et al. 1990). These norm invocations are counted in the agents' memories, and the counters are used to calculate the salience of the norm to which the invocations apply and which are used to decide which action to take. This calculation is done using equation 1 (Troitzsch 2015b; Andrighetto et al. 2013)

$$\sigma = \alpha\left(\beta + \frac{C-V}{C+V}w_c + \frac{O_c - O_v}{O_c + O_v}w_o + \frac{\max(0,(O_v+V)-P-S)}{O_v+V}w_{npv} + \frac{Pw_p + Sw_s}{\max(P+S, O_v+V)} + \frac{E_c - E_v}{E_c+E_v}w_e\right) \quad (1)$$

where

- C and V are counters for events when the agent itself complied with the respective norm or violated it, respectively,
- O_c and O_v are counters for events when an agent observed another agent which complied with the respective norm or violated it, respectively,
- P and S are events when an action was punished or sanctioned, respectively,
- E_o and E_v are events when an agent explicitly invocated the respective norm because of a compliance or a violation, respectively,
- w_c, w_o, w_{npv}, w_p, w_s and w_e are the weights for the six factors ("norm cues") derived from Cialdini et al. (1990) and defined in Andrighetto et al. (2013) (see also Andrighetto and Castelfranchi (2013)), namely *own norm compliance / violation*, *observed norm compliance / violation*, *non-punished violation*, *punishment*, *sanction* and *explicit norm invocation* where these factors are calculated from the counters listed above, and
- α and β have to be chosen dependent on the weights w_c, w_o, w_{npv}, w_p, w_s and w_e in a way that $0 \leq \sigma \leq 1$.

Table 1 Agents' actions and norms

Agent	Action	Norm	
Type		Traditional	Civic
Public	Shop selection	Buy from pizzo-payer	Buy from addio pizzo shop
Entrepreneurs	Denunciation	Denounce	Do not denounce
	Peaction on menace	Pay extortion	Do not pay extortion
Extorters	Confession	Do not betray accompices	Abjure crime
Police	Prosecution	Save your life	Try hard to imprison

The final propensity to act is a weighted mean of the salience of the respective norm and a so-called individual drive which depends on the utility of the action. The calculation of this utility-dependent individual drive is different for each norm and for each agent type; for the norm *denounce* relevant for the entrepreneurs this is, for instance, (1 - *percentage-of-undetected-cases*) × (*percentage-of-cases-with-punishment*) + *percentage-of-critical-consumers*, hence taking account the chance that an extortion will be punished and the public opinion in favour of an extortion-free society. As an extension of the model one might think of an element in the calculation of the individual drive which depends on the information the victim has about the offender actually approaching it.

Parameters of the model and sensitivity analysis

The theoretical terms and concepts underlying the model are mainly about individual normative drives and behaviours which can in principle be measured in questionnaires (quite successfully in marketing research and in election research, but not in our field) or in laboratory or field experiments (also quite successfully in the fields mentioned, but not in this field). The empirical background (documents) which were used for micro theorising are individually reliable but not necessarily representative (as if one had asked a handful of voters for an election research study). On the other hand there are theoretical concepts on the macro level which are obviously related to the theoretical concepts on the micro level; the latter — particularly the weights in the normative salience formula — are not extremely well founded. Macro level variables can easily be measured as they leave their traces in publicly available documents (quite easily found in election research, less easily in marketing, as firms want to keep data like these secret, but also easily, but less reliably found in criminal statistics and our Palermo data base).

This leads to the following enumeration of the main parameters of the model (these are constant within a run, and their values are randomly selected from the distributions reported below[2]):

discount: the degree to which older information is discounted: before adding additional messages to the counters enumerated above the counters are multiplied with a number uniformly distributed between 0.8 and 1.0,

locality: the distance within which norm compliances and violations can be observed: a number uniformly distributed between 2 and 10,

normative drive weight (*ndw* in Table 2): a number uniformly distributed between 0.3 and 0.7,

background of the public (traditional to civic): the initial values of all the counters, a number uniformly distributed between -10 and 10; -x means that all counters for norm invocations in favour of a traditional norm are set to 10 whereas all others

[2]In earlier runs the range of the input parameters was even wider but it turned out that outside the narrower ranges reported bemow the correlations between input parameters and output metrics decreased substantially. This applies to locality, too, implying that norm invocations from far away (as if transported by the mass media) have no significant additional effect.

Table 2 Squared correlation coefficients and standardised regression coefficients between input parameters and output metrics

Output metric	R^2	Standardised regression coefficients			
		Discount	Locality	ndw	Background
Undetected	0.489	n.s.	−0.079	−0.217	−0.659
Completed	0.651	n.s.	−0.056	−0.137	−0.793
Unreported	0.555	n.s.	−0.078	−0.202	−0.713

n.s.: not significant, excluded from the regression

are set to 0, +x means that all counters for norm invocations in favour of a civic norm are set to 10 and the others are set to 0.

On the other hand, the most important output metrics of the model are the percentages of undenounced or unreported (as contrasted to denounced) extortions and the percentage of completed or successful (as contrasted to only attempted and hence unsuccessful extortions), as only these — see below — can be compared to the main source of aggregate empirical data.

The parameters explain between about 50 and 65 per cent of the variance of the output metrics, see Table 2 with squared correlation coefficients and standardised regression coefficients. It is easily seen that the parameter called background is responsible for the greater part of the variance reduction, as (for the percentage of undetected extortions, for the other two metrics qualitatively the same holds) this parameter alone yields an R^2 of 0.630, whereas the two others contribute another 0.018 and 0.003 whereas the contribution of the discount or forgetfulness variable is not significant at all. The "undetected" or dark figure output metric was included in Table 2 just for completeness although there is no chance for empirical validation — which, as one will see later, makes empirical validation difficult.

The discount or forgetfulness does not play a significant role (at least not in its range between 0.8 and 1.0, but 0.8 seems low enough, as in this extreme cases messages three steps back in the list of received messages have already lost one half of its power), and how far an agent can send or receive messages plays only a minor role, and the role of the weight of norm as contrasted to utility is also quite weak. Hence the model is a model in which norms, formal and informal, play a major role (but it is interesting to see that a simpler version of the same model — namely one without norm learning and depending only on constant propensities to take this or a contrasting action yields very similar correlations between the two main output metrics (see Troitzsch 2015a, b).

Empirical data available to design micro behaviour

For designing the microspecification of the simulation model the following sources were used:

Stylised facts and anecdotal evidence from the literature: There is a plethora of historical and biographic material describing the history of the mafias in Southern Italy describing the influence of social norms on the individual behaviour of criminals, victims, the pubic and the police (Catanzaro 1998; Dickie 2007, 2013; Gambetta 1993; Lupo 2004; Palagonia 2009; Reski 2013; Varese 2013).

Interviews with stakeholders: During the GLODERS project a number of persons involved in fighting the mafia in Italy were interviewed, and the information collected during these interviews went into the design of the simulation model in its various consecutive versions. These, as well as the evidence from the literature are documented in (Militello et al. 2014, Subsection 3.3), (Neumann et al. 2014, section 4) and (Andrighetto et al. 2014, subsection 3.2).

Sicurezza dei cittadini (ISTAT 2008): This survey carried out by the Italian National Institute for Statistics in 2008 (Istituto nazionale di statistica) (for the third time after 1997 and 2002, the 2015/2016 wave is not yet available) asked 60,000 households for their experience with crime, among them menace and extortion, but not explicitly for their experience with mafia-related crime. 2,187 respondents reported that they had suffered from crimes similar to the latter (namely menace — section 10.A — and assault or aggression — 10.B —), but among them were a number of persons who would not become victims to typical mafia extortion (subordinate employees or persons who are neither employed nor self-employed) or persons meanced or offended by relatives or close or loose acquaintances (although one cannot exclude that ≪una persone che conosceva di vista≫ was a mafioso), such that all over Italy only 214 remain, of which 90 (or 42 per cent) in Puglia, Calabria and Sicily and 120 in the rest of Italy (whereas these three regions have only 18.4 per cent of the total population of Italy). The denunciation rate in the three provinces in Southern Italy was 22.2 per cent whereas in the rest of Italy it amounted to 14.5 per cent — which is an indicator that a high prevalence of this kind of crime co-occurs with a higher denunciation rate, but the difference is not statistically significant ($\chi^2 = 2.121, \alpha = 0.145$).

European Value Study (2008): This study (EVS 2008) deals with value orientations all over Europe. Among the questions relevant to mafia-related crime there is a group of items dealing with norms or values which people find important enough to teach their children.[3] Obedience and responsibility are the ones which could be used to estimate the importance of *omertà* related values in different parts of Europe and of Italy. The percentage of respondents counting obedience (and not responsibility) among the five most important values is highest in Southern Italy and the Islands and lowest in Baden-Württemberg and the Netherlands (the latter two were taken for a comparison as they are the regions from which the two separate case studies mentioned below were taken). The percentages of

[3]The question (Q62) was "Here is a list of qualities which children can be encouraged to learn at home. Which, if any, do you consider to be especially important? Please choose up to five!" In a factor analysis it turned out that "obedience" loads the same factor as "religious faith" with a positive factor loading whereas "independence" and "feeling of responsibility" have a high negative loading on the same factor. This justifies to qualify this factor as a dimension "traditional" — "civic".

those who count responsibility (and not obedience) among the five most important items have exactly the reverse order. This is an empirical hint at the importance of a rather traditional norm — and the unimportance of a more liberal, civic norm — in Southern Italy. The number of interviewees in Southern Italy and the Islands is (with 531) large enough to differeniate between the regions (mainly Calabria with 69 and Sicily with 124 respondents), but unfortunately not between the provinces. Anyway, a difference between these two regions is significant on a level of 0.007 (measured with χ^2) showing that people in Calabria plan to teach their children both norms with a much higher frequency than those in Sicily whereas the latter believe that other norms are more important than these two (see Table 3).

Eurobarometer 79.1 (2013): This Eurobarometer (Commission and Opinion 2011) is the only survey so far which deals with crime similar to mafia-related cases, but deals mainly with corruption. For this kind of crime a few questions (QB5 to QB14) were asked: From the sparse data available on the problem of the relation between falling victim to a crime such as bribe request and denouncing this attempt one can conclude that the prevalence of corruption (QB5) and the readiness to denounce are negatively correlated, at least where the prevalence is high. In general the number of respondents in Italy was only 1,021, hence differences within Italy are only exceptionally significant (with the exception of the percentage of respondents who said they had reported a case of corruption after they had experienced one — QB13 —, in Northern Italy these were 7 out of 19 or 35 per cent, whereas in Southern Italy and the Islands this was one out of 23 or 3.2 per cent; and in spite of the small subsample this was significant with a Pearson χ^2 and $\alpha = 0.006$). The belief in the prevalence ("very widespread") of corruption in the respondent's own country is much higher in Italy than in the rest of EU15 (26.7 per cent) or EU27 (45.2 per cent): this percentage reaches 51.7 per cent in Northern Italy (for the definition of "Northern Italy" see Table 3) and even 70.0 per cent in Southern Italy and the Islands, where the latter two differ with a χ^2 of 31.161 and

Table 3 Most important values in Northern and Southern Italy

		Importance of obedience(v173) and responsibility (v180)				N
		Both items	only Responsibilty important	only Obedience	Both items unimportant	(weighted)
Northern Italy	%	22,6	62,9	6,1	8,4	704
Southern Italy and Islands	%	29,9	51,0	7,9	11,1	531
of which: Calabria	%	39.1	52.2	7.2	1.4	69
Sicily	%	21.8	54.8	9.7	13.7	124
Rest	%	30.9	49.4	7.4	12.4	340

Northern Italy (NUTS 380012 and 380013) comprises the regions Piemont,Valle d'Aosta, Liguria, Lombardia, Alto Adige, Veneto, Friuli-Venezia Giulia and Emilia Romagna), Southern Italy and the Islands (NUTS 380015 and 380016) comprises the regions Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia and Sardegna.

$\alpha = 0.000003$. On an individual level the correlation between the belief of corruption prevalence and readiness to denounce is not significant but mainly due to the fact that both distribution are fairly skewed. The finding that the perceived prevalence of a crime — here: corruption — is negatively correlated with the reported readiness to denounce seems to contradict the finding reported above from the Sicurezza dei cittadini Survey, but first of all the latter was not statistically significant, and the Eurobarometer was about the question whether the respondents thought that corruption was widespread in their country whereas Sicurezza dei cittadini asked for personal experience and involvement in (a slightly different) crime. And the finding from the Eurobarometer is also supported by the findings of the Progetto PON Sicurezza 2007–2012 (Progetto Programma Operativo Nazionale Sicurezza 2013, p. 351)

Sicilia and Calabria Extortion database: This database established during the GLODERS project by the Palermo team contains case-related data mainly from police and judiciary files in Sicily and Calabria and a few from newspapers (630 cases with detailed descriptions of what happened), http://dx.doi.org/10.7802/1116. Details in these cases could be used to determine the amount of extortion money or equivalent requested and the propensity of victims to refuse, to connive or to acquiesce.

Beside these, the complete documentation of two cases of extortion and of money laundering in the Netherlands and in Baden-Württemberg, Germany, could be used to get information about individual behaviour.

The overview of the empirical evidence which could be used to design, to parameterise and to initialises shows that the available data are not very strong, particularly if individual data — microspecifications — are at stake.

Empirical data available to compare to macro simulation results

Empirical data

On one hand, several national and cross-national surveys discussed in the previous section yielded distributions of extortion, crime and mafia related attitudes on an individual level, although no attitudes directly related to extortion rackets of the mafia type were available. This is also true for the aggregate level (provinces, regions), but additionally these aggregate data derived from the surveys discussed above are based on relatively small numbers such that parameters can not reliably be estimated.

The only exception is the Sicilia and Calabria Extortion database from which some aggregate data on the level of provinces in Sicilia and Calabria can be derived — both the official provinces of the Italian state and the "provinces" of the mafias. The variables of this database which lend themselves to being quantitatively compared to simulation output metrics are mainly those which measure the proportion of different extortion types per province, distinguishing them along the contrasts

1. denounced by the victim / observed by the police,

2. attempted and refused by the victim / completed and hence successful from the point of view of the extorter,
3. arrested by the police or escaped
4. convicted by a court or acquitted (if arrested at all)

A fifth contrast is empirically unavailable, namely the contrast between detected by the police and never detected, as there is always a 'dark figure of crime' in this criminal category — unlike murder or arson of which the investigative forces usually get nearly perfect knowledge (although even here the criminals might not be identified in the end). Unfortunately the database contains a high number of missing data with respect to the contrasts no. 3 and 4: 249 out of 631 cases do not have information about what happened to the (known) extorters, and unfortunately even more this is true for nearly all cases from two key provinces, namely Palermo and Reggio Calabria which together yielded nearly one third or all cases; hence one could only compare the provinces of Agrigento (81 cases, all with known outcome), Catania (110 / 108), Messina (87 (87) and Siracusa (60 / 60) as well as Trapani (42 / 25, but the number of cases in this provinces is too small to yield reliable estimates). Apart from this deficiency the database covers the territory of the two regions in a fairly representative manner (see Fig. 1) — that most of the cases represented in the database stem from the coastal zone is due to the fact that these are the more densely populated regions in which extortions more often occur than in the less densely populated center.

The distribution of the contrasts mentioned above can be found in Table 4 and in the right-hand diagram of Fig. 3.

Simulation output

The simulation model yields a plethora of output metrics, mainly because simulation models never contain unobservables (as reality does): At every time step one can

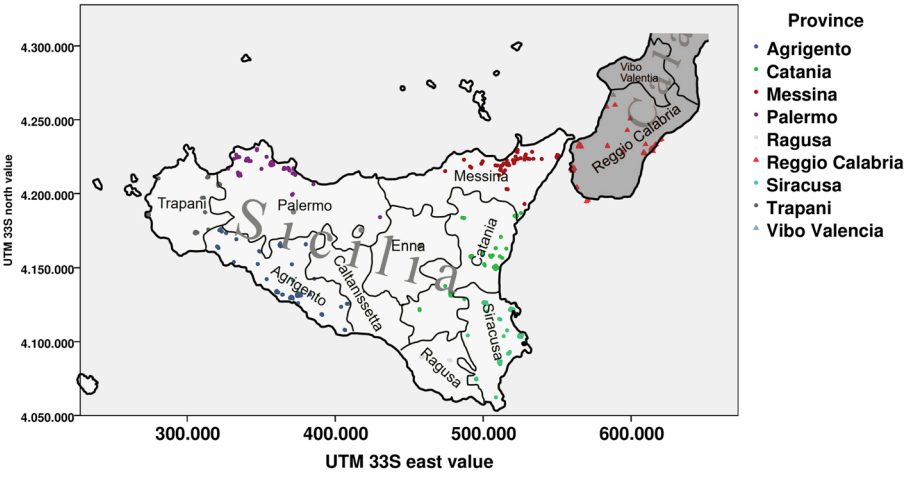

Fig. 1 Geographical distribution of the extortion cases documented in the Sicilia and Calabria database

Table 4 Distribution of different kinds of extortion cases in the provinces of Southern Italy (in per cent)

Province	undenounced[a]	completed	arrested	convicted	N
Agrigento	71.6	63.0	3.7	95.1	81
Catania	76.4	84.5	0.0	92.6	110
Messina	75.9	75.9	0.0	100.0	87
Palermo	82.7	67.2	MD	MD	139
Ragusa	100.0	86.7	0.0	100.0	15
Reggio Calabria	76.0	67.5	MD	MD	87
Siracusa	86.7	83.3	0.0	100.0	60
Trapani	76.2	33.3	0.0	57.1	42

[a]"undenounced" refers to cases where the police detected the extortion without a formal charge brought forward by the victim.

The cases missing from the sum of 631 stem from other provinces with only one or two documented cases.

measure distributions of saliences and individual attitudes, count actions over time and show trajectories of output metrics over time. The user interface of the NetLogo model shows a wide variety of these, both numerically and in diagrams, but most of these can only be used for something like a "verification" of the model, i.e. the check whether the simulation program performs as it is expected to perform, "examining the model output for reasonableness under a variety of settings of the input parameters" (Al-Aomar et al. 2015, p. 314), as empirical data which can be compared to simulation output are only exceptionally available for the reasons discussed in "Empirical data available to design micro behaviour" and "Empirical data" section.

The simulation model produces a list of extortion cases in a structure similar to the Sicily and Calabria database (see Table 5). This can be compared to empirical database, and one can determine under which input parameter settings the model

Table 5 Extortion database (simulated and empirical)

Case no	Time	Victim	Extorter	Denounced	Successful	Amount paid	Punishment	Arrested	Convicted
1	0	119	163	no	no	0.00 €	0.00 €	no	no
2	0	111	154	yes	yes	1,514.22 €	0.00 €	yes	no
3	0	132	151	no	no	0.00 €	0.00 €	no	no
4	0	92	179	no	no	0.00 €	0.00 €	no	no
	N.	nome estorto	nome estorsore	presenza di dinuncia				ripercussioni	
	37	D.R.	S.G. e al.	sì	Tentata	Importo non meglio specificato		Arresto in flagranza dell'estorsore	
	38	M.V.	G.	no	Tentata	Importo non meglio specificato			
	39	DM.P.	L.C.	no	Consumata	2500 € al mese			

produces output whose contents is similar to the empirical database or parts of it (selected cases for one province, for instance). But given that one will have hundreds or even thousands of such simulated databases one would first try to find out whether the model produces output which is quantitatively similar to the empirical data.

Comparison: simulation vs. empirical data

This quantitative comparison is most comfortably done by analysing the multivariate distributions of simulation runs with their input parameters and output metrics and trying to find out whether the Italian provinces under observation are realisations of this stochastical universe. The stochasticity of the simulation output comes from two sources, first of all the initialisation of the virtual worlds with their input parameters and of all kinds of agents with their regional locations in the virtual geography and with their initial norm invocation counters and second the actions which the individual agents take after calculating their propensities to take this or an alternative action — which is then converted into a probability, and a pseudo-random experiment decides which action will be actually taken. In a way, each run of the simulation model generates the history of a virtual region (or: province) with its initial condition and its stochastic changes.

Hence the model will produce a wide variety of outcomes, for instance, measured with the two percentages of undenounced and completed extortions and thus reduced to a manageable dimension.

Figure 2 shows the joint distribution of the percentages of unreported (x) and completed (y) extortions along the two axes together with the background parameter represented with colours[4] and showing the high reduction of variance of the former after regression on the latter. The high correlation between the two output metrics is also shown, but their relation is obviously nonlinear. It follows equation 2 if one includes all runs in which nothing happens at all.

$$y = x^{0.979}(1-x)^{0.244} \qquad R^2 = 0.940 \tag{2}$$

If one excludes those runs in which extortions do not occur (exclusively for civic backgrounds) equation 3 follows which is more or less the same as with these runs included, but with a slightly smaller variance reduction.

$$y = x^{0.978}(1-x)^{0.244} \qquad R^2 = 0.867 \tag{3}$$

The residuals are not normally distributed, thus the usual calculations of confidence intervals do not apply. As the left diagram in Fig. 3 clearly shows the joint distribution of the two output metrics (for this diagram they were rounded to the nearest multiple of 0.05) is bimodal, hence it is difficult to decide whether the empirical percentages in the seven provinces marked in Fig. 2 lie within the 95 per cent confidence region. For Agrigento and Trapani the residual evaluates to 0.0995 and 0.2071, respectively, for the other five provinces they are even larger such that one would not

[4]Earlier work with the model (Troitzsch 2015a, b) showed that the input parameter *background* makes a difference for the two output metrics mainly in the region between -10 and 10, this paper reduces the range of this parameter to this narrower interval.

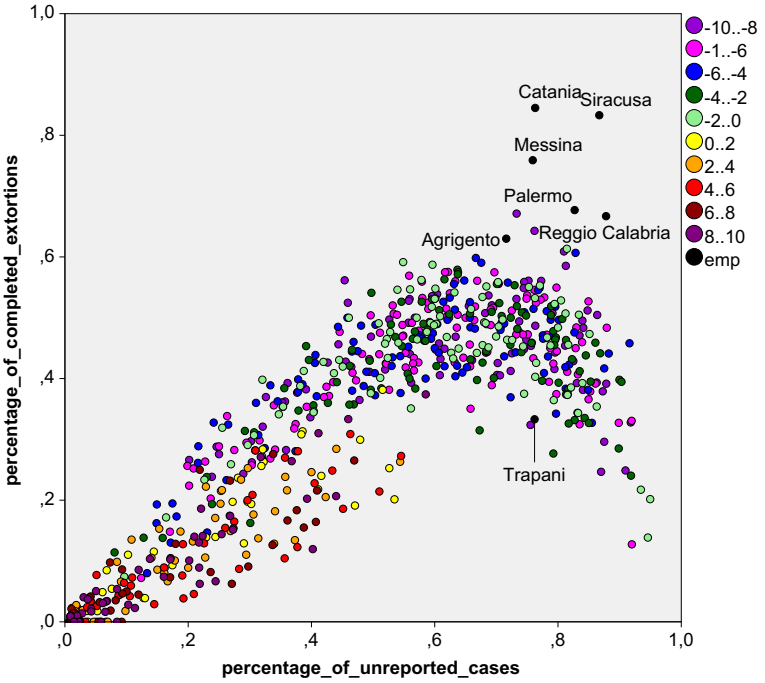

Fig. 2 Simulated virtual provinces and real provinces

assume that they are within this confidence region. To be able to evaluate this in more detail, the frequency density function was estimated as the exponential function of a polynomial up to the fourth order (a more accurate approximation to the true frequency density function), and this is shown in Fig. 3 (right diagram): again the joint

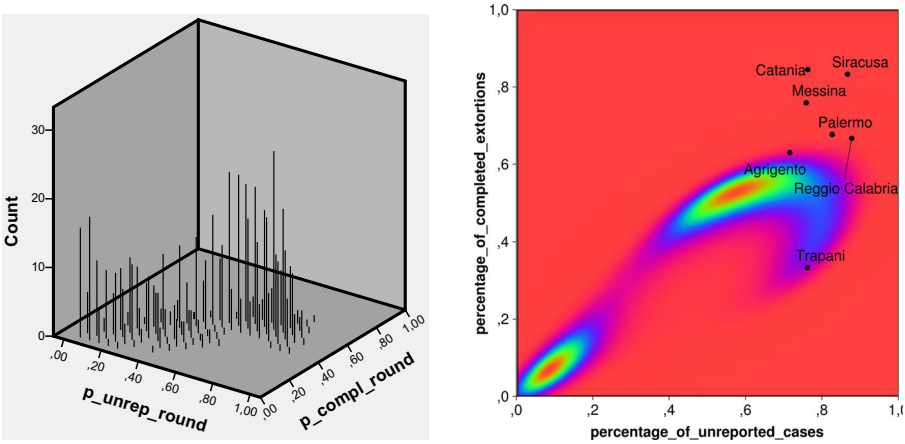

Fig. 3 Approximate frequency density function of the joint distribution of of the percentages of unreported(x) and completed (y) extortions

distribution is bimodal. Hence obviously the simulation model produces two different kinds of outcome (apart from the case that no extortions happen at all). These are shown with their main characteristics in Table 6.

From Table 6 it becomes clear that runs similar to the Sicily and Calabria database will have been initialised with a traditional background, but the empirical provinces still have a higher percentage of undenounced and of completed extortion than the model predicts, perhaps with the exception of the provinces Agrigento and Trapani whose representative points in the right diagram of Fig. 3 are at least in the magent zone of the frequency density function of the joint distribution of the runs. This means that there is a tendency that the model could predict even the extreme cases of Southern Italy, but only with some modifications which will have to be added to it. The model described in Nardin et al. (2015) performs better as it delivers a point prediction for the province of Palermo (but not for the other provinces either).

The case that among the runs classified as "lower" in Table 6 there are still some with a traditional background and that among the runs classified there as "upper" there are some with a civic background is a hint at some path dependence: The current version of the NetLogo model generates more or less extortion-free runs in a traditional virtual society and on the other hand also runs with a lot of undenounced and / or completed extortions in a modern or civic virtual society. This could already be seen in Fig. 2, but this scattergram did not show the saddle point between the two frequency maxima which are much more clearly visible in Fig. 3. To get a deeper look inside the history of such typical and untypical runs, four runs were selected with background parameter values near the most traditional ones (about 9.9) and near the most civic (about -9.9), and their histories were plotted (Fig. 4).

These four sample runs can be described as follows:

orange was initialised with civic values, i.e. all agents had about 10 norm invocations in their memory in favour of civic norms (denounce extortion, do not pay, do not buy from ≪*pizzo payers*≫, ...) and experienced only few successful extortions (less than 20 per cent of all attempts) during the first five periods; in this virtual society the percentage of undenounced extortions remained low (less than 40 per cent), and the percentage of successful extortions remained low, too;

green was also initialised with civic values, but this society happened to experience nearly 40 per cent of successful extortions during the first five periods; in this

Table 6 Characteristics of the run types derived from Fig. 3

Type	Parameter	Background	Unreported	Completed	Runs
Lower	mean	0.2700	0.2035	0.1808	
	sd	5.7587	0.0922	0.1024	217
Upper	mean	−4.1863	0.6113	0.4816	
	sd	3.9672	0.1359	0.0925	433
	η^2	0.171	0.710	0.697	650

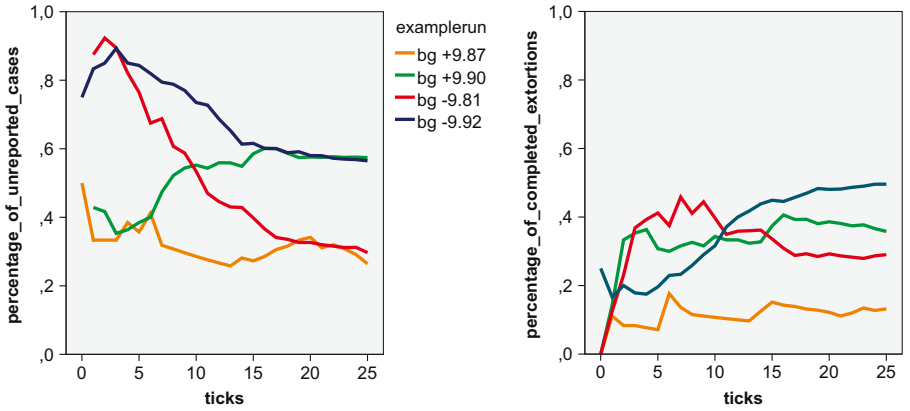

Fig. 4 Trajectories of four sample runs

virtual society the percentage of successful extortions remained high with about 40 per cent of all attempts, and the reluctance to denounce increased to nearly 60 per cent;

red was initialised with traditional values, i.e. all agents had about 10 norm invocation in their memories in favour of traditional norms (do not denounce, pay, buy from ≪*pizzo*≫ payers, ...), and experienced many successful extortions during the first five periods; in this virtual society the percentage of successful extortions decreased, and the same happened (even more drastically) to the percentage of unreported extortions — as if the early high prevalence of completed extortions converted this traditional society to a more civic one;

blue was also initialised with traditional values, but happened to experience only few completed extortions during the initial five periods; this virtual society had no reason to convert and consequently had to suffer from an increasing number of successful extortions, and its unwillingness to denounce decreased to only 60 per cent.

Hence a virtual society with a high prevalence of criminal success in its early stage becomes indolent or acquiescent with crime even if it is initialised with values motivating them not to tolerate crime, whereas a virtual society which experiences only a low prevalence of criminal success becomes more and more intolerant against crime even if it is initialised with values motivating them to tolerate crime — a clear case of path dependency in front of a background of norm related behaviour which still shines through in the history of completed extortions: these remain rarer in the civic societies (orange and green) than in the traditional societies with the same early experience (green and blue, respectively), but it is the early experience that determines the denunciation behaviour of the four virtual societies taken as examples here, as the denunciation refuse level of green and blue ends up at 60 per cent whereas this level among red and orange drops down to 30 per cent.

How valid are these results?

The NetLogo model replicates the (sparse) empirical data only partially. Only two provinces in Southern Italy were halfway similar to extreme cases of several thousand NetLogo runs with a wide range of input parameters. This is particularly true for the comparison with respect to the output metric *percentage of completed extortions* — which is underestimated by the simulation model. But also the *percentage of unreported extortions* is underestimated: The Sicurezza dei cittadini survey reports 22.2 per cent of extortion attempts reported to the police by the respondents with respective experience, hence one could have expected the upper frequency density maximum at about 0.778 instead of the 0.58 shown in the right-hand diagram of Fig. 3.

In the model, all these metrics are calculated as percentages of all extortions which happened during a simulation run whereas in the Sicily and Calabria database the respective variables are calculated as percentages of all extortions which became known by the police. And there is also no guarantee that all respondents in the Sicurezza dei cittadini survey who in fact experienced an extortion reported this fact in the survey. But recalculating the simulated percentages as percentages of the simulated detected extortions is not a helpful solution: This solution overestimates the percentage of completed extortion even more than the solution used throughout this paper overestimates it. Although the NetLogo model (and also its companion GLODERS-S) register all extortion cases, known as well as unknown to anybody except the victim and the offender, a correct microspecification which leads to the dark figure of crime is necessarily impossible. This is why this alternative solution is not discussed any further.

It seems that it is the dark figure of crime that makes a better comparison so difficult, hence this is more an empirical problem than a theoretical one. On the other hand one could try to make an intelligent guess about the size of the dark figure of crime, but it seems that so far nobody dared such a venture — scouring the Internet for ≪*mafia numero oscuro estorsione*≫ — does not yield any quantitative estimate but only a number of imprecise remarks (Progetto Programma Operativo Nazionale Sicurezza 2013, p. 351)(La Spina et al. 2013, p. 116)(Calderoni and Caneppele 2009, pp. 17–18). But if one assumes a certain number of undetected extortions the percentages of both undenounced and successful cases decrease alike with the effect that the representative points of the seven provinces in the right-hand diagram of Fig. 3 move automatically and on a staight line towards the origin of the coordinate system. For instance assuming a dark figure of 36 per cent of all extortions in the province of Siracusa would move its representative point into the orange area in the middle of the "upper" part of the distribution of the two output metrics of the 1,000 simulation runs, and the same would happen to the representative point of the province of Agrigento if one assumed a dark figure of 15 per cent. It seems that it is the dark figure of crime that makes a better comparison so difficult, hence this is more an empirical problem than a theoretical one. But it is certainly premature to claim that the simple algorithm used in the previous few sentences can be used for a quantitative estimation of the real dark figure (but this algorithm has at least some micro

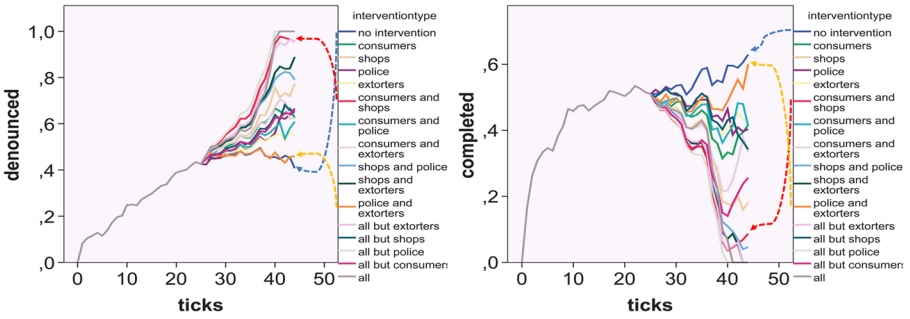

Fig. 5 The result of different interventions for the percentages of denounced and of successful extortions

foundation whereas the algorithms used for estimating the size of the shadow economy in billions of Euros (Pinotti 2012, pp. 12–20) only have a macro foundation albeit more reliable than crime related individual data).

Anyway the model predicts empirical data which are not observed in Southern Italy, but which may be observed in other parts of Italy and Europe where empirical data are even sparser, not so much because they have not been collected but because extortion of the mafia type is so rare there that a respective category does not even exist in the official German criminal statistics (Bundeskriminalamt 2013) which for 2013 report just eleven Italian mafia activities in Germany where in most of these cases extortion was not even mentioned; other organised crime groups ("Russian mafia", outlaw motor cycle gangs) were reported with a similar number of activities such that all these cases of violent organised crime make up for less than 10 per cent of all organised crime in Germany. The situation in other parts of Europe is similar (as also the analysis of Eurobarometer and European Values Survey showed, cf. section 1).

The NetLogo model predicts what can happen in different scenarios and, moreover after different interventions, but this is postponed to "Conclusion: modelling interventions" section.

To decide whether the behaviour of the model agents "truly reflects the way in which the real system operates to produce this behaviour" more empirical data are needed to feed the micro specification — preferably from a long-term experiment with a massive multi-player online role-playing game.

Conclusion: modelling interventions

The NetLogo model in its current version can be interrupted from the user interface but also within a multiple-run batch. When the simulation, for instance one that started with a traditional initialisation, is interrupted, the memories of all agents of one or several types are emptied and re-filled with civic values; then the simulation continues. In the multiple-run batch version 16 runs start with the same initialisation and

the same pseudo-random number generator and after 25 periods each run is stopped. One of them (run 0) continues with unaltered agent memories, in four runs (1…4) the memories of all agents of only one type — extorters, entrepreneurs, consumers, police, respectively — are exchanged, in six more runs (5…10) all agents of two of these types, respectively, are changed, in runs 11 through 14 all agents of all but one type are changed, and in run 15 this happens to all agents of all types. This experimental design allows for comparing, and the result can be seen in Fig. 5 which show the percentages of denounced and completed extortions as moving averages of these 16 runs over time.

As a matter of course, the histories of the 16 runs are exactly identical for the first 25 periods, but afterwards the differences are entirely different.

Interventions with respect to entrepreneurs and customers (red arrow in Fig. 5) lead to a higher rate of denunciations and to a substantial decrease in the number of successful extortion attempts. Interventions with respect to police and extorters only (orange arrow in Fig. 5) only have no visible effect, as their histories are mainly the same as the history of the run without any intervention (blue arrow in Fig. 5). This finding — a theoretical finding derived from an only partially validated simulation model — supports the statements of organisations such as Addio Pizzo (see the interview with Daniele Marannano, one of the leaders of the Addio Pizzo association (Andrighetto et al. 2014, subsection 3.2)) and is also reflected in a recent statement by the commander of the Palermo carabinieri, Salvatore Altavilla, who, according to *La Stampa* (3rd November 2015), underlined the importance that entrepreneurs and shopkeepers find the courage of rebelling against extortion rackets:

> ≪Denunciare conviene, è utile. Gli operatori economici devono sapere che le istituzioni e lo Stato sono al loro fianco e possono garantire una risposta in tempi rapidi.≫

To conclude with a look at physical theories and their empirical correlates (as this paper started with a paraphrased quotation from a text by Max Planck), one could ask whether the model was able to send "the same message as the real world would send" (Planck 1949, p. 235). Where physicists and astronomers are currently struggling with an anomaly of the movements of stars and galaxies in the gravitational field described but not explained exactly enough by the current theory of gravitation — such that they are considering to introduce the so far unobserved dark energy and dark matter into "the physicist's world view", computational criminologists might claim that the mismatch between the model described in this paper and the empirical data used for validating this model comes mainly from the dark figure of crime — an unobservable but nevertheless irrevocable fact.

Compliance with Ethical Standards

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Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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