Growing Social Structure: An Empirical Multiagent Excursion into Kinship in Rural North-West Frontier Province

Armando Geller, Joseph F. Harrison, Matthew Revelle

George Mason University

1 Introduction

As a social structure, kinship results from interactions among individuals and governs such interactions (Fischer, Read, and Lyon, 2005), giving rise to reciprocal, but asymmetric *emergent* (Sawyer, 2005) relations among kins and non-kins. While kinship has been theorized and empirically researched, its "true" nature remains fiercely debated among the constructivists who view kinship as a cultural artifact and positivists who limit it to merely genetics. Nevertheless, scholarly debate has also spawned a more conciliatory notion of kinship in which genetics and culture are both considered at play. Contentions do remain, but largely over what comes first, genetics or culture, and how much weight should be ascribed to each (Fischer, 2005, Hirschfeld, 1986, Kuper, 1982, Schneider, 1984, Shapiro, 2008, White and Jorion, 1996). Given the empirical evidence produced by these authors and the balanced quality of their arguments, we adopt their line of thought to frame our work in the remainder of this article.

Kinship is pervasive in human society, so analyzing it helps to understand society. A kinship group defines solidarity (Evans-Pritchard, 1929, Malinowski, 1930) and is a fundamental social structure, deriving its significance from a common progenitor. But kinship is more than mere genetic relationships. Functional and emotional relationships make it an extendable concept that depends on local culture (Read, 1998). Seen as an emergent social phenomenon, kinship can best be understood by analyzing individual cognition and action, the context in which they unfold, and how they are influenced by social structures. A variety of research methods have addressed this problem, some of which seem slightly exotic in a largely qualitative domain, ranging from ethnographic and social network analysis to mathematical modeling. Some researchers even use computer simulations, an approach also advocated by us in the research at hand.

Since multiagent simulations consist of purposive agents that interact with one another (Ferber, 1999) and create their own social environment (Cederman, 2001), they are especially suited to investigating emergent phenomena (Geller and Moss, 2008). Multiagent simulations lend themselves to "generative social science" (Epstein and Axtell, 1996, Cederman, 2005, Epstein, 2008) in which social phenomena are artificially created from the bottom up. By creating a model of a "target system"[1] that explicates representations of agents, agent behaviors and agent interactions, the essential *generative* mechanisms and processes driving the target system are made accessible to scientific scrutiny; or as Epstein (1999) puts it: "If you didn't grow it, you didn't explain it." Fundamentally different from hypothesis testing, multiagent modeling allows researchers to empirically inform agent behaviors and actions. What goes into a model can be defined in terms of empirical evidence accessible to researchers. Multiagent modeling links individual behaviors and actions observed "in reality" to higher, group level outcomes (Hedström, 2005). In multiagent simulations like the one described later, the micro-macro link is not simply theorized, it is played out.

We introduce a multiagent social simulation model founded on empirical data taken mainly from a case-study on the Swat Pashtun in the rural North-West Frontier Province (NWFP) of Pakistan.[2] Extensive documentation of the Swat Pashtun's culture and kinship system is ideal for our purposes, though any other equally well documented case would work. In her work on Pashtuns, Tapper (1991, p. 46) names patrilineality, affinity, and residential propinquity as important social organizational principles. We use the first two concepts for kinship. Representing genealogies by computer-assisted methodologies helps in "illustrating and elucidating points of social organization, terminology, and wider relations of kinship and society" (Fischer, 1994, pp. 80-81). Research comparable to ours was conducted by Read (1998) and Fischer (1994). Read (1998) studied the effects of culturally mediated decision making on emerging social structure by social simulation. Fischer (1994) created an object-oriented social simulation and examined the ideal formulation of arranging marriage in Pakistan. He was interested in the behavior of a social system given a set of social norms.

The main purpose of our model is to evolve, describe, and analyze kinship structures in a computational framework based on a common understanding of kinship mechanisms of lineage and affinity as reported in a case study. In par-

[1]In social simulation, "target system" denotes the object of investigation, the real world system modeled. It is not related to military terminology or thinking and should not be confounded with such.

[2]The current name of the NWFP is Khyber Pakhtunkhwa. Since parts of the data we use for this work stems from a time when the province was still named NWFP, we keep on referring to it as NWFP.

ticular we address the question of how kin groups emerge from kinship activities of procreation and marriage that are stated as simple agent rules. Kinship structure is generated using empirical ethnographic descriptions of social behavior (cf., Janssen and Ostrom, 2006). This approach is inverse to social network analysis where patterns in a given structure are identified, but not grown. The model has broad demonstrator value, because it shows how published qualitative data can be rigorously used in building a credible and cross-validateable model that can then be reused in other multiagent social simulation frameworks. Given the rapid development of computational social science and the adoption of its methodologies by such idiographically oriented fields as anthropology and history, this is a valuable task in itself. We also agree with Shapiro (2007) that research should be problem-driven and hence remain close to empirical evidence (Wendt, 2009). Furthermore, our approach underlines the need for endogenizing social structures like kinship in multiagent simulations. So far when kinship activities are not explicitly the focus of investigation, they are rarely taken into account. Lastly, our model extends work in political culture and anthropology (Fischer, 1994) and in social complexity (Read, 1998).

Modeling involves making choices on model purpose, case selection, available data, and simulation architecture, so modeling decisions may resemble "cherry picking". Our key source is Barth (1965) who conducted his work in Swat in the 1950s. Where necessary we resort to other sources like Tapper (1991) who conducted her work in the 1970s among Maduzai in Afghan Turkestan. Such choices of field evidence influence model output. However, these choices are no different in quality from research design decisions made in more established social science fields, if they are made deliberately and communicated transparently to the reader. In other words, our model reflects selections from an array of theoretically possible ethnographic choices. To demonstrate that it is possible to use ethnographic data in social simulation is one purpose of the model. To communicate that modeling decisions can influence simulation outcomes should empower the reader to criticize multiagent models, but should also strengthen the reader's confidence in the transparency and robustness of multiagent modeling as a scientific approach. Anomalies in model output that can be traced back to case selection and model input data can also flag the need for further empirical work, although using models as data generation and validation tools remains an underutilized opportunity in empirical social science research.

In Section 2, we review research in kinship studies and social simulation relevant to us. In Section 3 we introduce the empirical basis of our model and elaborate on the agent behavior rulesets. We discuss the model in Section 4, and report model output and comparison against historical evidence in Section 5. We conclude in Section 6 with a critical juxtaposition of our work against modeling in conflict and peace research. The discussion will not only exemplify our contributions concretely, but will also highlight that kinship should be an essential factor in the study of armed conflict (Ferguson, 1990, Snyder, 2003).

2 Kinship and Computational Models

The role of kinship in social life, the social needs it satisfies, and the influence it exerts on society have been studied in anthropology. Kinship systems describe a basal social structure, namely the one given by blood lines. The initial situation given by father, mother, and child defines the path for the offspring's later life (Malinowski, 1930). Evans-Pritchard (1929, p. 7) notes: "The solidarity of the sibling group is shown in the first instance in the social relations between its members." Shapiro (2008) shows that current research supports this assertion. However, kinship structures represent more than mere lineage systems. While kinship does define elementary family, it also provides a basis for social structures such as extended family, local group, clan, and tribe; functional relationships like marriage; and basic mechanisms such as affinity and emotions (Malinowski, 1930, Radcliffe-Brown, 1941). Read (2001, p. 114) points out that the "true" nature of kinship lies somewhere in between: "Once we recognize that genealogical tracing and the terminological space can both be culturally salient, yet need not be congruent [. . .] there is no conflict [. . .]." Critiques of kinship studies such as Schneider (1984) and Kuper (1982) note that kinship is fluid and constructed: People may perceive a kin relationship where there actually exists no genetic relationship. Kinship studies are also criticized as too absolute in asserting that kinship, marriage patterns and residence rules explain intricacies of social life. Some kinship research with postmodernist and constructivist bends, for example Sneath (2007), discredits parts of older work by highlighting the importance of overlapping relations within a group based on gender and role differentiation and emphasizes the individual as actively "constructing" relationships. What is considered tribe by Barth (1965) is viewed as simply aristocratic lineage by Sneath (2007). The middle-ground "truth" of kinship needs careful qualification insofar as the order of things is defined by empirical evidence: Blood kin structures appear to be primordial over culturally defined kin structures (Shapiro, 2008). Apparently this holds true for anthropological research conducted under cognitive premises (Hirschfeld, 1986). We cannot provide a final answer to this debate, but we tend to side with the less constructivist camp.

Social identity, its range within an aggregation of individuals, and how an individual is placed in this aggregation is influenced by social constructions of kinship (Read, 2001).[3] Kinship structures, processes, and mechanisms also play a vital role in political culture as a repertoire of cognitive, behavioral, and normative patterns in the production of power and in the organization of groups that cooperate and conflict.[4] From such a viewpoint kinship gains an almost entrepreneurial connotation.

Mechanisms and processes related to kinship that underly the production of horizontal and hierarchical social structures and dynamic changes of social structures have received increasing attention in recent research. Read (1998) developed a multiagent model to explore females' decisions that affect birth-spacing and how cultural rules affect marriage. His modeling results point to a "dynamic tension" between culturally "proper behavior" and ecological necessities (cf., Smith, 2003). Geller and Moss (2008) studied power structures in Afghanistan, looking at kinship and other social networks based on qualitative data. Alam, Meyer, Ziervogel, and Moss, 2007 report on a model devised to inform policy makers of the spread of HIV/AIDS in South Africa using ethnographic data on kinship and friendship networks.

The fact that kinship plays a pivotal role in the social, political and economic realms can be made useful in multiagent modeling. Kinship "carries with it not only a constructed basis for transforming a group of individuals into a system of interconnected individuals, but also a commonly understood conceptual basis of expected, and expectable, behaviors" (Read, 2002, p. 7253). Multiagent models of socialities are representations of individuals that have behaviors, perform actions, and interact with each other autonomously according to a specified set of rules (Ferber, 1999). Because kinship structures and their broader societal effects are notoriously challenging systems to model and understand, multiagent modeling comes in handy as a methodological disambiguation technique (Moss, 2008). Instead of looking top down at kinship structures, they are "grown" from the bottom up using empirical evidence about individual kinship activities. Multiagent simulations of kinship structures lend themselves also to study "what if" questions pertaining to cultural changes and the effects of such changes on a broad range of societal patterns.

[3]Identity can be understood as being present in multiples in a person, related to the multiple roles that individuals incorporate. This is crosscut by the "person", the socially defined aspects of the self, and the "individual", the uniquely experienced side of self. Identity is constructed of persons and individuals. In this paper we see kinship as a social structure that generates identity.

[4]See Azoy (2003) for an excellent case study on organizing Buzkashi events in Afghanistan.

3 Evidence from the NWFP

Multiagent modeling requires data on actors, and their behaviors and actions. The behavioral data we use stems from Barth's 1965 case study on Swat Pathans.[5] The data needed to develop a multiagent model of kinship structures in NWFP is summarized in Table 1. A note on the data appears to be necessary: The data available to us is partial, incomplete, fuzzy and variable.[6] We are aware that different data could lead to different models that could in turn lead to different results. In this article we show how to work with one extant corpus of data. Modeling with competing datasets falls beyond the scope of this work.

Pashtun society is primarily and foremost patrilineal; kin identity, rights, and status are passed from father to offspring. Siblings are considered equals and there exists no institutional sibling hierarchy (Barth, 1965, p. 23). Pashtun society maintains social links over large distances, well beyond immediate neighborhoods. Neighbors, in fact, may have distinctly different social relations from one another (cf., Hill and Dunbar, 2003). A mutually recognized kinship link between two Pashtuns means they will share associations and provide support to one another, both materially and in defense of life (Barth, 1965, p. 34). If patrilineal rules set up rigidly the inherited kin links, marriage rules form a different type of kin rules that have a greater degree of flexibility. Marriage is primarily to create bonds between families; males control social movements of the females (Barth, 1965, p. 2). Polygamy is permitted for men and there are virtually no age restrictions between the people who get married. Marriage is prohibited between two people who are closely related and rules with respect to incest and unlawful marriage are very specific: "Incest prohibitions apply only to the third generation ascendant or descendant, to siblings of father and father's father, to ascendant or descendant of wife, and to divorced wife of ascendant or descendant. [...] A man may not have intercourse with, nor marry, two women so related that if one of them were a male, they could not have intermarried." (Barth, 1965, p. 36)[7] Except for divorced women, all women are marriageable and the nearest agnate above puberty has the right to impose a marriage. There is a bride price required for marriage, usually around 65,000 Afghanis (Tapper, 1991, pp. 141-156), but the bride's head of household prefers a man of at least equal status. However, in the end the group as a whole

[5]For a critique of Barth (1965), see Edwards (1998) who believes that Barth considered earlier work by Evans-Pritchard too structure-oriented and aimed to correct it. Multiagent modeling serves both views through methodological individualism *and* emergence. However, Barth (1965) arguably remains the prime account of the Swat Pashtun.

[6]See Mussavi Rizi, Łatek, and Geller (2010) on how to fuse partial and incomplete quantitative datasets into a common dataset for multiagent modeling.

[7]We interpret in a way that one cannot marry his sister or brother.

ID	Rule description	Source	Implementation
Lineage Rules			
1.1	Patrilineality	22	Identity and status are passed from father to offspring.
1.2	Equality of siblings	23	No institutional hierarchies between siblings.
1.3	Head of household death	23-24	Eldest son takes over household, wealth is evenly split between sons. If there is no son, then the brother takes over, then the cousin.
Marriage Rules			
2.1	Social control over female	22	The social contact of females is controlled by the father. Marriages are arranged.
2.2	Marital residence	33	Most couples reside in the household of the husband's father.
2.3	Marriageability age	36	Female: 5; Male: 15.
2.4	Polygamy	36	Men may have up to 4 wives.
2.5	Incest prohibition	36	Marriage prohibited with third generation ascendant or descendant, siblings of father and father's father, ascendant or descendant of wife, divorced wife of ascendant or descendant.
2.6	Brideprice	37†	Fixed, average bride price of 65,000 Afghanis. Groom's household must meet threshold.
2.7	Inter-caste marriage	20	There seems to be no consistent rule. Endogamy rate: 60%; hypergamy rate: 23%; hypogamy rate: 17%. Women often marry upwards, men rarely do.
2.8	Widow remarriage	40	Widows are unlikely to remarry.

Table 1: Agent ruleset based on ethnographic data. All sources refer to page numbers in (Barth, 1965) except for the entry marked with †, the values for which are taken from (Tapper, 1991, p. 142).

decides who marries whom, thus implying a group decision mechanism. Divorce is rare and usually detrimental to both the husband and wife. It harms the husband's reputation, damages kin relationships, and adversely affects the whole group. Both kin and marriage relations are important for creating alliances as local affiliations or maybe more distant affinal relations, to strengthen existing ties (Barth, 1965, p. 35). Thus the Pashtun society evolves as a connected network of ties of patrilineal and affinal relationships that eventually translate into what makes a Pashtun, as required by *Pashtunwali*, their "code of honor".

4 Methodology and Implementation

4.1 Multiagent Computational Social Science

Modeling, including computer simulations, can be understood as a scientific activity with the aim of replicating a target system in such a way that the replication will react to inputs in ways resembling the reaction of the target system (Troitzsch, 1993). Most multiagent models are simulations. They consist of cognitive agents that have local knowledge of the system, possess limited resources, interact with each other according to defined sets of rules, and can influence each other (Ferber, 1999). Cederman (2001) points out that agents, by their mere interaction, also constitute their own environment. The agents interact with each other on the basis of defined behavioral rules and actions. The rules execute differently depending on environmental conditions and agent behavior changes accordingly. Sometimes the interactions amongst agents and between agents and their environment can lead to counter-intuitive emergent phenomena. Multiagent modeling should be viewed as a complementary alternative to existing quantitative and qualitative approaches.

There are several platforms available for implementing multiagent systems. We implemented ours in MASON, a multiagent simulation toolkit written in Java (Luke et al. 2005).[8]

4.2 Kinship Model: Rule Formalization and Implementation

Constructing a coherent chain between the raw data, the formalized, "modelized" form of the data, and the computational implementation constitutes the methodological core of the proposed computational model. Table 1 shows the data defining the agent rules. In the following section we describe how this data is incorporated into the computational model, i.e., how it is translated into Java computer code.[9]

The model consists of two types of agents, male and female. All agents have the same ethnicity (Pashtun), the same religion (Sunni), and belong to one of three

[8]To download and install MASON follow this link `cs.gmu.edu/~eclab/projects/mason/`.

[9]While the logic applied to create a coherent link between data source and agent rule is of broader value to the modeling community, the method used here is meant only for a small and well defined textual corpus. Once this body of data grows larger, other methods, though not necessarily other reasoning, needs to be applied. The code can be requested by the authors.

different castes (high, middle, low). Castes are assigned according to a uniform random distribution. Since all agents are Pashtun and Sunni, the only differentiation between groups is based on caste.

Male		Female	
Age cohort	Mortality rate	Age cohort	Mortality rate
0	0.08451	0	0.07077
1	0.0152	1	0.02715
5	0.00828	5	0.00833
10	0.00488	10	0.00482
15	0.006	15	0.00639
20	0.00914	20	0.00925
25	0.01025	25	0.01106
30	0.01188	30	0.01302
35	0.01523	35	0.01622
40	0.02143	40	0.02079
45	0.03282	45	0.02863
50	0.05125	50	0.04188
55	0.08188	55	0.06393
60	0.12017	60	0.09243
65	0.17984	65	0.1487
70	0.26998	70	0.23609
75	0.39284	75	0.35819
80	0.54976	80	0.51015
85	0.72216	85	0.68238
90	0.82172	90	0.79186
95	0.87173	95	0.85318
100	1	100	1

Table 2: Mortality rates showing the probability of dying at any given age for the year 2001. (Source: Pakistan Federal Bureau of Statistics)

Mortality rates are derived from 2001 life-tables, which we obtained from the Pakistan Federal Bureau of Statistics (`statpak.gov.pk/fbs/content/pakistan-demographic%C2%A0-survey-2001`; see Table 2). Other model parameters are summarized in Table 3.

The model uses a centralized "matchmaker" to evaluate potential pairings, and to choose and select couples for marriage. The matchmaker finds suitable couples via the algorithm presented below. There is a set of females F and a set of males M. For each male m_i a female f_j is randomly chosen from a subset of females for which the marriage rules as introduced above apply. If such a female f_j is

No.	Parameter	Value	Source
Initial conditions			
1	Number of households	10	Hand-picked
2	Children per household (avg.)	4	Empirical; SDGP†
3	Children per household (std. dev.)	1	Empirical; SDGP
4	Wealth per household (avg.)	100,000	Educated guess
5	Wealth per household (std. dev.)	10,000	Educated guess
Operating parameters			
5	Female age of marriageability	5	Empirical; Barth 1965, p. 36; Tapper 1991, p. 159
6	Female age of child-bearing	16	Empirical; SDGP
7	Female end age of child-bearing	30	Empirical; SDGP
8	Male age of marriageability	15	Empirical; Barth 1965, p. 36; Tapper 1991, p. 159
9	Birth rate‡	0.35	Empirical; SDGP
10	Endogamy rate	0.6	Empirical; Barth 1965, p. 20
11	Hypergamy rate	0.23	Empirical; Barth 1965, p. 20
12	Hypogamy rate	0.17	Empirical; Barth 1965, p. 20
13	Bride price	65,000	Empirical; Tapper 1991, p. 141-156
14	Number of generations for which dead heads of household are remembered	5	Educated guess

Table 3: Model parameters. †Statistics Division, Government of Pakistan (SDGP; `www.statpak.gov.pk`). ‡Birth rate signifies the probability of each married woman of child-bearing age bearing a child in a given year.

found, marry her to m_i, remove her from the list of available females F and update the kinship links. If f_j was the fourth woman m_i marries, then remove him from the list of available men. The process is shown in Algorithm 1 and Algorithm 2.

The matchmaker must find the subset of females which are compatible to marry a given male. Compatibility is determined by a rule-based system. The rules from Table 1 are codified here.

Algorithm 1 MATCHMAKER(F, M)

$F = f_1 \cdots f_m$ (set of available females)
$M = m_1 \cdots m_n$ (set of available males)
$M \leftarrow$ SHUFFLE(M)
for $m_i \in M$ **do**
    $F_c \leftarrow$ COMPATIBLESUBSET(F, m_i) (see Algorithm 2)
    if LENGTH(F_c) > 0 **then**
        $j \leftarrow$ RAND(1, LENGTH(F_c))
        MARRY(m_i, f_j)
        REMOVE(F, f)
        if LENGTH($m_i.spouses$) $= 4$ **then**
            REMOVE(M, m_i)

Algorithm 2 COMPATIBLESUBSET(F, m) returns the subset of F which are compatible to marry m

$F = f_1 \cdots f_m$ (set of prospective brides)
$m =$ prospective groom
$F_c \leftarrow$ COPY(F)
for $f \in F$ **do**
    if f and m are too closely related (see Rule 2.5 in Table 1) **then**
        REMOVE(F_c, f)
    if f and m are from incompatible castes (see Rule 2.7 Table 1, which is stochastic) **then**
        REMOVE(F_c, f)
return F_c

The inter-caste marriage rule (Rule 2.7 in Table 1) is probabilistic rather than strictly prohibitive. Inter-caste marriages are allowed, they are just less common than same caste marriages. Barth (1965, p. 20, pp. 40-41) recorded the rates of inter-caste marriages: 60% of marriages occur between couples from the same caste (i.e., endogamy), 23% of marriages occur between a man and a woman of a lower caste (i.e., hypergamy), and only 17% involve a man marrying a woman of a higher caste than his own (i.e., hypogamy).

We implemented rule 2.5 in Table 1 based on path length in the kinship graph. If the path length between a potential bride and a groom is 3 or lower, marriage is prohibited. Note that this allows marriage between cousins, which is actually not only common, but even preferable for it is considered a secure marriage (Fischer, 1994, 83).

When the path length is 4 or higher, marriages are allowed except in the case of grandparent's siblings (path length of 4). To handle this special case, we keep a generational counter and prohibit marriages with path length of 4 which differ by more than 1 generation.

For purposes of verification, we systematically compare model output and internal mechanisms against a set of test cases. Type-two test cases involve logic instead of mere value verification (type-one test cases) and include: "If the oldest son dies, who becomes head of household?", "What are the ties between old and new household?", "If the mother dies, who is the step mother?", "Where do widows go?", "Where do non-tied agents ('hermits') go?", "If the father dies, how do two brothers keep a link between themselves?"

The number of parameters and the size of the behavior space is kept as small as possible and closely matched with the available evidence. Like most empirically driven models, there are several parameters to adjust, but we have kept the ruleset minimally sufficient. Large parameter and rule sets tend to obfuscate the drivers and factors of simulation results. We nevertheless ran parameter and behavior space sweeps for those parameters and behaviors that were chosen by us based on an educated guess due to a lack of evidence in the data available to us. The sweeps did not unearth any unexpected results and confirmed our confidence in the general robustness of the model. Parameter and behavior sweep results are reported in detail in the Appendix.

Modeling implies deliberate simplification. We refrain from modeling haggling over bride price. We also choose marriage pairs with a centralized mechanism instead of a group decision mechanism. Shapiro (2008, p. 147) points out in general that groups are not necessarily marriage arrangers and that a primary importance resides within the individual. Our agents also do not act strategically, for example, building affinal relationships with distant allies to strengthen existing ties as described in Barth (1965, p. 40). Agents do not act strategically in the current model because that would have meant to increase the scope of the simulation considerably and unnecessarily for our given purpose. To act strategically agents would have to be equipped with purpose and incentives, including to have a dominant position in a defined number of generations, to spread risk over generations or to defend against a historical rival.

5 Results

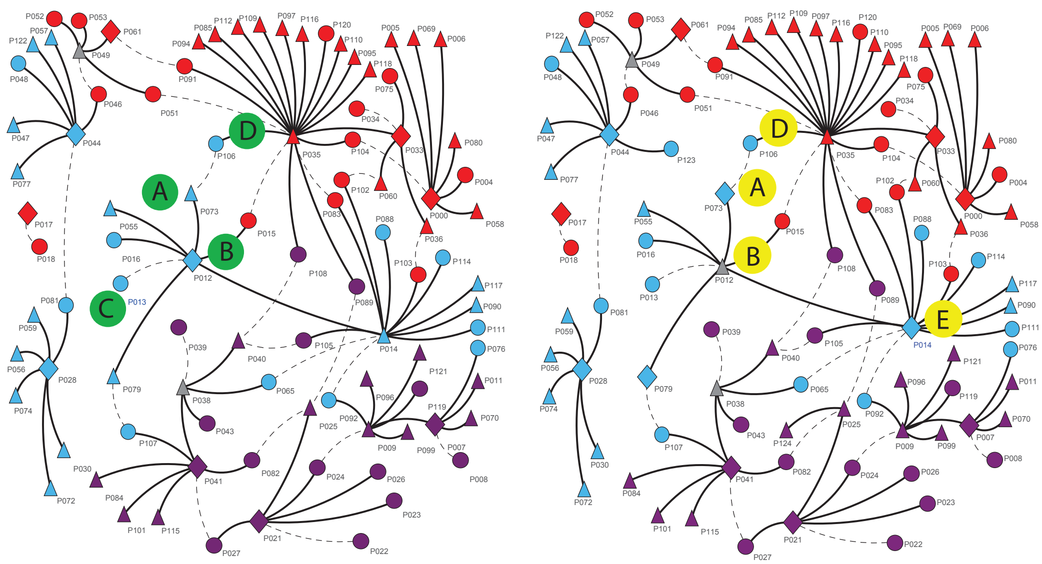
5.1 The Life and Death of P073

To help explain the micro-dynamics of the simulation, we narrate the life of agent P073 (marked with a green circle “A” in Figure 1(a)). P073’s story is typical of many other agents in the simulation. Figure 1 depicts two screenshots from the simulated kinship network at time steps 29 (left) and 30 (right).[10] It is a graphical representation of the evolution of the network P073 is embedded in. Each vertex denotes an agent. Triangles denote male, circles female agents. Red, purple, and blue coloring indicates class: Red is low, purple middle, and blue high. Dead agents turn gray. Solid edges between agents denote blood relations; dotted edges marriage relations. Edges are added when children are born to connect them to their fathers and when couples are married to connect the wife to the husband. When agents die, they and their edges are removed from the network, except for heads of household who are remembered for five generations (determined by model parameter 16 in Table 2).

In time step seven agent P073 is born to parents P012, the father (circled green “B” in Figure 1), and P013, the mother (circled green “C”), as their sixth child and third son. 22 time steps later P073 marries P106 (circled green “D”). Their marriage implies that all conditions according to rules subsumed under ID 2 in Table 1 were met, including that P073’s age is 22 and P106’s age at the time of marriage is five.[11] P106’s father, P035, is from the red caste. P106 is now member of the blue caste; she used to be a member of the red caste. This is an example of caste change according to rule ID 2.7 in Table 1. At time step 30 we see in Figure 1 (right) that P073’s father, P012, died. According to rule ID 1.7 in Table 1 P014 (circled yellow “E”) succeeds his father P012 and becomes the new head of household. Because P073 is already married he can found his own household and becomes head of household himself according to rule ID 2.2 in Table 1 (circled yellow “A”). In time step 44, P073 and P106 have a daughter, P144. The mother, P106, is 19 years old, which is in accordance with property number 7 in Table 3. P073 and P106 have more children at time steps 48, 49, and 50. In time step 52, P073 marries his second wife, P146. In the same time step he has another child with his first wife, P106, as well as in time step 54. In time step 62 he has his first child with his second wife, three years later they have their second child. One year

[10] A time step is one model iteration. It loosely means one year.

[11] It should be noted that in reality P106 would likely not move to her new household at this young age. However, she needs to be accounted for in the kinship graph as part of her new household since the marriage actually happened and she is not only “promised” to her spouse.



(a) (b)

Figure 1: Screenshots of the kinship graph at time steps 29 (a) and 30 (b). Males are shown as triangles, females as circles. Heads of household are drawn as diamonds. Solid edges represent genealogical relations, dotted edges marriage connections. The high caste is drawn in blue, the middle caste in purple, and the low caste in red.

later, in time step 66, P073 dies. He was 59 years old. One of his sons will succeed him as head of household.

After having developed a more thorough understanding of individual agent behavior and actions, and the model's microfoundations, we turn to aggregate views of the model. We look at how kinship structures emerge through group formation (intra-group) processes, cohesive network measures, and measurements for inter-group identification. Before we do so, let us briefly characterize the social structures that are evolving as a result of the implemented socio-demographic and marriage micro-interactions.

5.2 Network and Other Statistics

A natural way of looking at kinship structures is via dendrograms. They allow following the evolution of group structures over time in terms of hierarchical clusters. In kinship studies these clusters can be interpreted (with increasing cluster size) as families, clans, and tribes. Figure 2 depicts the evolution of a patrilineal dendrogram, i.e., only the patrilineal structure is reproduced.[12] The coloring of the dendrogram distinguishes different time periods.

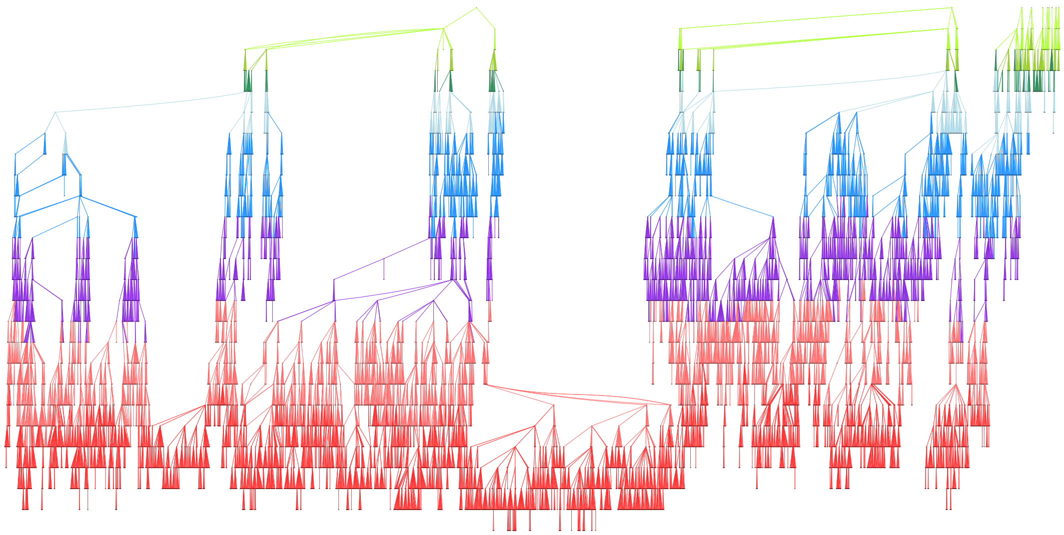


Figure 2: Dendrogram of patrilineal kinship structure at time steps 10 (light green), 50 (green), 100 (dark green), 200 (light blue), 400 (blue), 600 (purple), 800 (light red), and 1000 (red).

The simulation produces three distinguishable types of scenarios: “extinction”, “hegemony”, and “pluralism”. The scenarios are depicted in Figures 3, 4, and 5 as sequences of kinship network graphs correlated with population size time-series. Each sequence consists of kinship network graphs—each plot is similar to the two plots in Figure 1—constructed from data recorded at time steps 10, 50, 100, 200, 400, 600, 800, and 1000. Edges represent either genealogical or marriage relationships and vertices represent either male or female agents.

In the extinction scenario (Figure 3) the population dies out after an initially unknown number of time steps. The mechanisms driving the simulation result produce valuable insight. First, the decrease in population numbers has to do with the distribution of wealth in the population. As a result of the unequal distribution of wealth, many parent agents can no longer afford to marry their child agents off, which diminishes population diversity. A diminished population diversity further decreases the chances of marriage according to the marriage rules in Table 1,

[12]Note that the simulation always produces relational data for both, male and female agents and stores it in a datafile. Depending on what kind of network measure is computed it is important to know which links have been considered. With the exception of Figure 2 all measures and figures in this subsection have been produced using all available relational data, that is, male and female links.

which leads to a decrease in the number of offspring. Fewer agents mean not only a smaller likelihood of finding a marriage partner, but also a less dense and more compartmentalized network, the compartmentalization being an indication for the social exclusion of groups due to lack of inter-group marriage.[13]

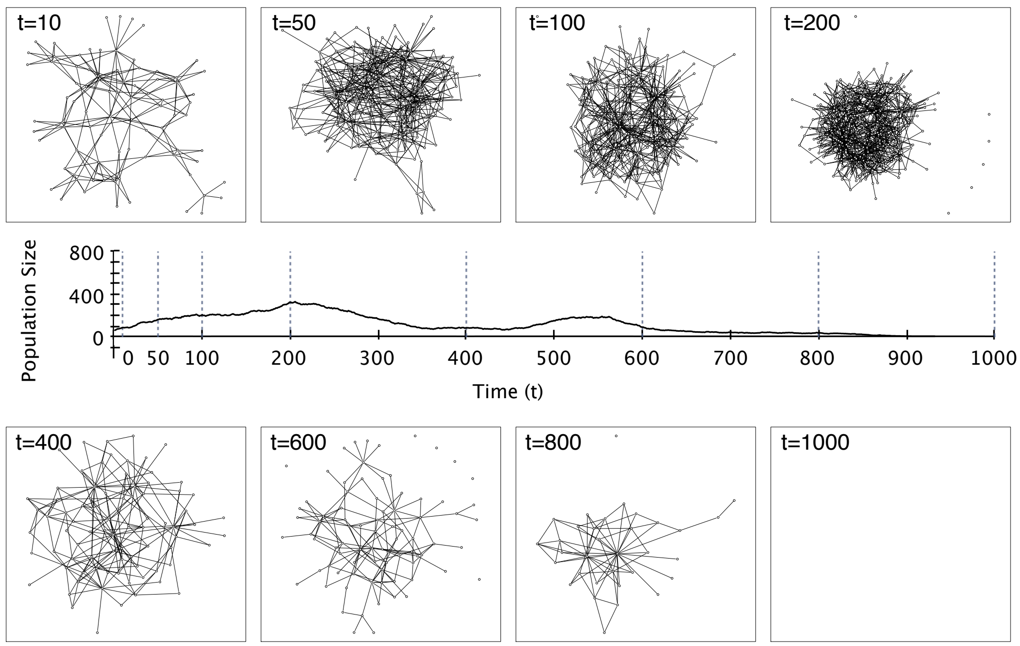


Figure 3: Sequence of kinship network graphs for an example of the "extinction" pattern, at time steps 10, 50, 100, 200, 400, 600, 800, and 1000 correlated with the number of total population. Vertices in the network plots represent either male or female agents; edges represent either genealogical or marriage relationships.

In the hegemon scenario (Figure 4) one caste takes over the other castes and ends up being the only survivor at the end of the simulation run. The case is interesting despite being pretty counter-factual—when is a society entirely homogenous?—in that it exemplifies the importance of critical size for the survivability of a particular group of people in the model. Once a certain agent population size is reached an agent group becomes biologically self-sustainable. However, as with the extinction

[13]We originally deemed this scenario to be counterfactual. However, one reviewer of the article pointed out to us that a model of a system in which "men can have four wives, with wives marrying up, guarantees that poor men will have few if any wives and eventually their lineage or sublineage will disappear and a new subgroup will emerge as the lowest wealth-group." Such a process appears to be indeed factual.

case, the hegemon case exemplifies the importance of modeling complex dynamics. While many processes on the inter-agent level are dealt with in a stochastic manner, this emergent phenomenon is of chaotic nature. Which caste eventually will prevail—or afore, if and when the population will die out—cannot be predicted on the basis of the initial parameters.

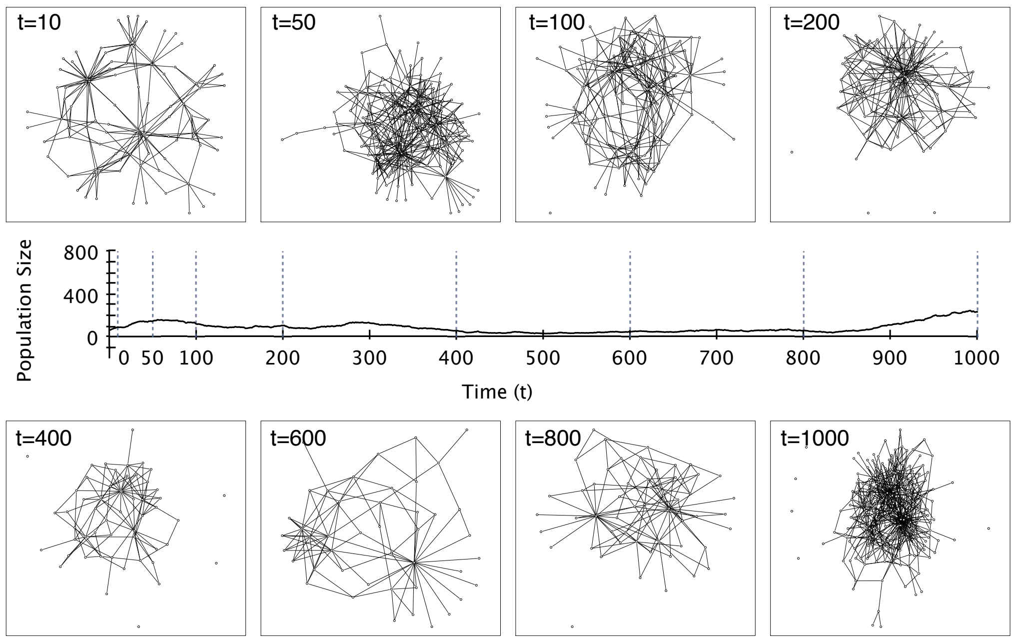


Figure 4: Sequence of kinship network graphs for a representative example of the "hegemon" pattern, at time steps 10, 50, 100, 200, 400, 600, 800, and 1000 correlated with the number of total population. Vertices in the network plots represent either male or female agents; edges represent either genealogical or marriage relationships.

The data shown in Figure 5 is from a series of simulations runs we dubbed the pluralism scenario. It is characterized by a relatively equal distribution of caste size and wealth in the total population, and a steady increase in total population size. The three processes taken together in theory allow for the realization of the maximum number of marriages under the model's social mechanism regime. That is, pluralism is not only favorable to marriage within a caste (endogamy), but also with regard to relative upward (hypergamy) and downward marriage (hypogamy). Runs of the pluralism type also suggest to evolve into a kind of system behavior that in the *longue durée* resembles a dynamic equilibrium or at least an evolution that converges into a steady state.

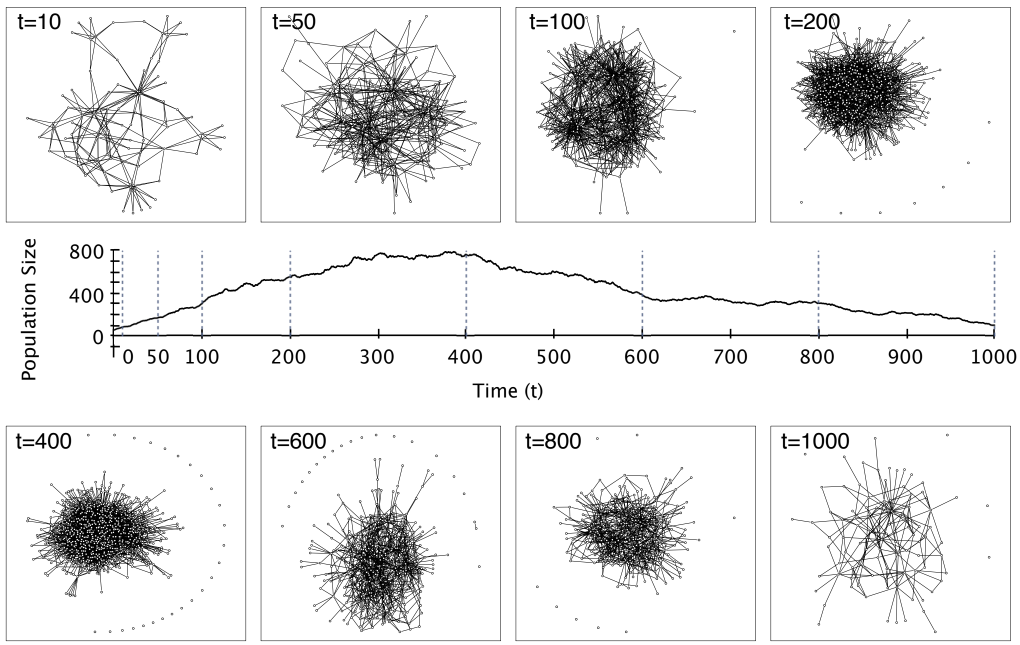


Figure 5: Sequence of kinship network graphs for a representative example of the "pluralism" pattern, at time steps 10, 50, 100, 200, 400, 600, 800, and 1000 correlated with the number of total population. Vertices in the network plots represent either male or female agents; edges represent either genealogical or marriage relationships.

So far we have seen that the model is driven by societal variety and equality, and metastability on the group level characteristic to complex social systems.[14] Furthermore, we noted that these processes are not independent of each other and that instead population diversity, population size, and relative wealth distribution are correlated.

What can we say about the types of networks created by the agent interactions, and social mechanisms and processes described? We expect to find densely

[14]For the purpose of this paper we understand complexity as a "condition in which agent behavior and social interaction combine to generate macro-level outcomes that could not be predicted from knowledge of the behavior and nature of interactions alone, and result in sporadic volatile episodes, the timing, magnitude, duration and outcomes of which are themselves unpredictable." (Geller and Moss, 2008, p. 322).

clustered networks with small average path-distances. Endogamy tends to favor clustering and the evolution of tightly knit networks, while exogamy creates short-cuts to distant areas in the network. The kinship and marriage mechanisms implemented favor the creation of vertices with a high degree centrality, such as heads of household.

Figure 6 shows degree, closeness, and betweenness centrality for 10 "pluralism" runs at different time steps.[15] Centrality measures can be interpreted as indicators of an agent's power (Degenne and Forsé, 1999, Chap. 6). Individuals with high degree centrality have a large number of connections to other network members. Individuals with high closeness centrality can reach any other individual in the network in relatively few steps. Betweenness centrality represents the relative number of geodesics that pass through an actor. Closeness and betweenness are indicators for controlling network communication.

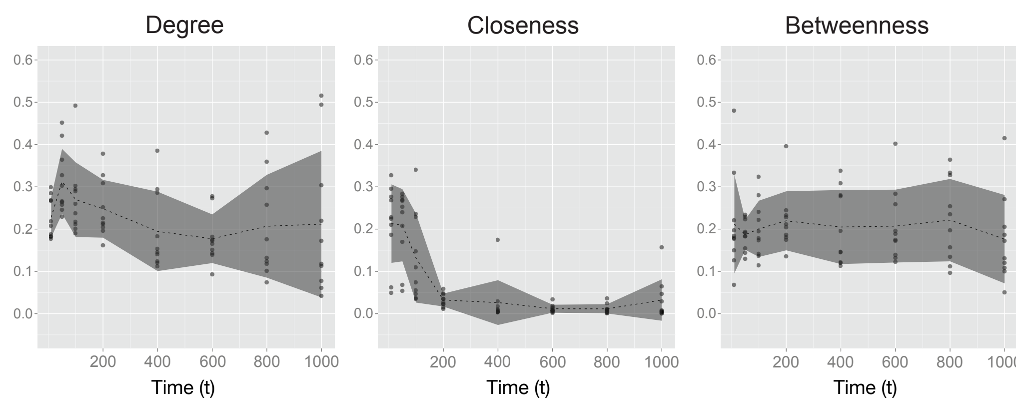


Figure 6: Degree, closeness, and betweenness centralization for 10 simulation runs of the pluralism scenario at time steps 10, 50, 100, 200, 400, 600, 800, and 1000. The gray ribbon indicates one standard deviation from the mean.

Watts (1999) reports small world (SW) structures likely to be present in many real world social networks. Geller and Moss (2008) report to have found a SW-like topology for Afghan power structures. We also expect to find SW topologies. SW networks are interesting because they combine two seemingly irreconcilable features: high clustering and short path distances (Watts, 1999, pp. 508-509). In other

[15] Applying graph-theoretic measures over a network snapshot, could increase the risk of losing the context of a particular agent's position in the network. An agent's behavior may not just be reduced to the notion of a mere node. In complex systems it is hard to anticipate how emerging patterns result from interactions at the micro-level and it could be misleading to apply network measures on just a single snap-shot of the network.

words, a SW network is defined by $n \gg k_{\text{max}} \gg 1$ while exhibiting $C \gg k/n$ (Watts, 1999, p. 511), where n is the number of vertices, k the number of undirected edges, and C the clustering coefficient.

SW networks differ from random networks in mean sparseness, mean k, and decentralization $k_{\text{max}} \ll n$, which are distinct features of the former. Thus, high C and short path distances L need to be understood relative to other network topologies like random graphs. We therefore expect $C_{\text{SW}} \gg C_{\text{random}}$ and $L_{\text{SW}} \ll L_{\text{random}}$.

In Figure 7 the values of 10 representative networks generated in the kinship simulation (circles) are compared with values from 10 Erdős-Rényi random networks (triangles). As hypothesized, we find sub-networks that are characterized by the presence of connections between almost any two nodes within them and a prevalence of short paths between vertices.

Small-world networks are of interest to us because they have properties of the sort that make them "sufficiently well connected to admit rich structure, yet each element is confined to operate within a local environment that encompasses only a tiny fraction of the entire system." (Watts, 1999, p. 499). The description's relatedness to what Simon (1996, p. 209) coined "near-decomposability" is evident: "most things are only weakly connected with most other things". But they *are* connected and that has consequences for social reality.

5.3 Cross-Validation

Simulation models are validated on the macro-level by comparing computationally derived statistical signatures (such as spatial distributions and time-series) against real world data (Axtell 1996, Moss and Edmonds 2005). Axtell et al. (1996) use the notion of relational equivalence to show that two systems exhibit similar internal behavior (comparison of internal validity). Indeed, macro-level cross-validation is not always appropriate or feasible, depending on model purpose and data availability. In such instances, case-by-case comparison and techniques from comparative research come into use. The simulation is then seen as a further case that needs to be understood against other, similar cases. The output from the simulation is compared against general accounts taken from the literature other than the one used to inform the model (out-of-sample).[16] Out-of-sample validation procedures deny

[16]The "easiest" way to conduct cross-validation, of course, would be to compare simulation results to Read's (2002) universal structure genealogical grid that is shared cross-culturally. However, the limits of our own model impede us from choosing such an approach. Though the kinship model presented by us is rather genealogical than genetic for it makes use of culturally defined marriage rules, it does not add up to the refined kinship terminology described by Read (2002).

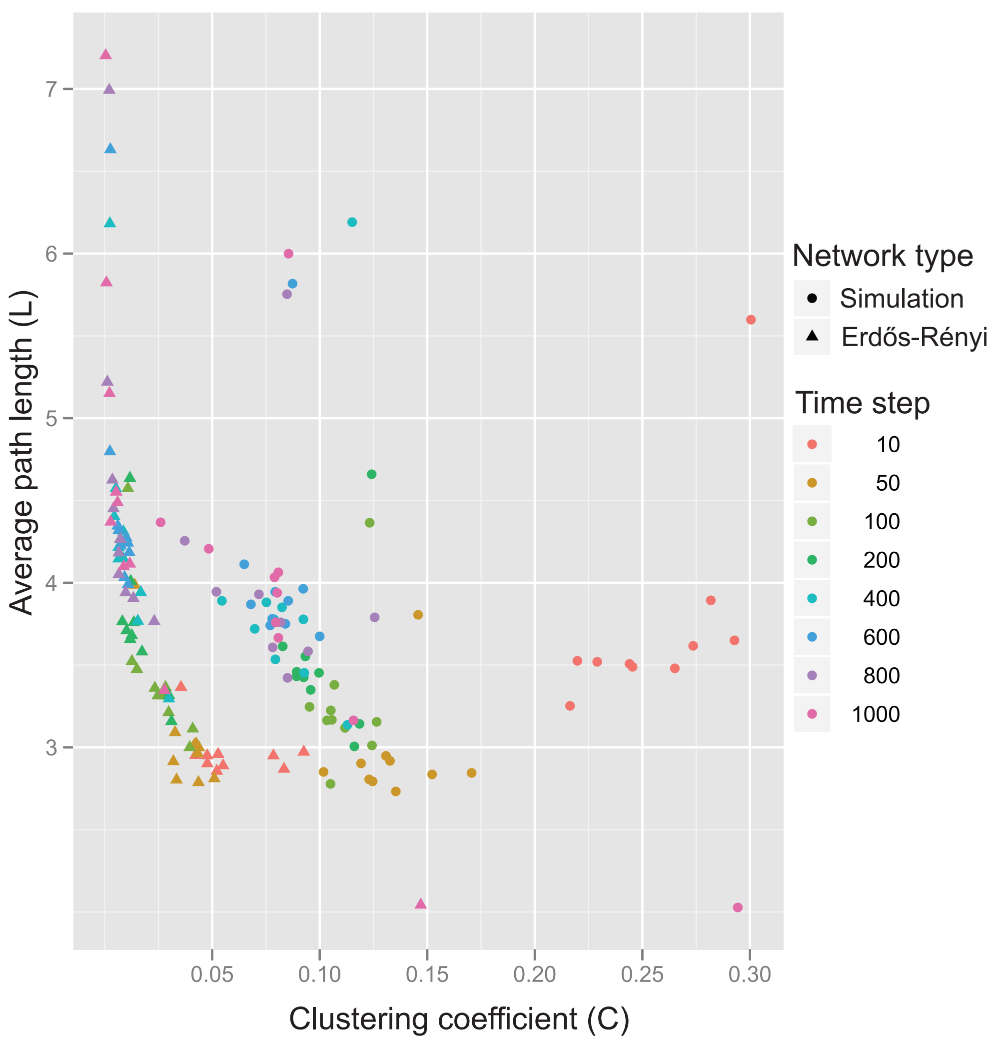


Figure 7: Comparison of clustering coefficient C and geodesic distance L of 10 representative kinship networks (circles) and 10 Erdős-Rényi random (triangles) networks. Colors represent time steps in the network evolution.

tautological conclusions (though not post-hoc fallacies).[17]

Where possible, we use real data and data structures to cross-validate. However, with some minor exceptions we cannot compare actual numbers against each other. Tapper (1991, p. 60) reports in her study of Maduzai Pashtun women that

[17]Note that population distribution, hypo- and endogamy ratios, and the like are hardwired into the model. Comparing related model output to actual demographic and ethnographic data is in such a case more accurately considered as verification, not validation.

out of 208 recorded marriages in the core lineages only 4 were hypogamous. This is a much lower rate than we got from Barth (1965, p. 20) and subsequently used in our model. This case is not particularly illuminating either, since we hard-wired the hypogamy rate into the model.

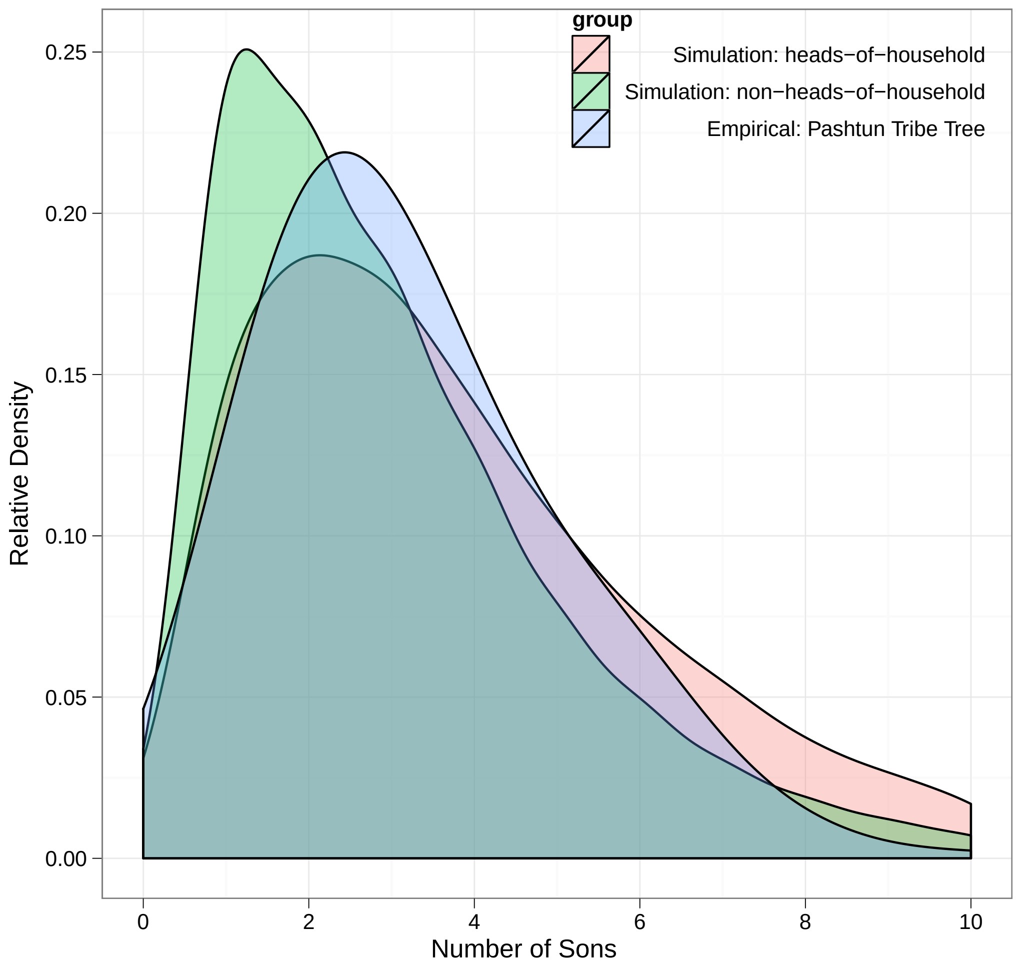


Figure 8: Distribution of son counts per man, comparing our simulation data to genealogical records reported in Volume 19 of The Imperial Gazetteer of India from 1908. Men without sons are excluded. The simulation data is separated into heads of household and the rest.

We instead compare the output of our model to aggregate data collected from Pashtun genealogy charts as reported in the 1908 Imperial Gazetteer of India, Volume

19, p. 207ff.[18] Genealogy charts of this kind are useful, but their limitations should be clearly noted. Specifically, they show only a subset of the tribe's actual history and the sample is skewed toward successful heads of household. Females are not included, nor are men who have no sons. Nonetheless, the genealogy data provides a partial view of the distribution of son counts of heads of household that allow us to make out-of-sample comparison between simulation output and real world data.

We compare this distribution to our simulation data, divided into heads of household and non heads of household (see Figure 8). Men without sons are excluded, just as they are excluded from the genealogical record. All three distributions are long-tailed indicating that it is more common to have a few sons than to have many. At face value we would also argue that the empirical data matches the set of heads of household more closely than non heads of household, which is a more asymmetrically shaped distribution with high positive skew and a high kurtosis. This is an encouraging result and strengthens our hypothesis that the genealogical record would be skewed toward heads of household.

In general it is difficult to extract consistent metrics from the kind of ethnographic information that we chose to use.[19] For example, Lindholm (1979, p. 488) states for Swat that patrilineal societies do not exhibit complex hierarchies. While it is intuitively intelligible what he means—only men pass identity down the genealogical line—it is difficult to accurately and precisely apply the statement to real data and thus include it as robust measure in the cross-validation process. The same applies for Lewis (1965, p. 92) who writes in a comparative perspective that tribes generally can be measured in terms of generational depth: The more depth there is, the stronger the patrilineal society is. What he refers to is the cultural idea of a "founding father". But there is no hint toward a robust metric that would allow to distinguish between what is a "shallow" and what a "deep" society.

As mentioned before, general accounts of what constitutes kinship (Read, 2001), how unilineal descent groups are organized (Fortes, 1953), and what contemporary polities look like in a tribal society (Lindholm, 1979) are of interest to us. Can we identify such patterns in our data?

Read (2002) uses four levels of social organizations, the first and second of which relate to non-human primate species. Beyond the first level all organizations are built from units of a lower level. To shift from the second to the third level, that is from a group to a societal group, the development of a shared belief system, a culture, is needed. Such a cultural representation is hardwired into the simulation by the matchmaker. Read also reports on the social organizations' characteristics. The

[18] The Imperial Gazetteer is accessible online through the Digital South Asia Library project of the Center for Research Libraries and the University of Chicago, `dsal.uchicago.edu/reference/gazetteer/`.

[19] But not impossible, see Fischer (2004)

patterns generated by our simulation should resemble those on levels three and four. Read (2002, p. 7252) reports that societies located on the third level are “composed of several residential groups, each of which may act as a corporate group with regard to resource ownership and access.” He continues that there typically “is no political structure or institutionalized position of power and authority.” Societies on the fourth level, he states, may exhibit such a centralized structure of power and authority. The type of clustered structures we describe and depict above as an emergent property can be seen as extended families and were they embedded in a geographic space would constitute a kind of residential unit. It is possible to anticipate how the head of household could successively institutionalize a position of power and authority with the ongoing of the simulation and the growth of society. This position could then also be interpreted as the epicenter of a common identity group.

Fischer (1994, p. 92) reports that marriage is used to consolidate status. It is hardwired into the simulation with fixed parameter values that agents can marry up and down. A further reflection of this principle is of course the idea that marriage is costly. Two phenomena emerging from the simulation can be related to this: First, the simulated population or parts thereof are sensitive on the macro-level to status consolidation (in the sense of inter-cast marriage). Too much or too little status consolidation leads to dominance of one group and disappearance of the other groups. Depending on how in- or exclusive are access rules to other groups in the simulation, the pattern will differ. Whereas Fischer (1994) refers to individual status consolidation, which we model, the simulation displays the emergence of consolidational processes on the inter-group level.

6 Conclusions

The aim of our research was to evolve, describe, and analyze kinship structures in a computational framework based on a common understanding of kinship mechanisms as reported in a case study. Technically, we demonstrated the development of a realistic social structure on the basis of qualitative data for modeling and simulation purposes. We showed how to use qualitative ethnographic data in computational modeling. We further showed that rigorously empirical model design as already hypothesized by numerous multiagent modelers, including Axtell, Bousquet, Geller, Janssen, Łatek, Moss, Mussavi Rizi and Ostrom, is an effective research strategy to produce computational models that are valid with regard to out-of-sample comparisons. This is even more noteworthy because much of the data we used to inform our model is inherently variable and fuzzy, yet plausible results are produced using a minimally sufficient model.

Against the backdrop of advances in generative social science theory and computational social science we might have given a fresh twist to a much debated aspect of kinship studies. White and Jorion (1996, p. 271) report having developed and empirically tested a new "relational conception" that does not forcefully separate marriage from descent and therefore circumnavigates endless arguments over their relative priorities (see also White and Jorion, 1992). Instead, they rhetorically ask whether marriage and descent are "one pair of instantiations" that are "relationally intertwined" or not (p. 271). Our approach to simply "grow" genealogical and marriage relations and the results of our simulation underline this standpoint. Beyond being simply a technical exercise, "growing" social structure includes significant reflection upon the case to be modeled, the data describing the case, the modeling techniques to be applied, and the model purpose. We found that the data is sufficiently rich in detail to enable us to create a sparse demonstrator model that reproduced kinship activities based on genealogy and marriage.

The original motivation to undertake this work, however, was different. Not only have social networks and their implications for individual behavior long been unrealistically and non-empirically represented in formal models of social systems; they have often been simply neglected. The consequences for social science research are severe, as the following brief discussion from conflict research will show. Kinship is extensively studied in qualitative approaches to armed conflict. Snyder (2003) reports in a survey article on anthropology and organized violence that the essential criterion for group cohesion and group establishment should not be territorial, but that the decision making autonomy lies at the level of unit identity. Patterns of armed conflict can therefore be affected by kinship systems (Ferguson, 1990). This is not to say that kinship is the defining factor of armed conflict, but it is an important *explanans* in the analysis of conflict patterns (cf., Salzman, 1978, 1983). This is no different for the case used to inform our model, the Swat Pashtun.

Tapper (1991, p. 45) reports for Durrani Pashtun social organization that all concepts of social grouping, including political structures, are influenced by the notion of patrilineal descent. Lindholm (1981) explains the structure of violence amongst the Swat Pashtun in terms of a quasi fractal pattern of ego–friend–enemy. Lindholm (1979, p. 488) notes that the "pervasive hostility between the sons of brothers led to the development of a network of alliances within every village that divided it across lineages into two approximately equal parties" that "are not formally structured", but are "simply a statement, couched in universal and abstract terms, of the fluid oppositions and alliances of individuals" (Lindholm, 1981, p. 151). A more general view on this is offered by the notion of *qawm* as an opportunistic solidarity space that consists of overlapping and non-exclusive solidarity networks. *Qawm* can mean extended family, tribe, descent group, ethnicity, "people like us" (Tapper, 2008, p. 101), "an occupational group" (Roy, 1992, p. 75);

or a discourse of solidarity applied in fluid ways to different groupings: A complex interpersonal "network" (Roy, 1992, p. 22) of political, social, economic, military, and cultural relations (Mousavi, 1997, Rasuly-Paleczek, 1998, Roy, 1995, Shahrani, 1998, Tapper, 1991, 2008). Since these meanings are not exclusive and static, *qawm* do not have clear boundaries nor do they divide society into mutually exclusive, stable groups. The system of *qawm* lends itself to concerted political purpose as in *wolus* for mutual support and *tayyfa* for political actions by a group (Tapper 1991, pp. 46-47), yet the amount of energy, prestige, and resources that flow into such an endeavor is considerable (Azoy, 2003).[20]

Despite the overwhelming qualitative evidence, an absurd debate in quantitative conflict studies about the role of kinship in shaping patterns of organized violence persists.[21] Fearon and Laitin (2003) find, to mention just one debate, that countries with more ethnic or religious diversity are not more prone to experience conflict and that other factors such as poverty, political instability, rough terrain, and large populations are better indicators for conflict onset. Their findings are supported by analysis for countries that are ethnically or religiously polarized. Cederman, Girardin, and Gleditsch (2009, p. 432) contest this view: Locating their study on the meso-level between aggregate state actors and individual agents they find that "border-crossing ethnic affiliations have a considerable impact on the likelihood of ethnonational civil wars." We are not in a position to solve this debate from a quantitative perspective, but we see our work as a contribution to refocus social science research on the problem and not have it driven by methodology in the first place (cf., Shapiro, 2007). Besides supporting to create a better understanding of kinship as part of dynamic social systems, we expect our work to have its broadest impact in this regard. More often than not, however, are underlying conflict factors, and perhaps causes, convoluted in character. Generative social science frameworks help to take some of these complications into account through exploring individual behaviors and actions, and social mechanisms that underlie reported relations and correlations. Understanding conflict implies developing an understanding for how social structures change, what behaviors and mechanisms are related to these changes, and what causes the changes (cf., Fischer, 1994). Knowledge of kinship mechanisms and patterns contributes to a better understanding of conflict in general. At the same time we would like to warn of a blind belief in modeling social structures in order to explain conflict. Social structures; thus kinship are emergent phenomena and cannot serve as explanations per se (Murdock, 1971).

We expect our research to have predictive value through the systematic analytic description of a social order and postulation of a pattern that has in itself

[20]Note that Azoy conducted his study in the North of Afghanistan amongst non-Pashtun people.

[21]Ethnicity is the term used in much of the conflict literature.

predictive power (cf., Lindholm, 1981). However, detecting or even predicting cleavages and alliances and how absolute they are in a social order is difficult, if not impossible, because ascribing meaning to kinship structures is contextually defined as instantiations of more general kinship classes. Meaning is also ascribed to organized violence depending on a variety of structural factors, including residential propinquity (Tapper, 1991, p. 46) and land pressure and territorial expansion (Lindholm, 1981, p. 153); idiographic factors, including historical circumstances and future opportunities; and normative factors like Pashtunwali (Janata and Hassas, 1975). Reification of concepts such as tribe, clan, and family lead to a false reliance on analytical concepts in vogue in current military and development efforts in Afghanistan and Pakistan.

References

Alam, S. J., R. Meyer, G. Ziervogel, and S. Moss (2007): “The impact of hiv/aids in the context of socioeconomic stressors: an evidence-driven approach,” *Journal of Artificial Societies and Social Simulation*, 10, 7, URL `http://jasss.soc.surrey.ac.uk/10/4/7.html`.

Axtell, R., R. Axelrod, J. M. Epstein, and M. D. Cohen (1996): “Aligning simulation models: A case study and results,” *Computational and Mathematical Organization Theory*, 1, 123–141.

Azoy, G. W. (2003): *Buzkashi. Game and power in Afghanistan*, Long Grove: Waveland Press.

Barth, F. (1965): *Political leadership among Swat Pathans*, London: Athlone Press.

Cederman, L. E. (2001): “Agent-based modeling in political science,” *The Political Methodologist*, 10, 16–22.

Cederman, L.-E. (2005): “Computational models of social forms: Advancing generative process theory,” *American Journal of Sociology*, 110, 864–893.

Cederman, L. E., L. Girardin, and K. S. Gleditsch (2009): “Ethnonationalist triads: Assessing the influence of kin groups on civil wars,” *World Politics*, 61, 403–437.

Degenne, A. and M. Forsé (1999): *Introducing social networks*, London: SAGE Publications Ltd.

Edwards, D. B. (1998): “Learning from the Swat Pathans: Political leadership in Afghanistan, 1978-97,” *American Ethnologist*, 25, 712–728.

Epstein, J. M. (1999): “Agent-based computational models and generative social science,” *Complexity*, 4, 41–57.

Epstein, J. M. (2008): *Generative social science*, Princeton: Princeton University Press.

Epstein, J. M. and R. Axtell (1996): *Growing artificial societies: Social science from the bottom up*, Cambridge: The MIT Press.

Evans-Pritchard, E. E. (1929): “The study of kinship in primitive societies,” *Man*, 29, 190–193.

Fearon, J. D. and D. D. Laitin (2003): “Ethnicity, insurgency, and civil war,” *American Political Science Review*, 97, 75–90.

Ferber, J. (1999): *Multi-agent systems: An introduction to distributed artificial intelligence*, New York: Addison-Wesley.

Ferguson, R. B. (1990): “Explaining war,” in J. Haas, ed., *The anthropology of War*, Cambridge: Cambridge University Press, 26–55.

Fischer, M. D. (1994): “Modelling complexity and change: Social knowledge and social process,” in J. Hann, ed., *When history accelerates. Essays on rapid social change, complexity and creativity*, London: The Athlone Press, 75–94.

Fischer, M. D. (2004): “Intergrating anthropological approaches to the study of culture: The “hard” and the “soft”,” *Cybernetics and Systems*, 35, 147–162.

Fischer, M. D. (2005): “Culture and indigenous knowledge systems: Emergent order and internal regulation of shared symbolic systems,” *Cybernetics and Systems*, 36, 735–752.

Fischer, M. D., D. Read, and S. M. Lyon (2005): “Introduction,” *Cybernetics and Systems*, 36, 719–734.

Fortes, M. (1953): “The structure of unilineal descent groups,” *American anthropologist*, 55, 17–41.

Geller, A. and S. Moss (2008): “Growing qawm: An evidence-driven declarative model of Afghan power structures,” *Advances in Complex Systems*, 11, 321–335.

Hedström, P. (2005): *Dissecting the social. On the principles of analytical sociology*, Cambridge: Cambridge University Press.

Hill, R. A. and R. I. Dunbar (2003): “Social network size in humans,” *Human Nature*, 14, 53–72.

Hirschfeld, L. A. (1986): “Kinship and cognition: Genealogy and the meaning of kinship terms,” *Current Anthropology*, 217–242.

Janata, A. and R. Hassas (1975): “Ghairatman—-Der gute Paschtune, Exkurs über die Grundlagen des Paschtunwali,” *Afghanistan Journal*, 2, 83–97.

Janssen, M. A. and E. Ostrom (2006): “Empirically based, agent-based models,” *Ecology and Society*, 11, 37.

Kuper, A. (1982): “Lineage theory: A critical retrospect,” in L. S. R. Parkin, ed., *Kinship and family: An anthropological reader*, London: Blackwell, 79–96.

Lewis, I. M. (1965): “Problems in the comparative study of unilineal descent,” in M. Bantom, ed., *The relevance of models for social anthropology*, London: Tavistock, 87–112.

Lindholm, C. (1979): “Contemporary politics in a tribal society: Swat District, NWFP, Pakistan,” *Asian Survey*, 19, 485–505.

Lindholm, C. (1981): “The structure of violence among the Swat Pukhtun,” *Ethnology*, 20, 147–156.

Luke, S., C. Cioffi-Revilla, L. Panait, K. Sullivan, and G. Balan (2005): “Mason: A multiagent simulation environment,” *Simulation*, 81, 517–527.

Malinowski, B. (1930): “Kinship,” *Man*, 30, 19–29.

Moss, S. (2008): “Simplicity, generality and truth in social modelling, part 1: Epistemology,” in *2nd World Congress on Social Simulation*, George Mason University, Fairfax, VA, USA.

Moss, S. and B. Edmonds (2005): “Sociology and simulation: Statistical and cualitative cross-validation,” *American Journal of Sociology*, 110, 1095–1131.

Mousavi, S. A. (1997): *The Hazaras of Afghanistan An historical, cultural, economic and political study*, St. Martin’s Press.

Murdock, G. P. (1971): "Anthropology's mythology," *Proceedings of the Royal Anthropological Institute of Great Britain and Ireland*.

Mussavi Rizi, S. M., M. M. Łatek, and A. Geller (2010): "Protocols for merging remote sensing data and population surveys in large multiagent empirically based models: The case of the afghan drug industry," Third World Congress on Social Simulation.

Radcliffe-Brown, A. R. (1941): "The study of kinship systems," *Journal of the Anthropological Institute of Great Britain and Ireland*, 71, 1–18.

Rasuly-Paleczek, G. (1998): "Ethnic identity versus nationalism: The Uzbeks of North-Eastern Afghanistan and the Afghan state," in T. Atabaki and J. O'Kane, eds., *Post-Soviet Central Asia*, London, New York: Tauris Academic Studies, 204–230.

Read, D. W. (1998): "Kinship based demographic simulation of societal processes," *Journal of Artificial Societies and Social Simulation*, 1, URL http://www.soc.surrey.ac.uk/JASSS/1/1/1.html.

Read, D. W. (2001): "What is kinship?" in R. Feinberg and R. Ottenheimer, eds., *The cultural analysis of kinship: The legacy of David Schneider and its implications for anthropological relativism*, Urbana: University of Illinois Press, 78–117.

Read, D. W. (2002): "Multi-trajectory, competition model of emergent complexity in human social organization," *Proceedings of the National Academy of Sciences*, 99, 7251–7256.

Roy, O. (1992): "Ethnic identity and political expression in Northern Afghanistan," in *Muslims in Central Asia: expressions of identity and change*, Durham: Duke University Press, 73–86.

Roy, O. (1995): *Afghanistan: from holy war to civil war*, Princeton: Darwin Press.

Salzman, P. C. (1978): "Does complementary opposition exist?" *American Anthropologist*, 80, 53–70.

Salzman, P. C. (1983): "Why tribes have chiefs: A case from Baluchistan," in R. Tapper, ed., *The conflict of tribe and state in Iran and Afghanistan*, New York: St. Martin's Press, 262–283.

Sawyer, R. K. (2005): *Social emergence: Societies as complex systems*, Cambridge: Cambridge University Press.

Schneider, D. (1984): *A Critique of the study of kinship*, Ann Arbor: University of Michigan Press.

Shahrani, M. N. (1998): "The future of the state and the structure of community governance in Afghanistan," in W. Maley, ed., *Fundamentalism reborn? Afghanistan and the Taliban*, London: Hurst and Co., 212–242.

Shapiro, I. (2007): *The flight from reality in the human sciences*, Princeton: Princeton University Press.

Shapiro, W. (2008): "What human kinship is primarily about: toward a critique of the new what human kinship is primarily about: toward a critique of the new kinship studies," *Social Anthropology*, 16, 137–153.

Simon, H. A. (1996): *The sciences of the artificial*, Cambridge: The MIT Press.

Smith, V. L. (2003): "Constructivist and ecological rationality in economics," *American Economic Review*, 93, 465–508.

Sneath, D. (2007): *The headless state: Aristocratic orders, kinship society, and misrepresentations of nomadic Inner Asia*, Columbia University Press.

Snyder, J. (2003): "Anarchy and culture: insights from the anthropology of war," *International Organization*, 56, 7–45.

Tapper, R. (1991): *Bartered brides - Politics, gender and marriage in an Afghan tribal society*, Cambridge: Cambridge University Press.

Tapper, R. (2008): "Who are the Kuchi? Nomad self-identities in Afghanistan," *Journal of the Royal Anthropological Institute*, 14, 97–116.

Troitzsch, K. G. (1993): "Mathematical modelling and computer simulation of social processes: Problems and a new solution," *Bulletin de Méthodologie Sociologique*, 40, 16–42.

Watts, D. J. (1999): "Networks, dynamics, and the small-world phenomenon," *American Journal of Sociology*, 105, 493–527.

Wendt, A. E. (2009): "The agent-structure problem in international relations theory," *International Organization*, 41, 335–370.

White, D. R. and P. Jorion (1992): "Representing and computing kinship: A new approach," *Current Anthropology*, 33, 454–463.

White, D. R. and P. Jorion (1996): "Kinship networks and discrete structure theory: Applications and implications," *Social Networks*, 18, 267–314.

Appendix: Parameter and Behavior Space Sweeps

We report in the Appendix sweeps for selected model parameters and behaviors. Note that we have introduced some randomness in the subsequent plots to the display of the dependent variables to make the graphs better readable. The ceteris paribus condition means that we kept all parameters/behaviors other than the dependent variable at the level indicated in Table 3.

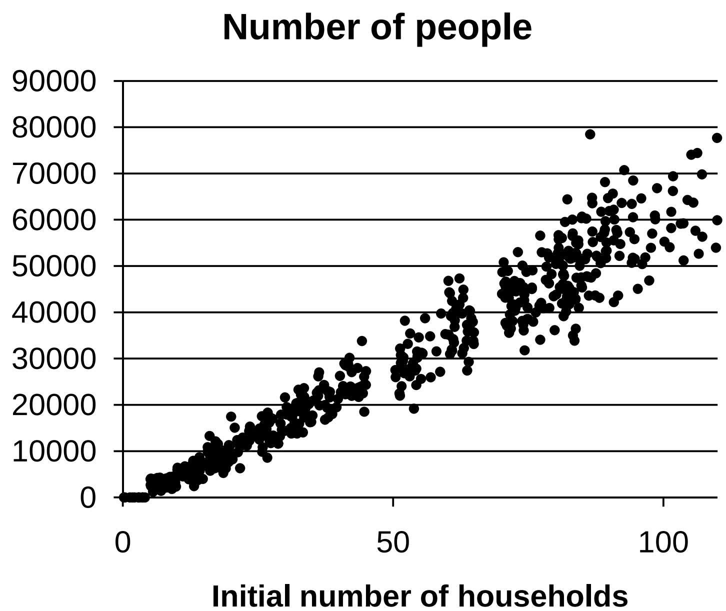


Figure 9: Parameter sweep for initial number of households. Ceteris paribus, we ran at minimum 10 simulations for each initial value for number of households, starting with 0 and ending with105 households at increments of 5 and 10. As expected, a larger initial number of households leads to a larger average population size over time. The relationship between initial number of households and population size is almost linear. Currently, the carrying capacity of the system is capped by an exogenously defined system size; in an open system—which for example would include an economy—we would expect the population size to reach a dynamic equilibrium.

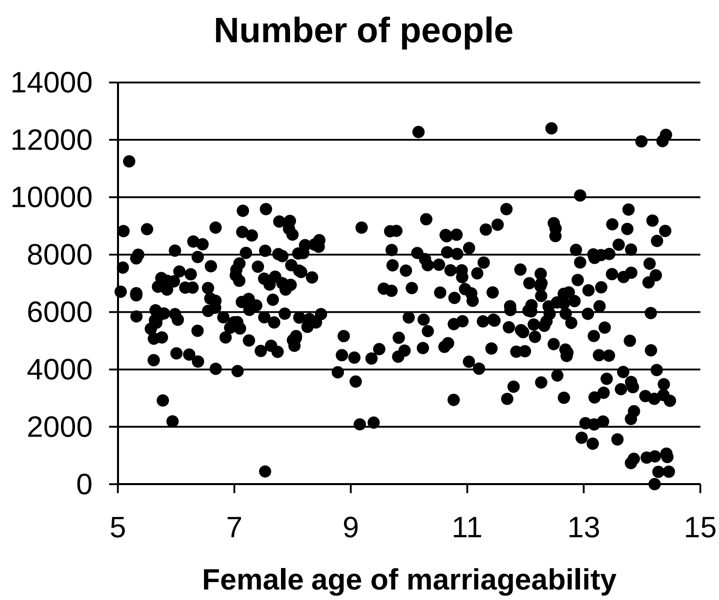


Figure 10: Parameter sweep for female age of marriageability. Ceteris paribus, we ran at minimum 10 simulations for each initial value of female age of marriageability. No significant effect on the size of the population can be observed. The reader should bear in mind that population size depends also on child bearing age and available men.

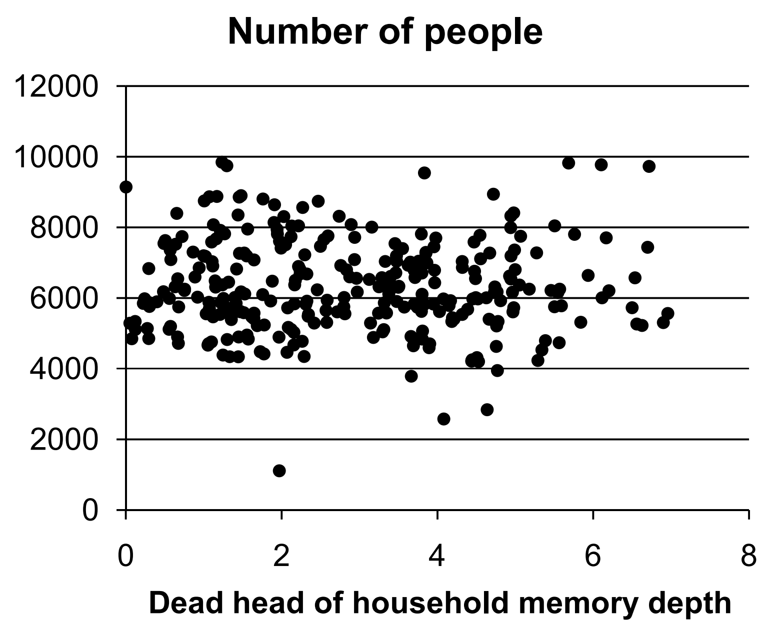


Figure 11: Parameter sweep for the time period dead heads of household are remembered. Ceteris paribus, we ran at minimum 10 simulations for each value for the time period dead heads of household are remembered, i.e. 1, 2, 3, 4 and 5. The length dead heads of household are remembered has no observable effect on the size of the population. This is good because in Table 3 parameter 14 is a an educated guess.

Figure 12: Parameter sweep for amount of bride price. Ceteris paribus, we ran at minimum 10 simulations for bride price amounts between 0 and 100,000 at intervals of 10,000. As expected, an increasing amount of the bride price leads to a decrease in population size. Households simply cannot afford marrying off their sons anymore.

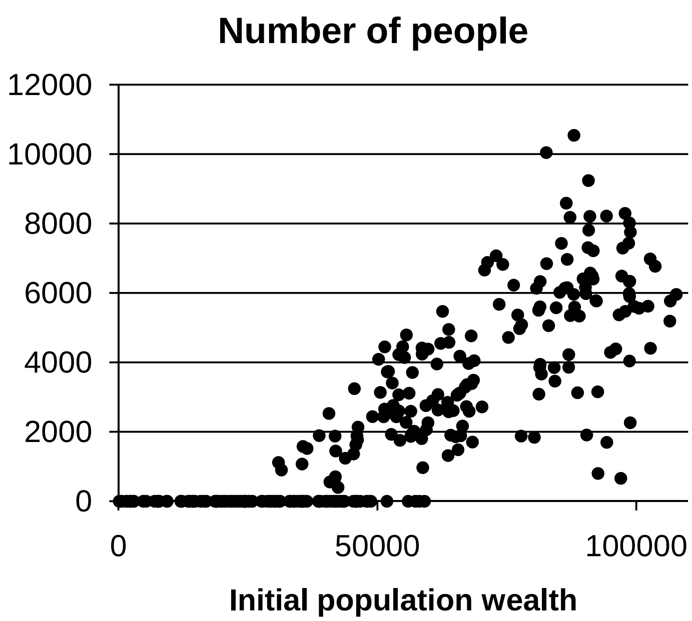


Figure 13: Parameter sweep for initial household wealth. Ceteris paribus, we ran at minimum 10 simulations for initial values for household wealth from 0 to 110,000 at increments of 10,000. As expected, increasing household wealth leads to increasing population size. Richer households can afford to marry off more of their children. Figure 13 shows also that in the model low household numbers lead to populations that die out.

Average population		Initial population wealth									
		10000	20000	30000	40000	50000	60000	70000	80000	90000	100000
Bride price	10000	2521	3257	11597	21352	24793	30570	31825	46491	54549	58002
	20000	1784	2942	5145	8185	11721	12164	18415	20702	24438	26039
	30000	626	1253	4309	6095	8274	6355	8280	9104	13595	15520
	40000	0	2312	3559	3796	6304	6704	7389	7682	9829	12459
	50000	558	0	0	1527	2816	4374	6875	7239	7577	8498
	60000	0	0	0	1023	2545	2661	4644	5737	5961	6968
	65000	0	0	0	523	865	3123	4355	5300	5580	5899
	70000	0	0	0	0	0	0	2708	3768	4743	5941
	80000	0	0	0	0	0	0	0	1671	3563	5947
	90000	0	0	0	0	0	0	0	2306	2997	5428
	100000	0	0	0	0	0	0	0	0	2199	3559

Figure 14: Effect of changes in initial population wealth and bride price on average population: The unidimensional effects observed in 12 and 13 are confirmed also here.