![JASSS logo]

Shah Jamal Alam, Armando Geller, Ruth Meyer and Bogdan Werth (2010)

Modelling Contextualized Reasoning in Complex Societies with "Endorsements"

Abstract

In many computational social simulation models only cursory reference to the foundations of the agent cognition used is made and computational expenses let many modellers chose simplistic agent cognition architectures. Both choices run counter to expectations framed by scholars active in the domain of rich cognitive modelling that see agent reasoning as socially inherently contextualized. The Manchester school of social simulation proposed a particular kind of a socially contextualized reasoning mechanism, so called endorsements, to implement the cognitive processes underlying agent action selection that eventually causes agent interaction. Its usefulness lies in its lightweight architecture and in taking into account folk psychological conceptions of how reasoning works. These and other advantages make endorsements an amenable tool in everyday social simulation modelling. A yet outstanding comprehensive introduction to the concept of endorsements is provided and its theoretical basis is extended and extant research is critically reviewed. Improvements to endorsements regarding memory and perception are suggested and tested against a case-study.

Introduction

1.1   When not the focus of research, agent reasoning is seldom adequately theorized in agent-based social simulation applications. Whereas "how" an agent reasons is part of the neuro-scientific and psychology domains, the question "What do agents reason about?" is inherently socio-scientific. The Manchester school of social simulation proposed a particular kind of a socially contextualized reasoning mechanism - henceforth called *endorsements* - to implement the cognitive processes underlying agent action selection that eventually causes agent interaction. Endorsements have been applied for example by Alam and Meyer (2010), Geller and Moss (2008), Moss (2000), and Werth (2010). Endorsements capture a subjective, but socially embedded agent's reasoning process about cognitive trajectories aimed at achieving information and preferential clarity over another, endorsed agent. The approach's usefulness lies in its lightweight architecture and the fact that it takes into account folk psychological conceptions of how reasoning works. In other words, the advantage in applying endorsements is that they allow for combining the efficiency properties of numerical measures with the richness and subtleties of non-numerical measures of interest or belief. These and other properties make it an amenable tool in everyday social simulation modelling.

1.2   Endorsements provide an alternative to more heavyweight cognitive architectures such as ACT-R and Soar, which are computationally too expensive for multi-agent simulations (Kennedy, Rouleau and Bassett 2009). Endorsements are not intended to compete with other concepts such as Simon's (1996, 1991) bounded rationality (or Bratman's (1987) version thereof, i.e. Belief-Desire-Intention) and Hayek's notion of propensity (1973) for endorsements loosely orient themselves on these very ideas.[1] Endorsements contrast, however, crude conceptualizations of rationality and psychometric metrics such as Likert (1932) scales.

1.3   In short, while endorsements are meant to be more than just a mere "modelling experience aiming at incorporating qualitative knowledge in ABM," as one reviewer of this article put it, there is no intention to represent with them anything close to neuro-scientifically informed cognition. Endorsements do not

compete with ACT-R, Soar, and the like. However, they pick up important concepts from the cognitive sciences, such as frequency (Petrov 2006), latency (Petrov 2006), modularity (Sperber and Hirschfeld 2004), and contextuality (DiMaggio 1997). Through the notions of modularity and contextuality endorsements also provide a space to deliberate about the content of reasoning, in the case at hand what agents reason about.

1.4 Arguably the two main shortcomings of endorsements is a lack of dependence on historicity and that they do not reflect socio-cultural categories. The first main contribution of this paper is to propose two technical solutions to these lacunae and to test them by computational implementation of a model for real case study of dyadic relationships in the village of Tzintzuntzan, Mexico. The implementation also serves as a demonstration that endorsements are a feasible way of introducing explicit and sometimes "lifelike" reasoning into agent-based modelling (Barthélémy 2006;Taylor 2006;Werth 2010) that is at times in accordance with literature in the cognitive sciences (e.g. DiMaggio 1997; Sperber and Hirschfeld 2004). Endorsements afford researchers to implement software agents as plausible representations of real world actors and enhance the design of agents to perceive events specified by qualitative descriptions, maintain the qualitative terms during processing these qualitative perceptions and then act in ways that can be characterized qualitatively. Ideally, but not exclusively, qualitative data is used in conjunction with endorsements. The concept of endorsements is integrated into a declarative simulation framework. Endorsements provide a concept to capture the way agents would reason about rich and socio-culturally grounded evidence-based data. Although we critically concede that endorsements as plausible representation of real world actor cognition have limitations, we articulate their usefulness in the analysis of emergent socialites in a large variety of social contexts.

1.5 On a more subliminal but not less important level, we wonder whether rich cognitive models could also lead to better grounded, that is, more complete explanations of social phenomena, and perhaps also to more accurate anticipations of future behaviour. Focusing on *what* agents reason about in order to make a decision requires a dimensional analysis of an agent's decision space that includes the agent's context. Questions concerned with a dimensional analysis such as who is preferred over who, why and when, provide essential insight into social relations and their underlying causes, and in a broader sense into the social structure an individual is embedded in. From a social simulation perspective, reasoning about social relations becomes "completer" only if it includes reasoning about the reasoning that underlies the emergence of social relations.

1.6 Being an applied concept, endorsements have not been thoroughly enough theorized as to be used in a social simulation context (though its foundations have; see Cohen 1985). The second main contribution of this article is to make up for this lapse and to provide a comprehensive introduction to the concept of endorsements by theorizing about it in more definite terms and giving a brief overview of some applications of the concept (Section 2). A critical account of the concept of endorsements and its applications is given in Section 3, which also serves as transition into this article's core: two critical improvements of the endorsement concept. In Section 4, we demonstrate an application of the suggested improvements to an agent-based model of "dyadic exchange" in Tzintzuntzan, primarily based on Foster's fieldwork and discuss this modelling experience of incorporating and reasoning about qualitative data in social simulation.

What endorsements are, and how and when they are applied

2.1 Interactions between two and more agents are an essential element in agent-based social simulation models. The conceptualization and computational implementation of these interactions must be based on certain information. This can be knowledge an actor has about another actor; it can be an actor's past experiences; and/or it can be an actor's socio-cultural situatedness. Endorsements provide an intuitive way of computationally implementing agent reasoning about this kind of information.

2.2 Endorsements were introduced by Cohen (1985) as a device for resolving conflicts in rule-based expert systems (Moss 1998). Endorsements can be used to describe cognitive trajectories aimed at achieving information and preferential clarity over an agent or object from the perspective of the endorsing agent itself. We use endorsements in this sense, namely to capture a process of reasoning about preferences and the establishment of a preferential ordering (Moss 2000; Moss and Edmonds 2005).

2.3 Given that endorsements capture the reasoning process of one agent, the *endorser*, about another agent, the *endorsed*, the information collected by the endorser is of a subjective nature. Endorsements can be considered as labels, which agents use to describe certain aspects of other agents. These can be affirmative and even positive like is-kin, is-neighbour, is-friend, similar, reliable, and capable, or non-affirmative and even negative like non-kin, unreliable, incapable and untrustworthy. Some endorsements are static in that, once identified, they do not change over the course of the simulation (e.g. is-kin), while others are dynamic and may be revoked, replaced, or dynamically adapted according to an agent's experiences. To assess endorsements, agents rely on

a so-called endorsement scheme, which associates each label with a weight to express how much value an agent assigns to this particular aspect related with another agent. Weights are modelled on an ordinal scale as integer numbers between *1* and *n* for positive labels and *-1* and *-n* for negative labels, respectively. This allows for computing an overall endorsement value *E* for an agent as depicted in Equation (1) where *b* is the number base and w_i is the weight of the ith endorsement token.

$$E = \sum_{w_i \geq 0} b^{w_i} - \sum_{w_i < 0} b^{|w_i|}$$
(1)

2.4 A social scientific interpretation is that the base *b* represents an agent's general disposition. This can be an indicator for an agent's nature, e.g. extreme or moderate; it should also be, as we will argue later, an indicator for the agent type or role, such as academic, businessperson, sport star, etc. The weights *w*, on the other hand, define the importance of the context, therefore assigning more or less weight to the base depending on a particular situation. Formally, *E* for an agent with Role *R* in a situation *x* is given by b_x^w; *E* for an agent with Role *R* in a situation *y* is given by b_y^w.

2.5 From a processual perspective, the endorser's endorsement scheme is projected onto the endorsee. If an agent A_1 wants to evaluate whether an agent A_2 should be endorsed or not, A_1 has no objective base to rate A_2 and its labels respectively and to make a decision based on this information. What A_1's individual endorsement scheme tells A_1, however, is how important some or all of A_2's labels are for A_1. If this is done for each of the endorsed agent's labels, *E* for the endorsee, in the given example A_2, can be calculated according to Equation (1).

2.6 *E* allows the endorser to choose the preferred one(s) among a number of agents it endorses. The process of choosing an agent is embedded in an agent's context, i.e. the agents visible or known to it. Relying on endorsements allows an agent to find the agent most appropriate to it within its context. This implies that the chosen agent may not be preferable to differently embedded agents with a different endorsement scheme. Figure 1 depicts this in that two agents, A_{12} and A_{13}, are in the process of endorsing a third agent, A_1. Both A_{12} and A_{13} have different contexts and different endorsement schemes, which influence their decision whether to endorse A_1 or not.

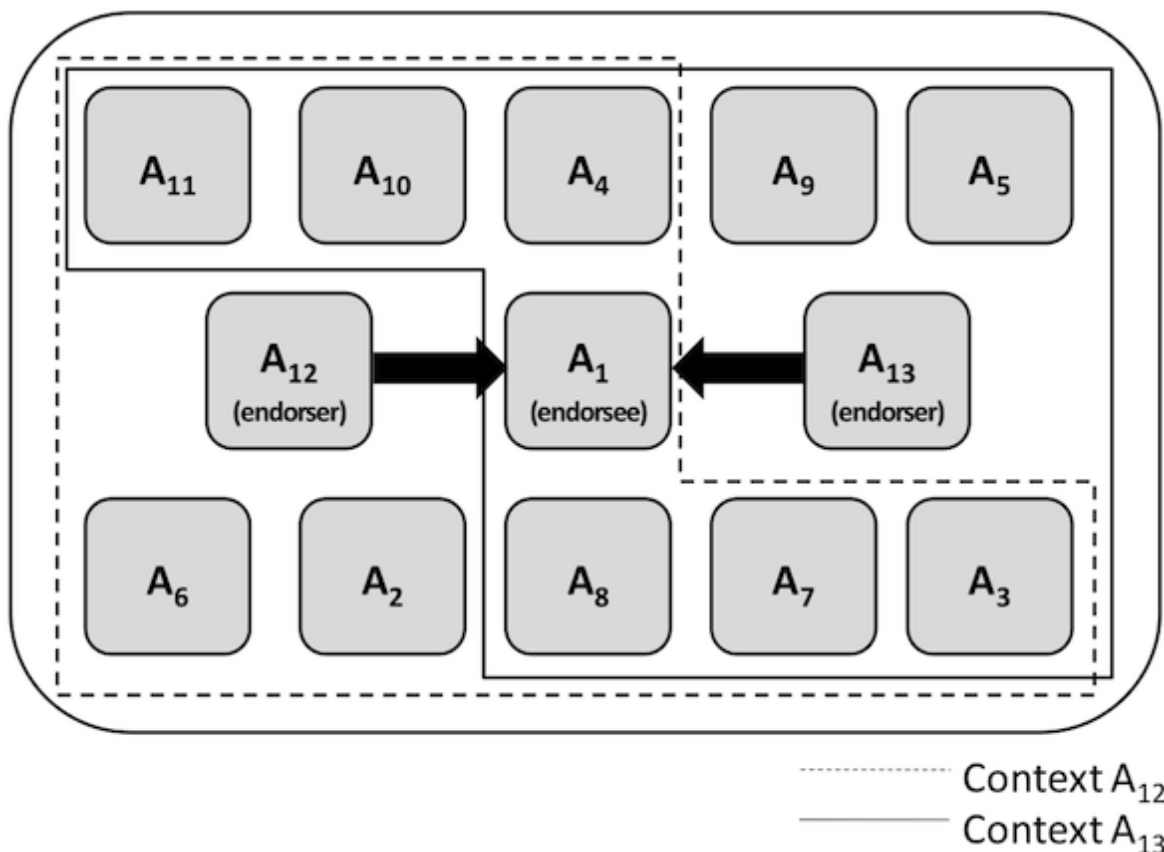Context A_{12}
Context A_{13}

Figure 1. Schematic representation of the embeddedness of the endorsement process.

2.7 Typically, agents are assigned endorsements schemes at creation, which may differ not only in the

weights they assign to the labels but also in the absolute values used for *b*. Whether endorsement schemes are assigned completely randomly or in randomized, but empirically based manner is at the researcher's discretion. Interestingly, the idea to represent reasoning in such a category-like way finds succours in neuro-scientific research. Sperber and Hirschfield (2004) report on how cultural categories correspond to the organization of human cognition into cognitive modules. And DiMaggio (1997) explains on the basis of plenty of evidence how culture - context, to use an even broader term - influences cognition and through it behaviour.

2.8 When applied to evidence-driven modelling, endorsements are often used in conjunction with a declarative modelling framework (Barthélémy 2006; Geller and Moss 2008; Taylor 2006). We denote as evidence information about the target system that allows informing a computational model of reality that can claim representativeness. This information can for example stem from case studies, empirically tested theories, and interviews with subject matter experts and stakeholders. In order to avoid bias and to ensure a model's validity, the triangulation of these information sources is encouraged. A model can be considered to be evidence-driven if the agents themselves, the agent reasoning, and the rules according to which agents behave are informed using this information. The presupposition thus is that the data makes concrete declarations of who the actors are, how and what they reason, and how they behave in specific social situations or across situations and cases.

2.9 More than other simulation approaches, evidence-based modelling pursues construct validity across different levels of analysis. It is important that the modelled processes and structures resemble the processes and structures identified in the target system (Boero and Squazzoni 2005). Thus, agent-based social simulation models are more than mere input-output models. Congruent with critical realism (Bhaskar 1975) and analytical sociology (Hedström 2005) the analytical focus instead lies on agency and structure and how the two bring about social reality.

2.10 Simulation results gain in credibility if evidence-based social simulation models are "cross-validated" (Axtell and Epstein 1994; Axtell et al. 1996; Moss and Edmonds 2005; Windrum, Fagiolo and Moneta 2007) and not only matched against circumstantial evidence. There are three validation strategies that should ideally be used in combination with each other: I) If models generate numerical output, such as time-series and adjacency matrices, the output is analyzed statistically or with social network analysis techniques and the resulting signatures are compared with signatures obtained from target system data; ii) The data generation mechanisms in the simulation and in the target system should be compared to each other. Systematic structural and processual similarities between the model and the target system are to be uncovered. The goal is to validate the model internally and to therefore ensure its construct validity.[2] iii) Circumstantial evidence existing in the target system should also be identified in the simulation.

2.11 A program is declarative if facts and rules are used to model target system behaviour. Facts describe the system state or, if used in agent-based simulations, the agents' potential knowledge about the system. Rules are used to produce new facts and delete or alter existing facts. In other words, to manipulate the agents' knowledge, each rule consists of a set of conditions and a set of actions to be performed when there are facts that match the conditions. The sequence of rules that will fire, and the particular facts that will match them, are determined only as the program is running. The sequence of actions represents the process of agent behaviour and leads in each case to a new state of the environment.

2.12 As is the case for all agent-based models, also in declarative models, agents will be changing the state of the environment for one another and the pattern of rules and therefore actions of all of the agents taken together will be influenced by one another. The outcomes for the model as a whole are in these circumstances impossible to predict with any exactitude. Frequently, such models exhibit the sort of episodic volatility associated with complexity. The same effect can be achieved by other means, but declarative representations of agents have a number of virtues in terms of ease of development as new evidence becomes available and in terms of yielding comprehensible outputs. Most important, one could simulate complex conditions in an imperative model, but it would likely require a series of conditional statements inside a main update function. This is especially the case when agents take decisions in circumstances of dense and mutually dependent social connectedness. Thus, in some of the subsequently mentioned applications, the Java Expert System Shell[3] (JESS) was chosen as a tool to incorporate the declarative approach into the modelling process.

2.13 By now in a variety of modelling exercises researchers made use of endorsements. In his study of e-commerce and value chains Taylor (2006) aims at computationally capturing the attitudes, perceptions and behavioural patterns observed in customers and other trading partners. He reports that endorsements allowed him to initialize the model with qualitative data and to maintain a "natural" data structure throughout the modelling process. Barthélémy (2006) considers in his study on household water demand endorsements a suitable implementation strategy because they allow to process information according to the problem domain's nature, origin, and individually weighted subjective value. The decisions agents make are based on a subjective perception of the situation. Alam and Meyer (2010) used endorsements to evolve dynamic social networks in a model of

HIV/AIDS in a South African village. The decision to form friendship ties is based on randomly assigned abstract tags that represent character traits and endorsements, such as *same-gender, similar-age, and same-church.* Geller and Moss (2008) report on a model of power structures in Afghanistan using the endorsement concept and developing an endorsement scheme for a typical "Afghan agent" based on interview and secondary data. Besides being helpful in implementing an evidence-driven reasoning scheme endorsements also allowed the authors to overcome statistical data scarcity. In his research on outsourcing of information technology and services Werth (2010) demonstrates that the use of endorsements helped him to implement a reasoning process for vendors and clients that is close to the evidence provided by the interviewed stakeholders and that stands in contrast to theories prominent in the field.

2.14 The brief overview of applications shows that endorsements are used most often where the existence of rich qualitative evidence adds additional insight to the pursuit of a research question. Being more than a mere "modelling experience", they are an amenable tool in everyday social simulation modelling.

Improving the Concept of Endorsements

Heterogeneity of Endorsement Schemes

3.1 In the models introduced in the previous section, all agents possess structurally equal endorsement schemes. Of course, each individual agent's endorsement scheme exhibits individual values for b, the number base, and w_i, the weight of the ith endorsement token. Implementations of homogeneous endorsement schemes led to acceptable simulation results, despite being a simplification.

3.2 Structurally, homogeneous endorsement schemes tilt towards the same weakness as statistical models in that that they neglect the heterogeneity of social reality. Different agent types possess different roles and functional characteristics and should therefore also be equipped with a cognitive structure that explicitly corresponds with their type. Agents are embedded in distinct endorsement cosmos and care about certain endorsements more than they do for others.

3.3 The solution for the above problem is to avoid assigning random endorsement weights w_i to the agents and instead assign weights that are in accordance with a particular agent type.[4] For instance, we assume that a businessperson in the Afghan model (Geller and Moss 2008) is most sensitive to not being paid in full and not being paid on time, it would consider the reliable endorsement as more important and therefore will have a higher weight than the rest of the endorsements, e.g. religion or ethnicity. Furthermore, depending on the social situation an agent is embedded in, weights may take on different values. For example, an Afghan businessperson might consider reliability as important in a professional situation, but may find it is less important in a religious context, where "hope" is more important to the businessperson. Figure 2 illustrates such a typified and weighted endorsement scheme.
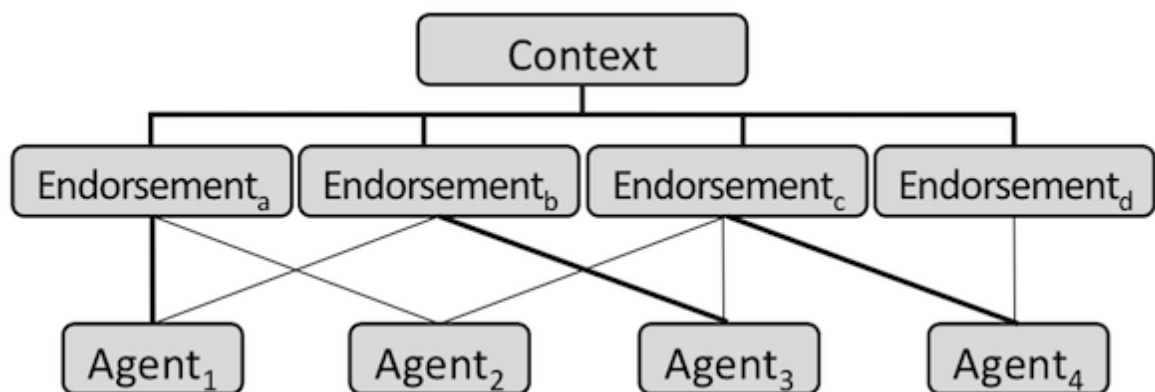

Figure 2. Typified and heterogeneous endorsement scheme. The weight of the lines indicates the importance of an endorsement for an agent.

3.4 Although the endorsement weights w_i remain randomly assigned, they are now assigned within a numerical range, which represents a particular agent type. This range should be ideally derived from evidence. Additionally, each agent type may have a different subset of the overall set of endorsement tokens. Expressed more formally, agents may acquire different roles { R_1, R_2, ... $R_{i,b}$ } in a model. Their bases b then correspond to R { R_1, R_2, ..., $R_{i,b}$ } → { b_1, b_2, ..., b_i }. Depending on the social situation S an agent is embedded in { S_1, S_2, ..., S_n }, the individual weights { w_1, w_2, ... w_i } an agent assigns to a particular label change. Thus, similar to the correspondence $R → b$, we find { S_1,

$S_2,..., S_n$ } → { $w_1, w_2, ... w_i$ }. Expressed differently, if we have agent A of the agent type q in context u, then the number base is b_q and the weight w_u leading to $b_q^{w_u}$ when inserted in Equation (1). However, if the same agent A is embedded in context v, then, when inserted in Equation (1), we get $b_q^{w_v}$.

Continuous Data Formalization

3.5 The applications of endorsements as presented in Section 2.13 do not adequately represent the dynamic character of cognitive processes (Maturana 1970). So far the endorsement process is founded on a discrete (i.e. non-continuous) assessment of the endorsee's endorsements: Only the most recent endorsement tokens are considered. Consequentially, an agent's cognition is based on a binary perception of the environment, which may lead to undesirable results. For example, in Werth (2010) the model missing a temporal dimension in the assessment of clients' satisfaction with vendors' performance over the transaction cycle led to several problems. The dyad of exchanging partners endorses each other constantly during the whole period of a transaction. In the case of the client, this models the constant monitoring of the vendor's performance and compliance to clients' requests, and in the case of the vendor it models the monitoring of the payment duties. In the current implementation, it is not possible to express a mediocre satisfaction with the transaction or a satisfaction grade, which would change with respect to the number of performance measures below/above a certain performance threshold.

3.6 In the case of the Afghan model, the static conception of endorsements leads to a misrepresentation of inherently non-static endorsements, e.g. loyal/disloyal, reliable/unreliable, successful/unsuccessful. These endorsements should depend on an agent's historicity. An endorser can endorse an endorsee only as being loyal if it has a point of reference that lies in the past and that enables it to compare a previous state with the current state, or if it can estimate the (positive or negative) trend of a number of previous states.[5]

3.7 Here we suggest an improved procedure that allows for a continuous formalization. We track the temporal evolution of each (dynamic) label by accumulating individual values over time. For example, a positive endorsement results in adding 1, while a negative endorsement results in subtracting 1 from the current accumulated value. If no endorsement takes place in a particular time step, the accumulated value remains constant. This is closely related to a procedure proposed by Petrov (2006) for the declarative memory in ACT-R. In ACT-R, declarative memory is organized in chunks, which get activated according to a base-level activation parameter that depends on the frequency and lateness of use. Thus, the less often and the less recently a memory chunk was used, the less likely it is that it will be activated again. Chunks that are used more frequently grow stronger than chunks that are infrequently used. The default decay parameter in ACT-R is 0.5 (Petrov 2006). The accumulation of individual values of E over time corresponds to the idea of "growing chunks" (Petrov 2006). Over time, issues become more or less predominant in the perception of agents. The mechanism with which they become more important depends on frequency and it being recent; the mechanism with which they become less important depends on the default decay parameter (0.5).[6]

3.8 Figure 3 shows the accumulated progression of a particular label for two different agents over time. When choosing between these two the discrete endorsement evaluation process (dashed) relies on a historic and binary data collection, as it only samples one point in time. The continuous evaluation process (solid), on the other hand, applies a time window and thus relies on experience and multi-valued data sets. Experience presumes that an agent possesses a "memory" that allows it to collect endorsement data over time as if it would gain knowledge. The time window models an agent's "memory"; its size and decay factor may be chosen randomly from a numerical range or based on empirical data - the later being preferred by the authors - in order to allow for agent heterogeneity. The collection of multi-valued data implies that the endorser not only increases knowledge of the endorsed agent on the basis of dichotomous variables i.e. is loyal/is-disloyal or is generous/is stingy, but also builds up the knowledge on the basis of aggregated data.
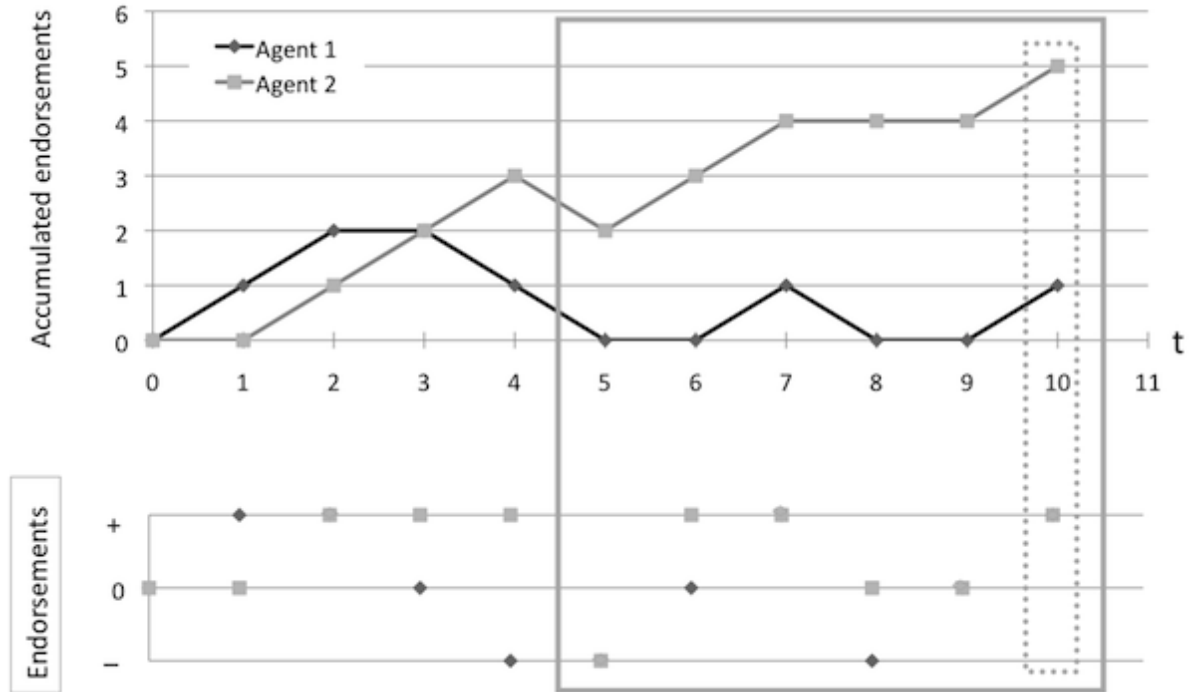
Figure 3. Schematic representation for Agents 1 and 2 of discrete (dashed) versus continuous (solid) endorsement evaluation process.

3.9   Whereas an endorser fitted with a discrete endorsement evaluation process must rely on the information stemming from one synchronous sample in time, an endorser fitted with a continuous endorsement evaluation process can rely on a (multi-dimensional) string of data representing information that has been accumulated over time. Rather than basing an endorsement decision on synchronous information, the agent can base it on a trend and experience. Figure 3 depicts this idea and Equation (2) formalizes it:

$$E_{cont} = \sum_{j} E = \sum_{j} \left(\sum_{w_i \geq 0} b^{w_i} - \sum_{w_i < 0} b^{|w_i|} \right) = \sum_{j} \sum_{w_i \geq 0} b^{w_i} - \sum_{j} \sum_{w_i < 0} b^{|w_i|} \quad (2)$$

3.10   The continuous evaluation process is a more "natural" way to model human cognitive behaviour and adequately represents individuals that are equipped with memory and who can recall past interactions with other actors.

🌎 Godparents, Family, Friends and Neighbours in Tzintzuntzan

The case

4.1   To test the suggested improvements we choose a sufficiently detailed and appropriate case-study that allows testing for the effects the introduction of heterogeneous endorsement schemes and continuous data formalization have on the simulation results.

4.2   Foster (1961) studied the Mexican village of Tzintzuntzan. Tzintzuntzan is a relatively isolated peasant society with a population of about 1800 individuals.[7] Socially and economically, Tzintzuntzan is predominantly homogeneous. There are no social classes. Most families earn their living from pottery-making and small-scale farming. The basic social unit is the nuclear family. There is little functional need for extended kin or other larger cooperative groups. Tzintzuntzan is also "at a particular technological point which maximizes the need for an effective nuclear family and minimizes the need for larger cooperative groups." (p. 1181). There are no factions in Tzintzuntzan. Relationships with outsiders and with neighbouring villages are not of long-standing nature. Neither is landownership a major function in the village nor is made extensive use of kinship. In fact, the village's policy and control remains in the hands of outsiders. There is no need for functional groups.

4.3   One might wonder what it is that keeps Tzintzuntzan together. "About all the Tzintzuntzeño asks from his system, and about all he gets, is a modicum of personal, economic, and emotional security which rests primarily on dyadic ties within the village and secondarily on similar ties with people outside the village" (p. 1178).

4.4   Every Tzintzuntzeño organizes his social contacts that go beyond the nuclear family of father,

mother and children on the basis of informal dyadic contracts, in which goods and services are continually exchanged. These contracts are built upon a number of social institutions, i.e. extended family, neighbours, friends, and the highly regarded *compadrazgo* (godparent system). Taken together, they constitute a pool from which a person may choose potential partners. The parents and godparents of their children form a *compadre* relation, which is perceived in high regards in the Tzintzuntzan society and the contracts formed among the villagers.

4.5   All such contracts are implicit, in that they lack ritual or legal basis, and reciprocal. They exist only on the basis of the pleasure of the contractants and are valid only as long as the contractants continue to exchange goods and services. The goods and services that are exchanged are tangibles. "The favor or act simultaneously repays a past debt, incurs a future obligation, and reaffirms the continuing validity of the contract binding the partners." (p. 1187)

4.6   In the long run, reciprocity is complementary. Each partner in a dyadic relationship owes the other the same kinds and quantities. In the short run, however, the exchanges are not complementary. The contracts seize to exist when one or both of the contractants stop reciprocating. Note that Tzintzuntzan is not a gift-giving society; rather, it is a *quid pro quo*. As Tzintzuntzeños are able to calculate over the long run how much goods and services they provided and how much they received (pp. 1174-1176).

4.7   This system of a few select contracts enables the Tzintzuntzeños to deal with an otherwise overwhelmingly sumptuous system of social ties and obligations. No matter whether with family, friends or neighbours, the dyadic relationship prevails. "These contractual ties are the glue that holds his [a Tzintzuntzeño's] society together and the grease that smoothes its running." (p. 1176)

Case-study implementation

4.8   The model implementation follows Foster's (1961) case study and the subsequent fieldwork by anthropologists such as Brandes (1979), Foster et al. (1979) and Kemper (1982). The model represents actors from the case study as individual agents. The village in the model is initialized based on the household composition reported in the literature. Typically, the majority of the households consist of a nuclear family that is a married couple living with their children. The rest are characterized as "joint households" where two or more married brothers are living in the same house with their parents and unmarried siblings. Initially, houses are placed randomly on a non-toroid grid representing the village. A household's neighbourhood is determined by the existence of other households within a defined radius on the grid. This reflects Tzintzuntzan, where households on the border of the village are likely to have fewer neighbours. The size of the agent population depends upon the initial number of households, which is a model parameter. Married couples form new households after marriage. Households without inhabitants are removed.

4.9   Kinship ties are randomly initialized so that the neighbour and kinship ties are overlapping. Similarly, *compadrazgo* ties are initialized by randomly assigning godparents to children. Following Foster (1965), adult agents from different households are assigned as godparents and if an adult agent is married then both, husband and wife, become godfather and godmother, respectively. Children in a nuclear family may have different sets of godparents. *Compadre* ties are assigned between parents and their children's godparents. Unlike the kinship and compadrazgo ties, an agent's friendship network changes over time depending upon its endorsement scheme.

4.10   Agents use endorsements to categorize and assess their acquaintances. Both static and dynamic endorsements are applied, reflecting the nature of the social ties in Tzintzuntzan. Neighbour, kin and *compadre* are static endorsements. Friend, reliable/unreliable and contract are dynamic endorsements, meaning that they can be assigned to and retracted from an endorsee. The breaking of a contract is weighed negatively by agents and lessens the chance for the establishment of future contracts between past contractants. Additionally, there is a personal preference based on the *similarity* of traits. These personal traits are modelled as abstract tags (Alam and Meyer 2010; Moss 2008).

4.11   A time step in the model corresponds to a week. By default, a simulation runs for 30 years (1500 time steps; 1 year in the model equals 48 weeks). The model is implemented in Java using the Repast 3.1 (North, Collier and Vos 2006) and CERN's Colt libraries. The parameter list and the simulation schedule are presented in the Appendix. The model's source code is publicly available on the Google Code Repository under the BSD License.[8]

Model structure

4.12   Agents in the model represent individuals primarily characterized by gender, age, and marital status. Agents grow old during simulation and remain socially active during their lifetime. Life expectancy for male and female agents is modelled according to World Health Organization life tables for 2006 for

Mexico. We assume that all agents are fed adequately. There is no explicit representation of agents' health status and requirement for food. Agents follow the profession of their parent households, such as farming, pottery, and other work with initial proportions of 15%, 75%, and 10% respectively (Brandes 1983). Each agent in the model experiences birth, engagement, marriage and death. Baptism and communion, two other important events in the life of a Tzintzunzteño, are not modelled.

4.13 Children agents are born to married mothers only. Birth is only possible if the agent mother is pregnant and a year has passed since last delivery. The number of births per simulation year is bounded by the annual birth rate (47.3 per 1000 people) for the Michoacán region in central Mexico (Lopez et al. 2006). Fertility range by age for female agents is from 16 to 45 years (Jansen 2003). Each model week female agents are randomly selected and give birth according to the constraints mentioned.[9]

4.14 Marriage is a key event in the social life of the people of Tzintzuntzan. It provides a natural way to extend one's dyadic exchange network by means of the *compadrazgo* system. The majority of the marriages result from elopement (Foster 1965). A bride almost always runs away with the groom by consent. The marriage is then formally approved by the couple's parents and/or godparents (Foster 1965). The random marriage pattern reported in Schnegg and White (2009) suggests a lack of preferential rules such as endogamy or exogamy. In the model, we assume that a male and a female agent engage sexually in a random way given incest prohibitions.[10] Agent grooms are either of similar age or older than the bride (Brandes 1968), with a preference for spouses with similar age (see Appendix). Marriages in the model are strictly monogamous and there is no divorce. Following the Catholic traditions prevalent in Tzintzuntzan. Marriage in the model results in patrilocal residence. Married female agents remain related to their maiden household, maintaining links with her extended family (Foster 1963). In the model, the wife's maiden household and the husband's household endorse each other as relatives.

4.15 The time that passes between elopement and marriage is determined by drawing a random number from a normal distribution (Brandes 1983; see Appendix). Elopement also triggers a married brother to decide on when in the future to build his own nuclear household (Brandes 1979; Foster 2002). This results in either the married brother moving with his family to their own house before his brother's marriage or the two brothers living together with their families in their parents' household for some time. With Brandes (1979) we assume that the youngest brother remains with his parents and inherits the parents' house. Foster (1961) explains that a son's decision to find a dwelling near his parents' house depends upon how well he gets along with his other siblings, if any, as well as the existence of an affinity between his wife and his mother. In the model, decisions made by the married sons to find a location for their houses that is near their parent's house depend upon the similarity of tags (representing personal traits) between brothers and the similarity of tags between the wife and her mother-in-law.

4.16 Parent agents chose godparents on the basis of relevant endorsements. Ideally, godparents are a married couple with the same social status with some possibility for a future commercial tie between the *compadre* (Foster 1969). Deviations, however, are commonly observed (Foster 1969). The "ideal" criteria and the observed deviations are implemented in the model by assigning contextualized weights to relevant endorsements. For instance, agents in our model exhibit higher weights on endorsements such as same-status, married, friend, reliable or expect-commercial-tie, when they choose *compadre*. They may use different weights for the same endorsements at other situations, such as, when making friends or exchanging services/goods with them.

4.17 Godparents are chosen from either of the parents' side although Foster reports a slightly bigger proportion from the father's side. We assume that godparents are chosen with equal probability from the mother's and the father's side. It is likely that the same potential godparents are chosen by the parents depending upon their respective endorsements' weights. Marriage godparents in the model are chosen by either the groom's or the bride's parents (see Appendix). This ties the married couple's parents with the couple's godparents as *compadres* and expands the *compadrazgo* network (Foster 2002).

Dyadic exchange in the model

4.18 The described model's underlying social structure, the structure's purpose, and the reason it exists is closely tied to a system of exchange prevalent in Tzintzuntzan. Exchange of services and goods are modelled as dyadic contracts (Foster et al. 1979). "Each person is the centre of his private and unique network of contractual ties, a network whose overlap with other networks has no functional significance. That is, A's tie to B in no way necessarily binds him to C, who also is tied to B. A may have a contractual relationship with C as well as B, but this does not give rise to a feeling of association or group." (Foster 1967:215) Foster further explains that the existence of a contract is realized by a continued exchange of goods and services, sharing food, exchanges in rituals and fiestas, the only functional requirement being that an exact balance is never struck over the long run.

4.19 The exchange of services and goods is modelled assigning individual timers for agents that when activated trigger an individual to send goods or services. As Foster (1963:1293) reports, a Tzintzuntzeño "tries and tests" its potential contacts before selecting a few from the pool of available social ties. There are two types of dyadic ties: horizontal contracts ("colleague") and patron-client relationships (Foster 1967). We model only horizontal contracts. Within the boundary of these contracts, agents perform three types of exchanges: ordinary goods/services, fiesta services, and responding to the invitation for a *rite de passage* occasion.

4.20 Ordinary services/goods in the model are meant to represent day-to-day exchange between individuals, especially between friends and *compadres*, such as lending a helping hand, exchange of foods or offering a drink. Each agent selects a number of friends (including neighbours) and *compadres*, on the basis of the endorsements for this type of exchange. "The formal institutions of Tzintzuntzan present each individual with a near-infinite number of people whom he has culturally defined bonds implying mutual obligations and expectations. But no individual could possibly fulfil all the roles imposed upon him by the statuses he occupies in his village's institutions; he is forced to pick and choose, to concentrate on relatively few. [...] The individual by means of the dyadic contract mechanism, selects (and is selected by) relatively few with whom significant working relationships are developed." (Foster 1967:215)

4.21 The time between two offerings of goods/services by an agent is modelled using an exponential distribution with a mean intermediate time of 2 weeks. We implement two models for selecting the recipients for this type of exchange. In the first model, an agent selects the top 20-40% from the combined list of friends of *compadres*. Individuals from this combined list are then chosen with a probability that is in proportion to their endorsement value. Thus, an individual who has a high endorsement value is more likely to be offered a service/good than agents with a low endorsement value though agents with low endorsement values also have a chance to get chosen. This reflects the idea that Tzintzuntzeños try and test acquaintances in advance for possibly establishing an exchange tie. We implement this using the RangeMap structure from Repast 3.1. In the second mode (default setting), an agent chooses its possible contracts strictly based on the endorsement values in descending order (see Appendix).

4.22 The second type of exchange represents services/goods offered at the time of rituals and fiestas. Based on Brandes (1983) we assume 6 to 8 fiestas happening per year. At these fiestas agents offer their goods/services to *compadres* and a few chosen friends and relatives. The implemented mechanism is the same as in the case of the day-to-day exchange described above except that we assume that several fiestas reoccur within a year and that the values associated to the services/goods are higher than those offered in the day-to-day exchange.

4.23 Agents also respond by means of exchange of goods/services in the event of birth, marriage, and death amongst their acquaintances. Notice that in the two mechanisms mentioned above the time for sending a good/service is modelled as separate exponential clocks for each adult agent. Here, the timing of birth, marriage and death depends endogenously on the model's processes and whether and how an agent is being invited to the occasion of a *rite de passage*. The *compadrazgo* network involves a much wider range of obligations than the routine exchange of favours and services in the village. A godfather takes the responsibility of the baptismal and communion arrangements of his godson/-daughter. *Compadres* are invited to dinners, and are expected to render support in fiestas arrangements and occasions of ritualistic and religious nature (Foster 1967, 1969).

4.24 Godparents are chosen at *rites de passage* in an individual's life. We model two occasions in which an individual's godparents are selected by their parents: birth and marriage (see also Appendix). The role of godparents at birth and marriage and the services that are expected from them are explained by Brandes (1968) and Foster (1969). Birth godparents are expected to arrange for a child's birth celebrations and oversee baptism. They are also expected to settle matters between the two families when elopement occurs. Marriage godparents usually take care of the wedding arrangement and expenses, while birth godparents arrange for a small feast at the wedding. Also, birth godparents arrange for funeral if the godchild dies at young age. These services, as Foster explains, are part of the dyadic exchange between the godparents and the parents of a child. The value associated with these services as well as those of the other exchange types are arbitrary.

4.25 In summary, we assume that goods and services are tangible and have associated values. If an exchange is established between two agents, reciprocity is complimentary in the long-term, i.e., each agent in a dyadic tie offers goods/services of similar value to another agent. This may be interpreted such that each partner expects similar kinds and quantities of things in the long run. Each partner in a dyad maintains a history of past exchanges, with different recall durations (memory) of past exchanges. Table 1 summarizes the exchange types implemented in the model.

Table 1: Summary of exchange types used by the agents between their contractual partners in the model

Exchange Type	Summary
Godparent obligations	Godparent's services and bearing expenditure at the event of baptism, settling elopement, wedding, and funerals of godchildren.
Contributions to births, weddings and funerals	Contributions of services and goods in cases of birth, wedding and funeral of selected few (or contractants) and their children.
Ordinary goods/services	Between friends, *compadres* and neighbours
Fiestas and rituals goods/services	Between *compadres*, relatives, and friends

4.26 A summary of the implemented rules and their source from Foster (1961) is provided in Table 2. We chose to inform agent rules as much as possible by the evidence available to us.

Table 2: Rules adapted from Foster (1961)

ID	Rule description	Page	Rule implementation
1.0	*Generic rules*		
1.1	Reciprocity (reciprocal obligation): If alter gives ego something, then ego reciprocates.	1174 1177 1181 1176 1185 1174 1176	• Who do I select to give to? From the primary social unit, i.e. *compadrazgo*, friend, neighbour (locality as the primary social unit), and from the extended family • What (how much) do I give? Similar goods and services of approx. equal value (measured in time and monetary terms). "[…] formally calculated yet somehow weighed so that in the end both partners balance contributions and receipts. In the usual situation each member of the dyad simultaneously counts a number of credits and debits which are kept, over time, in approximate balance." • What do I expect? Similar goods and services of approx. equal value (measured in time and monetary terms; reciprocity)
1.2	Exchange of goods and services	1176	• Continual • Until contract ends
1.3	Make contract	1178 1176 1174 1179	• Between pairs of individuals only (dyad) • The symbolic meaning of this contract is accepted by all villagers • Establish a bi-directional link • Even marriage is a dyadic contract (as a result of elopement). Thus, marriage is modelled randomly
1.4	End contract	1176 1185	• As long as it is "validated" by the other side • When ego and alter are "even"
2.0	*Nuclear Family*		
2.1	Incorporation	1179	• Randomly mating (elopement)
2.2	Cooperation	1180	• Cooperation
2.3	Dissemination	1185	• Death

3.0 *God parenthood (compadrazgo)*		
3.1 Becoming godparents	1182 1181 1182	• Formal establishment of a contract between the *compadres* and the godchildren and between the *compadres* and the godchildren's parents. The latter is the more important relationship • At birth, communion, and marriage
3.2 End being godparents	1183	• The ties only uphold when maintained in the sense of the dyadic contract (see rules 1.1 and 1.2)
3.3 Commercial relationship resulting from *compadrazgo* network	1182	• A number of *compadrazgo* result in commercial relationships
4.0 *Friendship/Neighbourhood*		
4.1 Selection criteria	1183	• Choose from a set of surrounding agents
Become a neighbour	1183	• Depending upon physical propinquity
Become a friend	1183	• Being chosen from the set of neighbours • Length of the dyadic relationship (see rule 1.1 and 1.2)

Endorsement schemes implemented in the model

4.27 Three different endorsement schemes instead of one single scheme with randomly assigned weights are implemented. A friendship-selection scheme is used by agents to select friends from their acquaintances (comprising of relatives, neighbours and *compadres*). A different set of endorsement labels and their corresponding weights is used by agents in the *compadre*-selection scheme in order to choose their *compadres*. In order to offer services or goods, agents choose "a few" from their relatives, *compadres*, and friends/neighbours. This preferential selection is performed based on the third endorsement scheme, the dyadic-exchange scheme. Table 3 summarizes the three endorsement schemes. The corresponding weights assigned to the agents are drawn randomly from the ranges specified in the table.

Table 3: Endorsement schemes implemented in the model with corresponding endorsements and weights

Static	Friendship selection	*Compadre* selection	Dyadic exchange
Relative	U(-1,1)	U(0,2)	U(0,2)
Sibling	U(-1,1)	U(1,3)	U(0,2)
Neighbour	U(0,3)	N/A	N/A
Compadre	U(1,3)	N/A	U(1,3)
Godparent	N/A	N/A	U(1,3)
Godchild	N/A	N/A	U(1,3)
Married	N/A	U(2,3)	N/A
Shared interest	U(1,3)	U(0,2)	N/A
Same gender	U(3,5)	U(1,3)	N/A
Same age	U(3,5)	U(1,3)	N/A
Same profession	N/A	U(0,3)	U(0,3)
Same status	N/A	U(2,5)	U(1,3)
Above status	N/A	U(0,2)	U(0,2)

Different gender	U(-3,0)	U(-3,-1)	U(-3,-1)
Different age	U(-5,-2)	U(-3,-1)	N/A
Different profession	N/A	U(-3,-1)	U(-3,-1)
Below status	N/A	U(-3,-2)	U(-3,-2)
Dynamic			
Friend	N/A	U(2,5)	U(0,2)
Intense	N/A	U(1,3)	U(1,3)
Similar	U(1,3)	N/A	N/A
Commercial tie	N/A	U(0,3)	U(1,3)
Not-intense	N/A	U(-2,0)	U(-3,-1)
Dissimilar	U(-1,0)	N/A	N/A
Past friend	U(-3,-1)	N/A	N/A

4.28 We classify endorsements into two distinct categories: static endorsements and dynamic endorsements (Geller and Alam 2010; Geller and Moss 2008). Static endorsements are labels that once assigned, remain unchanged. For instance, a person's nuclear and extended family ties are given and are not by choice. On the other hand, dynamic endorsements may change over time depending upon the interaction history and the individual endorsement scheme.

4.29 In the model, relatives and siblings are the relations that an agent is assigned at the time of creation, in addition to nuclear relationships such as parent, spouse and offspring. The dyadic exchange built by an agent is beyond its nuclear family; hence, only the siblings and relatives (from the extended family) are relevant in our case (Foster 1969). These relations are given to an agent who may use them in building friendship and *compadre* ties from a pool of relatives. Agents may choose their other acquaintances as *compadre* and friends when expanding their network of contacts, or may opt for reinforcing already existing extended-family ties when selecting them as *compadre* (Foster 1969). Following Foster's (1969) observation, weights for relatives and siblings endorsements in the *friendship-selection* scheme are set low. For at least half of the agents, endorsements may contribute nothing or serve as negative preference when it comes to choosing one's friends. The idea is to expand an individual's opportunities of contractual ties beyond the existing kinship network.

4.30 Neighbours, according to Foster (1961), may be friends; a phenomenon that may be reflected by the weights in the friendship-selection scheme. Notice that the agent's neighbours in the model may change when a married son builds his own house or when a female agent moves to her husband's house after marriage. Change in agents' lists of neighbours thus depends upon the location of the new house.

4.31 The *compadrazgo* relation increases the chance for a pair of agents to become friends over time. As mentioned before, Foster (1969) describes "ideal" godparents to be married couples and those of same social status as parents. The corresponding weights for being married, same-status/above-status is thus set as high for selecting a *compadre*. On the other hand, agents in the model have a high positive bias for being same-gender and similar-age, when it comes to endorsing their acquaintances as friends. Likewise, there is a high negative bias for opposite gender and difference in age in the friendship-selection endorsement scheme. Those with the highest endorsed values are chosen as friends depending upon the maximum number of friends an agent can have at a time (a model parameter).

4.32 From the dynamic endorsements, the similar and dissimilar endorsements depend upon the similarity in agent tags (bit strings) representing personal traits. Through a small probability, agents tend to get closer to their acquaintances over time, and thus there is some chance, albeit small, that an agent may endorse another as similar where it may have endorsed the other as dissimilar in the past (and vice versa). Representation of tags and the evolution of tag propensity are adapted from Moss (2008).

4.33 Each agent in the model possesses a memory that allows it to collect endorsement data over time as if it would gain knowledge. The time window models an agent's memory. Its size may be chosen randomly from a numerical range in order to allow for variety among different agents (see Appendix). Memory recall implies that the endorser does not only increase its knowledge of the endorsee on the basis of most recent exchange, but is building up its knowledge on the basis of the aggregated data.

4.34 A challenging aspect of the model is to model and intensify (in terms of exchange) dynamic endorsements. Even more challenging is to model the choice mechanism, i.e. how agents choose their dyadic exchange partners. Currently, agents recall past exchange history based on a small time

window (default: 6 months on average) in determining the intensity of their ties with others (see Appendix). This time window is sampled from a lognormal distribution and therefore varies in the population. Agents count the sent and received goods/services over this time period when determining whether their relationship, e.g. friendship with another agent is intense or not. Agents do not distinguish between types of goods/services in the model (see Table 1). "The forms can be examined in terms of services and goods offered and reciprocated in ritual and non-ritual settings. These lines are not hard and fast in the minds of Tzintzunzeños, however, and a material return in a non-ritual setting may help counterbalance a service previously offered in a ritual setting." (Foster 2002)

4.35 In Tzintzuntzan, people chose compadrazgo also based on the expectation that a relationship can evolve into a long-standing commercial relation (Foster 1961: 1183). Expectation of an evolving commercial-tie depends upon whether two agents belong to the same-profession and same-status and whether they have similar traits.

Simulation Results

4.36 Figure 4 shows the average population growth and the number of households for 10 simulation runs for 1500 time steps (approximately 30 years). The number of initial households in Figure 4 and in Figure 5 is set to 150. Note that the population growth in the model is dependent upon the birth rate and the WHO life tables for Mexico. This is further constrained by processes concerning elopement and subsequently marriage of a couple and the bounds for agents' marriage and fertility age. Marriage and elopement of a sibling, as mentioned before, trigger a household development cycle, when a nuclear family living in a joint household builds its own house in the village. Households without head of household or members are removed. The population growth rate and the number of households from the simulation scale correspond at face value with descriptions in Brandes (1983) on what has been termed "caricature" level by Axtell et al. (1996), that is the model - or aspects thereof - is in qualitative agreement with empirical macro-structures.
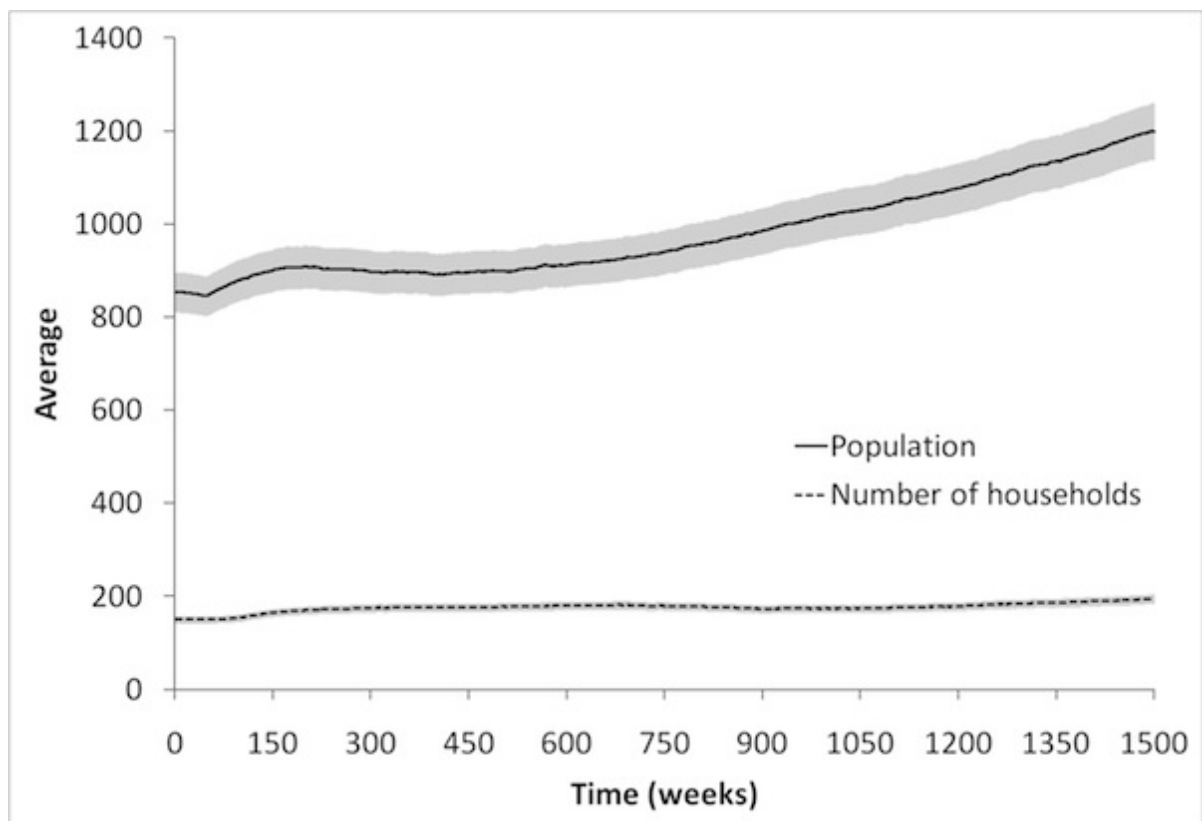

Figure 4. Average population (solid line) and average number of households (dashed line) with 95% confidence interval shown in gray for 10 simulation runs with 150 initial households.

4.37 Figure 5 depicts the average number of nuclear and joint household types taken from the data used in Figure 4. We assumed that 80% of the initial households are of the nuclear type and that the rest is of the joint household type. Note that the average number of nuclear households declines during the initial phase of the simulation due to a greater number of eligible female and male agents being able to get married, which results in patrilocal residence of the married couple. The number of agents that are single and eligible for marriage declines around the middle of the simulation. This is the time where agents elope and await to marry given the time lag between elopement and marriage. Moreover, those born during the initial phase of the simulation become eligible for marriage at the age

of 16. We therefore see a decline in the number of nuclear households first and then an increase in the later phase of the simulation.
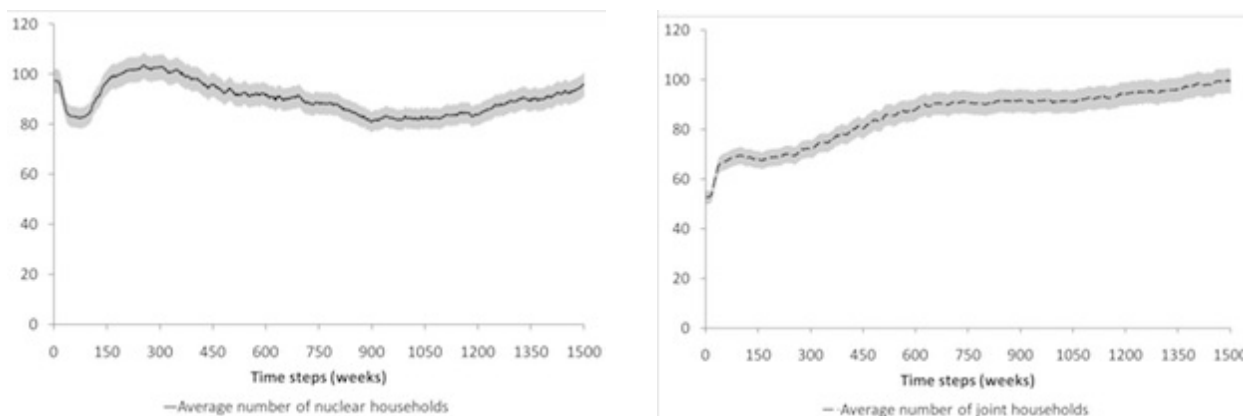

Figure 5. Average of nuclear (left) and joint (right) household types with 95% confidence interval shown in gray for 10 simulation runs with 150 initial households.

4.38 In what follows we explore six cases in which the suggestions made afore are tested. We implement two types of memory recall for the agents, a simple counting of past exchanges and a nonlinear recall based on the logistic distribution. We implement two different endorsement evaluation modes, namely discrete and continuous. We also implement the assignment of weights according to a context or randomly to three endorsement schemes. Table 4 summarizes the settings used in the six cases.

Table 4: Summary of the settings used for recall type, evaluation mode, and weight assignment in six test cases

	Recall type	**Evaluation mode**	**Weight assignment**
Case I	Simple count	Continuous	Contextualized
Case II	Nonlinear recall	Continuous	Contextualized
Case III	_	Discrete	Contextualized
Case IV	Simple count	Discrete	Random: U(0,3)
Case V	Simple count	Discrete	Random: U(0,3) +/- sign
Case VI	Simple count	Continuous	Random: U(0,3) +/- sign

4.39 In cases I, II and III we use the contextualized weights for the endorsement schemes that are listed in Table 3. In cases I and II the continuous evaluation mode is used. In case I the simple counting and in case II the nonlinear recall is used. In case III the discrete evaluation of endorsements is employed, i.e. an agent takes into account only the endorsements made in the previous time step. In cases IV and V endorsement weights are randomly assigned to endorsement schemes. The evaluation mode in these cases is chosen to be discrete. In case IV all endorsements are assigned random weights from Uniform (0,3). In case V positive and negative weights sampled from Uniform (0,3) and corresponding to the positive and negative endorsements respectively are assigned. Finally, in case VI we employ the same weight assignment procedure as in case V but with the continuous evaluation mode.

4.40 In the "simple count" recall type, accumulation of endorsements over time is done linearly (i.e. +1 for a positive and -1 for a negative endorsement). In the nonlinear recall, we assume a cut-off based on the logistic distribution, after which adding another +1 or -1 would not make any difference. Unless specified, the default parameter values used are the same as mentioned in the previous section and in the Appendix. Agents decide whether their exchanges are intense or not-intense depending on their memory recall ("just" counting or using a logistic distribution). We assume that the period of recall of exchanges for the agents is on average 12 months with a standard deviation of 3 months. The number of initial households for these simulation runs is 100.

4.41 In all the implemented endorsement schemes in this model, agents calculate the endorsement values of persons known to them over time. Figure 6 shows the distribution of the number of time steps (in years) agents use for calculating the cumulative endorsement values for the three endorsement schemes described in the previous section. For every agent in the simulation, this is assigned from the lognormal distribution, with an average of approximately 7.8 years (kurtosis 0.844; skewness 0.139).
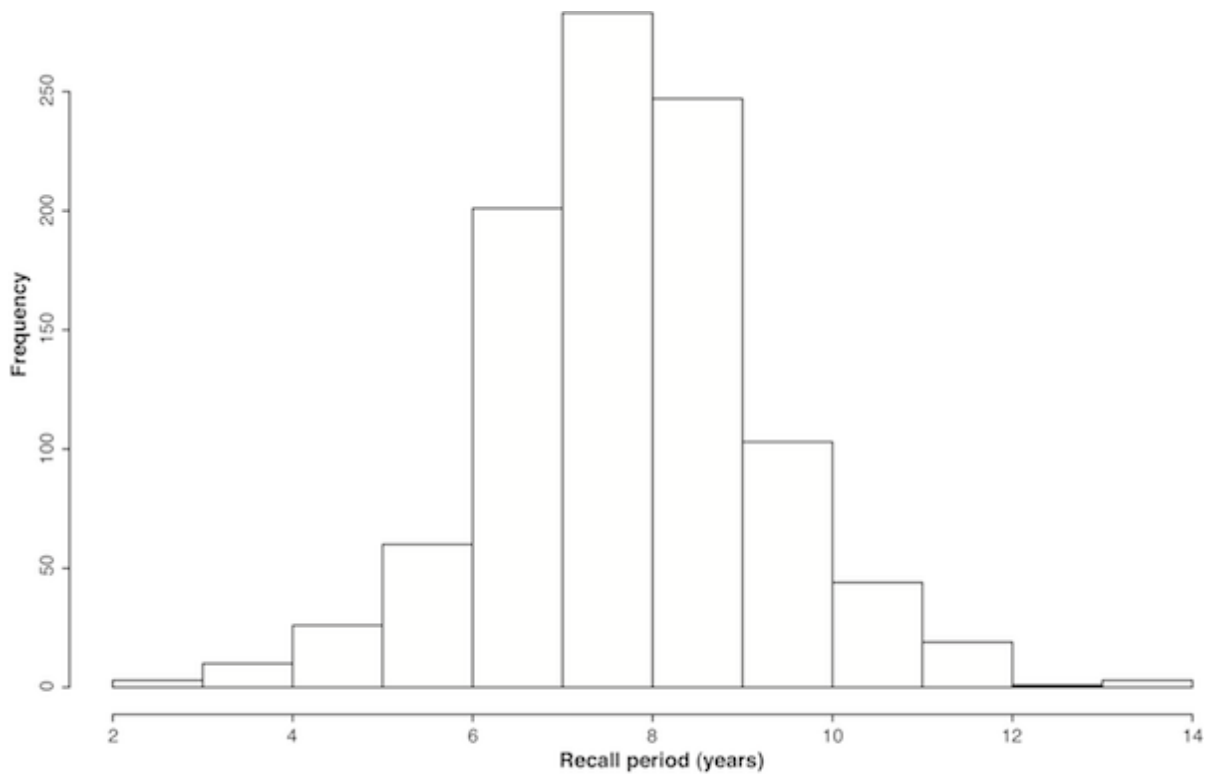
Figure 6. Frequency distribution of the time (in years) that agents in the model use in evaluating the endorsement values of their known persons (acquaintances).

4.42 Figure 7 shows the average number of *compadres* in the model for 10 simulation runs for the six cases described above. Notice that we include only those agents that are either married or widowed and that have at least one *compadre* at a particular time step (week). This is because *compadres* in the model are sought at the time of a child's birth or marriage of an offspring. Agents who never married or are childless do not have *compadres*.
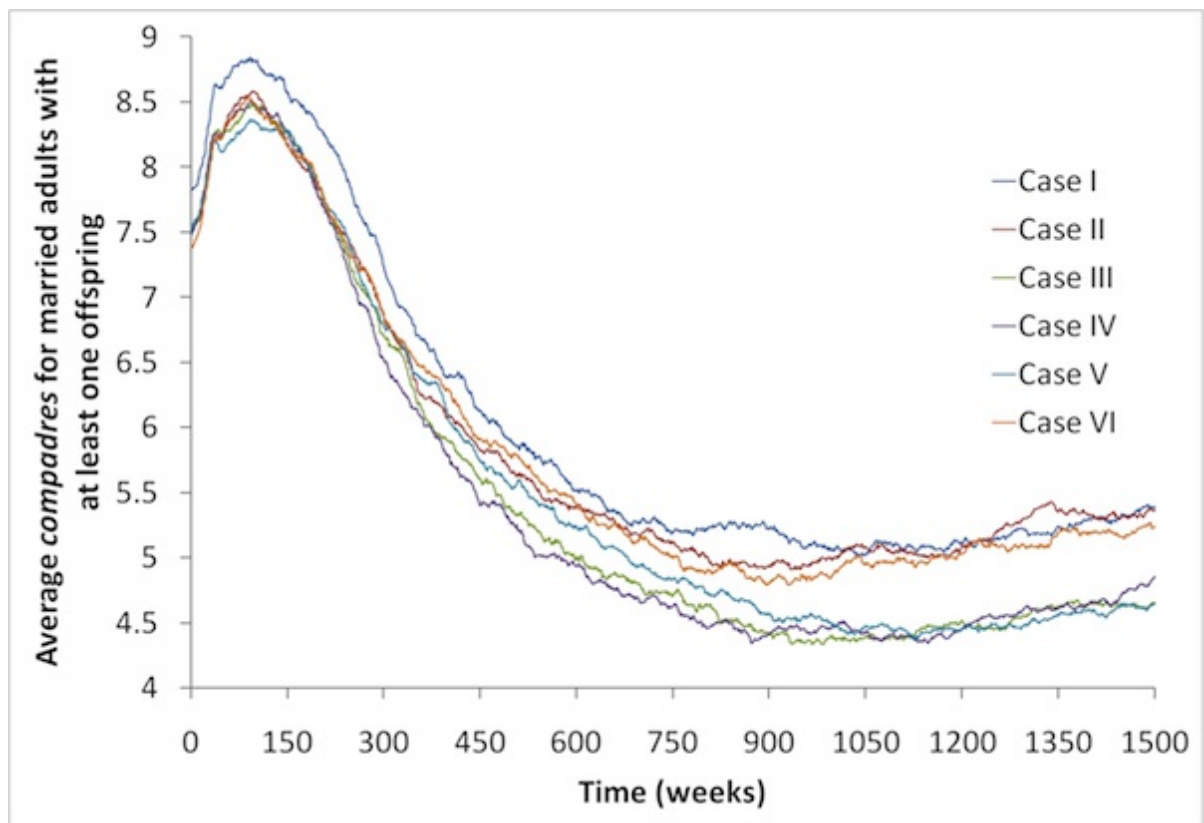

Figure 7. Average of the agents' *compadres* for the six cases for 10 simulation runs.

4.43 As Figure 7 shows, the average number of *compadres* for cases I and II were higher than the other cases concerning discrete time step evaluation of the endorsement values (i.e. cases III, IV and V). Comparing cases I and II, there is an absolute difference of about 10% for the average number of

compadres; case II being lower than case I. This is because in case II, where agents use a nonlinear recall, a smaller number of past exchanges are recalled by the agents. Or in other words, agents are likely to "forget" those exchanges occurred in the distant past within the time window of their memory recall. In both cases I and VI, the agents recall every single sent and received goods/services in the recall period. It thus increases the likelihood of choosing agents with whom an existing exchange is not intense.

4.44   Regarding discrete versus continuous evaluation of endorsements, one sees a clear distinction in the average number of *compadres* between cases I, II, VI (continuous) and cases III, IV, V (discrete), in particular when considering the latter half of the simulation runs. Although case VI uses randomized weights, it is still contextualized in terms of the positive and negative signs corresponding to the cases I and II. On the other hand, in cases concerning the discrete evaluation mode, the static endorsements are likely to contribute mostly as determinant factors behind the selection of godparents for off springs; thus, there is a higher likelihood for the existing *compadre* to be selected as *compadre* again.

4.45   While agents reinforce their existing *compadre* ties by making their existing *compadres* godparents for further offspring, choosing new agents as compadres (i.e. without existing or weak exchange tie) allows them to increase their *compadrazgo* network. The *compadrazgo* network allows an individual to increase its social network and in turn "glue" together the Tzintzuntzan society. Notice that in the model the average number of *compadres* depends upon the average number of events in the *rite de passage* of an individual. In Tzintzuntzan godparents are chosen at a number of other occasions such as communion that are not incorporated in the model. For instance, Foster reports that an average person would "probably" acquire "about a dozen" *compadres*. This we plan to explore on the likelihood of an individual for acquiring this many *compadres* by incorporating other events in the *rite de passage* and also the possibility of change in weights (preferences) in the endorsement schemes of an individual agent as they expand and reinforce their *compadrazgo* ties during their lifetime.

4.46   Figure 8 depicts the effect the endorsement evaluation mode has on dynamic endorsements. The ratios of intense and non-intense endorsements per person per year for cases I to VI are plotted. The effect of using contextualized or random weights for the endorsement schemes is clearly visible. For cases I, II, and VI, where a continuous evaluation mode is employed, the difference in the ratio of intense and non-intense endorsements is small. However, the ratio in case VI, for randomized weights, is higher than in cases I and II, where contextualized weights are used. One reason for the small difference is that we assume the drawn weights (in all the cases) to be integers and from within small ranges. Nevertheless, a difference can be observed between the contextualized and random weights, although it is not likely to be of significant order.

4.47   Following Figure 7, we observe that for cases III, IV and V, there is a much higher ratio of intense and non-intense endorsements, which is evident since for agents to recognize the exchange with others as intense, they must have received a good/service in the time step. This is much less likely, given that agents in the model use their own stochastically modelled clock for sending exchanges. Note that the effect of whether using a discrete time step evaluation mode in this model (and any other similar model) depends upon the underlying assumptions about agents' activation of clocks and the scheduling of events in the model's simulation loop. Moreover, it also depends upon the assumptions concerning the rules governing agents' decision to endorse others as intense and not-intense. The rules determining endorsements will therefore be constrained further with evidence in future.
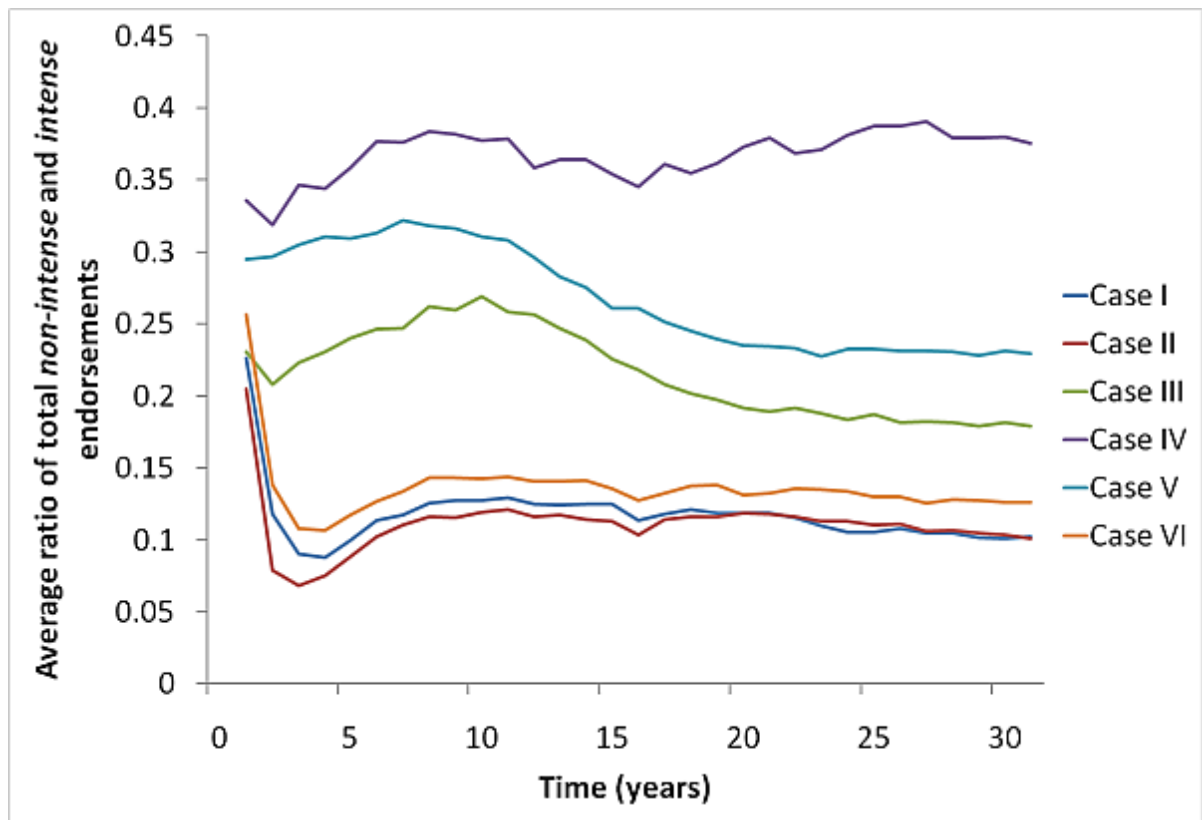
Figure 8. Ratio of intense and non-intense endorsements per person year for cases I to VI. Ratios are averages over 10 simulation runs.

4.48   Figure 9 shows, for cases I to VI, how the compadrazgo network and the endorsement mechanism contribute to extending an agent's ties beyond the social institutions of extended family, friends and neighbours. For cases I and II, which have continuous evaluation and contextualized weights, half of the compadres selected by the agents given their endorsement schemes were on average either friends, relatives (including siblings) or both. On the other hand, about half of the compadres are miscellaneous or of the type "others", i.e. those who do not fall into the above categories. This is because of the underlying model assumption that birth godparents may be chosen from the entire network of either parent's side with an equal probability (cf. Figure 7). In the event of a wedding in the model, godparents are chosen from either, the bride's or the groom's side. Since agents select their marriage partners randomly (apart from similarity in age), the dyadic contracts from the friends/neighbours, extended family and above all the compadrazgo ties, put the entire adult population almost always in a single component, even when individuals maintain their dyadic exchange to only a small proportion of their ties. For the rest of the cases, especially those concerning with the discrete evaluation mode, we find a decrease in the average proportion of the selected compadres that were either exclusively friends or friends/relatives due to the relatively greater dominance of the static endorsements in compadres selection. This is further clarified in Figures S-1, S-2 and S-3 in the Appendix, which separately show the proportion friends, relatives and miscellaneous/others respectively, in the selection of compadre for the above six cases. The observed effect highlights the role which agents' endorsements schemes (including the evaluation mode, recall types and assignment of endorsement weights) play in the observed dynamics at the population level. It also highlights our earlier discussion in this paper on the need for constraining the model with both qualitative and quantitative evidence.
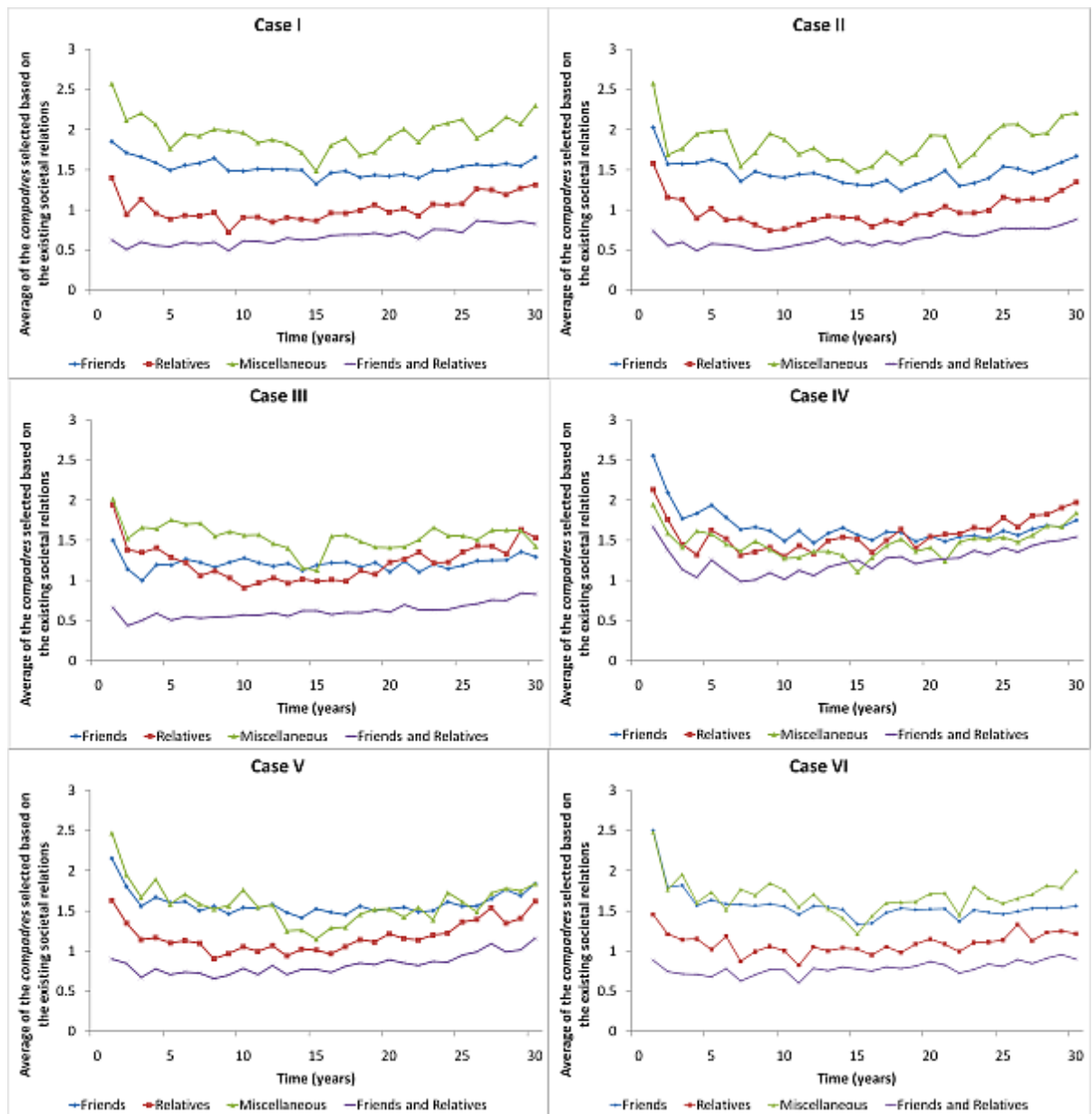
Figure 9. Time series for the average proportion of compadres selected that are friends, relatives, friends and relatives, or miscellaneous/others for the six cases for 10 simulation runs.

4.49 Summarizing the results, we designed six cases, each exhibiting a distinct implementation of recall, evaluation mode, and endorsement weight. Using a nonlinear recall implementation leads to agents recalling a smaller number of past exchanges than using a simple count or linear implementation. Forgetting quickly gives the agents the freedom to potentially also interact with people with whom they did not have intense exchange in the past. The case-studies indicate that Tzintzuntzeños are rather extroverted in making contacts; a nonlinear implementation appears to be the preferred choice. Concerning the discrete and continuous evaluation modes, we find that the latter affects the emergence of social relationships more positively than the former. This is what we expect from the social logic of Tzintzuntzan for the compadrazgo network that allows an individual to "glue" its social network together. Finally, contextualized endorsement schemes on average lead to the evolution of a more egalitarian composition of ego's social network, which is in accordance with the evidence available to us.

Conclusions

5.1 This article's goals were to disambiguate and improve the concept of endorsements. Disambiguation was achieved by laying out the concept of endorsements in detail and by critically discussing it. We improved the concept by adding experience to the agent reasoning process through continuous data formalization and by introducing typified heterogeneity through weighing agents' believe and values according to their role types. The extensions were tested using an evidence-driven agent-based social simulation of the Mexican village of Tzintzuntzan as reported by Foster (1961, 1969). We show that the suggested improvements lead to outcomes that are better in accordance with the evidence available to us than when these improvements are not at work in the simulation.

5.2 We consider the concept of endorsements to be particularly useful in situations where socio-cultural dimensions of the reasoning process need to be described using qualitative data. We argued that empirically driven agent-based social simulations should pursue construct validity and that the structures and processes that are modelled should represent structures and processes identified in the target system. Declarative type of modelling enables the implementation of evidence-based qualitative data into these kinds of models while endorsements provide a "natural" approach to computationally capture the ways agents in social simulations reason and the kind of rich narratives they reason about.

5.3 We discuss how qualitative information is incorporated in a model of a real case study using endorsements. As Polhill et al. (2010) have shown, there is no single procedure for incorporating qualitative evidence into agent-based models. Nevertheless, representing evidence obtained from fieldwork and the literature in the endorsements construct informs more precise questions about actor behaviour and thus may be useful in identifying gaps in the existing knowledge about a case study. For instance, Foster (1961:1189) illustrates for a particular case in Tzintzuntzan, "to look at the problem negatively, and not counting overlapping categories, of 16 primary godparent ties, only 6 were recognized; of 16 neighbourhood ties, another 6 were recognized; and of 9 sibling-parent ties, 5 were recognized." Although, this particular case informs about ego selecting only a proportion of individuals from his social network (comprising of compadre, siblings/relations and friendship/neighbourhood ties), there is little information available on the average number of contracts or the upper bound of the number of contracts ego may maintain. The purpose of the Tzintzuntzan case-study in the paper is to serve as a demonstrator. An extensive parameter exploration, a detailed analysis, and an in-depth cross-validation, as well as other noteworthy societal dynamics and transitions would be beyond the purpose of this article and are currently elaborated in a separate paper.

5.4 Fostering research that is concerned with representing the socio-cultural integration of agent cognition and behaviour in the study of emerging socialities in a variety of contexts is essential. We, for our case, foresee future work going into the direction of investigating how heterogeneous entry signals (events) are processed by endorsements and how vector-based endorsements can be replaced by semantic networks. It has also not escaped our notice that agents equipped with endorsements would profit from being endowed with strategic reasoning capabilities, such as reported by Łatek et al. (2009).

5.5 We do not advocate endorsements as being the silver bullet. Instead, we acknowledge their usefulness in a growing body of research, such as Alam (2008), Bousquet et al. (2005), Moss and Edmonds (2005), Hoffer (2006), Galán et al. (2009), Geller and Moss (2008), Janssen and Ostrom (2006), Polhill et al. (2010), Saqalli et al. (2010) and Yang and Gilbert (2008), that is concerned with rendering agent-based models as more empirically driven.

Acknowledgements

Notes

[1] Bounded rationality is the idea that rationality of individuals is limited by: the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make decisions. For the idea of "propensity", see Hayek (1973:75-76): "Rule in this context means simply a propensity or disposition to act or not to act in a certain manner, which will manifest itself in what we call a practice or custom. As such it will be one of the determinants of the actions which, however, need not show itself in every single action but may only prevail in most instances. Any such rule will always operate in combination and often in competition with other rules or dispositions and with particular impulses; and whether a rule will prevail in a particular case will depend on the strength of the propensity it describes and of the other dispositions or impulses operating at the same time."

[2] A strategy that may also be applied in the case of statistical data scarcity.

[3] See Friedman-Hill (2003).

[4] Currently, we assume these agent types to be static. It would be plausible to assume that agent types change based on frequency and recency of endorsements made and thus on different memory

agents possess, and that agents incorporate more than one type/role.

[5] A precursory version of this was implemented in a model reported by Alam and Meyer (2010), where the history of states was kept separately from the endorsements. Only when the trend of a number of states was positive (enough), a particular endorsement was made.

[6] By means of typified endorsement schemes, we account also for weights, which, beside frequency and recency, is the third important factor in memory organization (O'Reilly and Munakata 2000).

[7] Where not otherwise indicated, the following is paraphrased from Foster (1961).

[8] http://code.google.com/p/tzintzuntzan-model/ (last accessed: 30/06/2010)

[9] This follows the mechanisms used in other descriptive models (Alam and Meyer 2010;Moss 2008). The demographic data used to populate the model stems of course from a time newer than the time Foster has made his work in. While this fact would affect policy modeling and its implications, it has no influence on the argument regarding endorsements we make in this research.

[10] In checking incest prohibitions, we first check with nuclear family and then for uncles/aunts and grandparents. We also assume no extra-marital relations, no polyandry, and no re-marriages of widows/widowers.

References

ALAM S J (2008) *Understanding Social Complexity in the Context of HIV/AIDS: A Case Study in Rural South Africa.* Ph.D. thesis, Center for Policy Modelling, Manchester Metropolitan University, Manchester, United Kingdom.

ALAM S J and Meyer R (2010) Comparing Two Sexual Mixing Schemes for Modelling the Spread of HIV/AIDS. In Takadama K, Cioffi-Rivella C, Deffuant G (Eds.) *The Second World Congress on Social Simulation (WCSS'08)*, Berlin et al.: Springer-Verlag

ALAM S J, Meyer R, Ziervogel G, Moss S (2008) The Impact of HIV/AIDS in the Context of Socioeconomic Stressors: An Evidence-Driven Approach. *Journal of Artificial Societies and Social Simulation* 10 (4) 7 http://jasss.soc.surrey.ac.uk/10/4/7.html.

AXTELL R and Epstein J M (1994) Agent-based Modeling: Understanding Our Creations. *The Bulletin of the Santa Fe Institute* 9 (2) 28-32.

AXTELL R, Axelrod R, Epstein J M and Cohen M D (1996) Aligning Simulation Models: A Case Study and Results. *Computational and Mathematical Organization Theory* 1 (2) 123-141. [doi:10.1007/BF01299065]

BARTHELEMY O (2006) *Untangling Scenario Components with Agent Based Modelling: An Example of Social Simulations of Water Demand Forecasts*. Ph.D. thesis, Center for Policy Modelling, Manchester Metropolitan University, Manchester, United Kingdom.

BHASKAR R (1975) *A Realist Theory of Science*. London: Verso.

BOERO R and Squazzoni F (2005) Does empirical embeddedness matter? Methodological issues on agent-based models for analytical Social Science. *Journal of Artificial Societies and Social Simulation*, 8 (4) 7 http://jasss.soc.surrey.ac.uk/8/4/7.html.

BOUSQUET O et al. (2005) Our Companion Modelling Approach. *Journal of Artificial Societies and Social Simulation* 6 (2) 1http://jasss.soc.surrey.ac.uk/6/2/1.html.

BRANDES S (1968) Tzintzuntzan Wedding: A Study in Cultural Complexity. *Papers of the Kroeber Anthropological Society* 39, 30-53.

BRANDES S (1979) The household development cycle in Tzintzuntzan. In Clark M M, Kemper R V, Nelson C (Eds.) *From Tzintzuntzan to the Image of Limited Good: Essays in Honor of George M. Foster*, Berkeley: Kroeber Anthropological Society. pp. 13-23.

BRANDES S (1983) *Power and Persuasion: Fiestas and Social Control in Rural Mexico*. Philadelphia: University of Pennsylvania Press.

BRATMAN M (1987) *Intentions, Plans, and Practical Reason*. Cambridge: Harvard University Press.

COHEN P R (1985) *Heuristic Reasoning about Uncertainty: An Artificial Intelligence Approach* . Boston: Pitman Advanced Publishing Program.

DIMAGGIO P (1997) Culture and Cognition. *Annual Review of Sociology* 23, 263-287. [doi:10.1146/annurev.soc.23.1.263]

FOSTER G M (1961) The Dyadic Contract: A model for the social structure of a Mexican peasant village. *American Anthropologist* 63 (6) 1173-1192. [doi:10.1525/aa.1961.63.6.02a00020]

FOSTER G M (1963) The Dyadic Contract in Tzintzuntzan, II: Patron-Client Relationship. *American Anthropologist* 65 (6) 1280-1294. [doi:10.1525/aa.1963.65.6.02a00040]

FOSTER G M (1965) Peasant Society and the Image of Limited Good. *American Anthropologist* 67 (2) 293-315. [doi:10.1525/aa.1965.67.2.02a00010]

FOSTER G M (1967) *Tzintzuntzan: Mexican Peasants in a Changing World*. Boston: Little, Brown.

FOSTER G M (1969) Godparents and Social Networks in Tzintzuntzan. *Southwestern Journal of Anthropology* 25 (3) 261-278.

FOSTER G M (2002) A Half-Century of Field Research in Tzintzuntzan, Mexico: A Personal View. In Kemper R V, Peterson Royce A (Eds.) *Chronicling Cultures: Long-Term Field Research in Anthropology*, Walnut Creek: Altamira Press.

FOSTER G M, Scudder T, Colson E, Kemper R V (1979) *Long-Term Field Research in Social Anthropology*. New York: Academic Press.

FRIEDMAN-HILL E (2003) *Jess in Action: Rule-Based Systems in Java*. Greenwich: Manning.

GALÁN J M, López-Paredes A, del Olmo R (2009) An agent-based model for domestic water management in Valladolid metropolitan area. *Water Resources Research* 45.

GELLER A, Moss S (2008) Growing *qawm*: An evidence-driven declarative model of Afghan power structures. *Advances in Complex Systems* 11 (2) 321-335. [doi:10.1142/S0219525908001659]

GELLER A, Alam S J (2010) A Socio-Political and -Cultural Model of the War in Afghanistan. *International Studies Review* 12 (1) 8-30. [doi:10.1111/j.1468-2486.2009.00910.x]

HAYEK F A (1973) *Law, Legislation and Liberty: Vol. 1, Rules and Order*. Chicago: University of Chicago Press.

HEDSTRÖM P (2005) *Dissecting the Social: On the Principles of Analytical Sociology*. Cambridge: Cambridge University Press.

HOFFER L D (2006) *Junkie Business: The Evolution and Operation of a Heroin Dealing Network*. Belmont: Thomson/Wadsworth.

JANSEN R P S (2003) The effect of female age on the likelihood of a live birth from one in-vitro fertilisation treatment. *The Medical Journal of Australia* 178 (6) 258-261.

JANSSEN M A, Ostrom E (2006) Empirically Based, Agent-based models. *Ecology and Society* 11 (2) http://www.ecologyandsociety.org/vol11/iss2/art37/.

KEMPER R V (1982) The Compadrazgo in Urban Mexico. *Anthropological Quarterly* 55 (1) 17-30. [doi:10.2307/3317372]

KENNEDY W G, Rouleau M, Bassett J K (2009) Multiple Level of Cognitive Modeling within Agent-Based Modeling. In *Proceedings of the 18th Conference on Behavior Representation in Modeling and Simulation*. pp. 143-144.

ŁATEK M M, Axtell R, Kaminski B (2009) Bounded Rationality via Recursion In *AAMAS '09: Proceedings of The 8th International Conference on Autonomous Agents and Multiagent Systems*. Budapest: International Foundation for Autonomous Agents and Multiagent Systems. pp. 457-464.

LIKERT R (1932) A Technique for the Measurement of Attitudes. *Archives of Psychology* 140, 1-55.

LOPEZ E, Bocco G, Mendoza M (2006) Peasant emigration and land-use change at the watershed level: A GIS-based approach in Central Mexico. *Agricultural Systems* 90 (1) 62-78. [doi:10.1016/j.agsy.2005.11.001]

MATURANA H (1970) Neurophysiology of Cognition. In Gavin P L (ed.) Cognition: A Multiple View.

New York/Washington: Spartan Books. pp. 3-23.

MOSS S (1998) Critical incident management: An empirically derived computational model. *Journal of Artificial Societies and Social Simulation* 1 (4) 1 http://jasss.soc.surrey.ac.uk/1/4/1.html.

MOSS S (2000) Canonical tasks, environments and models for social simulation. *Computational and Mathematical Organization Theory* 6 (3) 249-275. [doi:10.1023/A:1009629602618]

MOSS S, Edmonds B (2005) Sociology and simulation: Statistical and qualitative cross-validation. *American Journal of Sociology* 110 (4) 1095-1131. [doi:10.1086/427320]

MOSS S (2008) Simplicity, generality and truth in social modelling, part 1: Epistemology. Paper presented at the 2nd World Congress on Social Simulation, George Mason University, Fairfax, VA, USA.

NORTH M J, Collier N T, and Vos J R (2006) Experiences Creating Three Implementations of the Repast Agent Modeling Toolkit. *ACM Transactions on Modeling and Computer Simulation* 16 (1) 1-25. [doi:10.1145/1122012.1122013]

O'REILLY R C, and Munakata Y (2000) *Computational explorations in cognitive neuroscience: Understanding the mind by simulating the brain.* Cambridge: MIT Press.

PETROV A A (2006) Computationally efficient approximation of the base-level learning equation in ACT-R. In Fum D, del Missier F, Stocco A (Eds.). *Proceedings of the 2006 Seventh International Conference on Cognitive Modeling.*

POLHILL J G, Sutherland L-A, Gotts N M (2010) Using Qualitative Evidence to Enhance an Agent-Based Modelling System for Studying Land Use Change. *Journal of Artificial Societies and Social Simulation* 13 (2) 10 http://jasss.soc.surrey.ac.uk/13/2/10.html.

SAQALLI M, Bielders C L, Bruno G, and Defourny P (2010) Simulating Rural Environmentally and Socio-Economically Constrained Multi-Activity and Multi-Decision Societies in a Low-Data Context: A Challenge Through Empirical Agent-Based Modeling. *Journal of Artificial Societies and Social Simulation* 13 (2) 1 http://jasss.soc.surrey.ac.uk/13/2/1.html.

SCHNEGG M and White D R (2009) Getting Connected: Networks of kinship and compadrazgo in rural Tlaxcala, Mexico. In Greiner G, Kokot W (Eds.). *Networks, Resources and Economic Action: Ethnographic Case Studies in Honor of Hartmut Lang.* Berlin: Dietrich Reimer.

SIMON H (1996) *The Sciences of the Artificial.* Cambridge: Cambridge University Press.

SIMON H (1991) Bounded Rationality and Organizational Learning. *Organization Science* 2 (1) 125-134. [doi:10.1287/orsc.2.1.125]

SPERBER D, Hirschfield L A (2004) The cognitive foundations of cultural stability and diversity. *Trends in Cognitive Sciences* 8 (1). pp. 40-46. [doi:10.1016/j.tics.2003.11.002]

TAYLOR R (2006) *Agent-Based Modelling Incorporating Qualitative and Quantitative Methods: A Case Study Investigating the Impact of E-commerce upon the Value Chain.* Ph.D. thesis, Center for Policy Modelling, Manchester Metropolitan University, Manchester, United Kingdom.

WERTH B (2010) *Uncertainty in the IT Sector of large business organizations.* Ph.D. thesis, Center for Policy Modelling, Manchester Metropolitan University, Manchester, United Kingdom.

WINDRUM P, Fagiolo G, and Moneta A (2007) Empirical Validation of Agent-Based Models: Alternatives and Prospects. *Journal of Artificial Societies and Social Simulation* 10 (2) 8 http://jasss.soc.surrey.ac.uk/10/2/8.html.

YANG L, Gilbert N (2008) Getting away from numbers: Using qualitative observation for agent-based modelling. *Advances in Complex Systems* 11 (2) 175-185.