ABSTRACT

Title of Dissertation: ESSAYS ON INSTITUTIONS, CULTURE AND ECONOMIC OUTCOMES

Nona Karalashvili, Doctor of Philosophy, 2017

Dissertation directed by: Professor Peter Murrell, Department of Economics

This dissertation examines how institutions and culture shape each other and affect individuals' behavior. Chapter 1 analyzes the interplay between the law and prevailing values to understand the origins of legal order in an environment where neither legal nor non-legal institutions, taken separately, are capable of supporting agreements. These institutional imperfections give rise to a distinct way in which the law and prevailing values reinforce each other, and subsequently facilitate transactions. The model gives rise to multiple stable equilibria where identical societies in terms of laws and values may exhibit fundamentally divergent behavioral patterns with significant welfare implications. Analysis of the dynamics of laws and values reveals that the continued congruence of the legal system with the prevailing values may determine the steady-state culture and the equilibria that emerge along the way.

Chapter 2 builds on a widespread notion that culture is acquired through learning and explores ways in which institutions, social structure, and human capital influence culture through a process of learning. In the model, institutions determine the uncertainty of the payoffs from cultural traits, social structure determines the strength of information flows from family and peers, and human capital determines the productiveness of individual deliberations. A unique and stable equilibrium culture emerges from this learning process. Institutions and social structure may influence the spread of values even without affecting the expected payoffs associated with these values. Institutions, social structure, and human capital frequently mute each other's effects on culture.

Finally, Chapter 3 develops a behavioral experiment to investigate effects of institutions on an important cultural trait – individuals' tendency to trust in others – even in those contexts where these institutions are irrelevant to the particular trust behavior. In contrast with the previous experimental results but consistent with the literature on the importance of others' intentions for decisions to reciprocate, I find evidence that institutions facilitating cooperation may decrease an individual's tendency to trust in others in a seemingly unrelated context. Identifying a systematic bias prompted by the institutional environment helps in understanding the potential ways in which institutions may impact individuals' behavior.

ESSAYS ON INSTITUTIONS, CULTURE AND ECONOMIC OUTCOMES

by

Nona Karalashvili

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2017

Advisory Committee:
Professor Peter Murrell, Chair
Professor Josh Wallis
Associate Professor Ethan Kaplan
Associate Professor Emel Filiz-Ozbay
Associate Professor Karol Soltan

Table of Contents

Table of Contents ii

List of Tables iv

List of Figures v

Chapter 1: A Theory of the Origins of Legal Order 1

1. Introduction 1
2. Model Setup 7
3. Model Analysis 18
   3.1. Compliance equilibrium 20
   3.2. Multiple equilibria 27
4. Dynamics 33
5. Conclusions 39

Chapter 2: Institutions, social structure and human capital as determinants of culture 42

1. Introduction 42
2. Model Setup 48
   2.1. Culture 51
   2.2. Social structure 54
   2.3. Institutions 55
   2.4. Human capital 59
   2.5. Analysis of information about cultural traits 60
3. Equilibrium Culture 63
   3.1. Consideration effect 65
   3.2. Precision effect 66
4. Results 69

4.1. High-quality institutions promote the spread of beneficial cultural traits 69

4.2. Human capital promotes the spread of beneficial cultural traits 71

4.3. Institutions and human capital as joint determinants of equilibrium culture 74

4.4. Stronger social ties may hinder the spread of beneficial cultural traits .. 76

4.5. Institutions and social ties as joint determinants of equilibrium culture . 82

5. Conclusions 83

Chapter 3: Understanding Trust and Institutions: A Behavioral Experiment 85

1. Introduction 85

2. Experimental Design 88

2.1. Discussion of the treatments 90

3. Results 93

4. Summary and Conclusions 98

Appendix A-1: Derivations for Chapter 1 100

Appendix A-2: Mathematica and Stata codes for Chapter 1 121

Appendix B-1: Derivations for Chapter 2 129

Appendix B-2: Mathematica codes for Chapter 2 159

Appendix C: Experimental Instructions for Chapter 3 168

Bibliography 173

List of Tables

Table 3-1: Manipulation Check, Behavior of As in Part I 93

Table 3-2: Non-parametric Estimate of Treatment Effect 94

Table 3-3: Probit Regression, Trust Behavior of Cs *(1 = trust)* 97

Table C-1: Gender Distribution Across Treatments 172

List of Figures

Figure 1-1: Compliance Equilibrium 25

Figure 1-2: Multiple equilibria 31

Figure 1-3: Multiple equilibria with flexible L 33

Figure 1-4: γ_H and L over time 37

Figure 2-1: Timing of events in each learning period τ 53

Figure 2-2: Effect of institutions on $\partial q/\partial \rho$ 76

Figure 2-3: Ceteris paribus effect of social ties on equilibrium culture 78

Figure 2-4: Effects of family ties (p_F) on equilibrium culture 80

Figure 2-5: Interaction of institutions and social ties 83

Figure 3-1: Experimental Design 91

Figure B-1: Effect of institutions on $\partial q/\partial \rho$ 151

Figure B-2: Ceteris paribus effect of family ties (p_F) on equilibrium culture 152

Figure B-3: Ceteris paribus effect of non-family ties (p_P) on equilibrium culture 153

Figure B-4: Effects of family ties (p_F) on equilibrium culture 154

Figure B-5: $\partial q/\partial p_F$ and its relation with institutions 155

Figure B-6: $\partial q/\partial p_P$ and its relation with institutions 156

Figure B-7: Effects of institutions on $\partial q/\partial p_F$ keeping the total strength of social ties constant 157

Figure C-1: Interaction AB 170

Figure C-2: Interaction AC 171

Chapter 1: A Theory of the Origins of Legal Order

1. Introduction

One of the most basic building blocks of economic development is an exchange that is potentially mutually beneficial. Such exchange is self-enforcing if goods (or money) of immediately obvious quality and quantity are exchanged simultaneously and voluntarily. However, even the slightest complication to this simplest scenario may render the exchange impossible to realize as each party may benefit from unilateral departure from the others' aspirations (Williamson 1985). Types of the environment in which complex exchanges are possible may be loosely arranged on a spectrum from "seamless web of laws" (Hadfield 2005) to "the true realm of Lawlessness and Economics" (Dixit 2004). On the laws' side of this spectrum, Becker's (1968) original study on the design of rules, punishments and rewards, and monitoring structures initiated a vast literature applying tools of economics to analyze law and its effects. As optimal laws and enforcement have been recognized to be exceedingly difficult to develop, perhaps later than desired (as noted by Murrell 2001), methods of supporting exchanges in the environments that lack government-provided legal institutions received more attention (e.g. Axelrod 1984, Ellickson 1991, Greif 1993, Milgrom, North, and Weingast 1990).

This paper examines the origins of legal order in an environment between the two ends of the spectrum where neither legal nor non-legal institutions, taken separately, are capable of supporting transactions. My focus on this environment is motivated by two main considerations. First, historical evidence suggests that Europe during the time of the revival of trade in the early Middle Ages had rather imperfect institutions. Understanding how complex exchanges, such as transactions over long-distance, may occur without apparent commitment or enforcement mechanisms may provide useful insights into the history of Europe. Second, imperfections in legal as well as non-legal institutions supporting transactions give rise to a distinct way they may reinforce each other, and subsequently influence individuals' behavior.

More specifically, in this paper's model, buyers consider whether or not to provide investment, I, to "perfect stranger" sellers (i.e. potential partners in transaction know nothing about each other's past, present, or future), who may choose to deliver a good that is of lower value than the original investment. For simplicity, investments are always welfare enhancing. There are two types of individuals, honest (H) and dishonest (D). H-types deliver a good of value $S_H > I$ to their buyers, while D-types deliver a good of value $S_D < I$. The terms "honest" and "dishonest" reflect values of individuals since it is assumed to be equally costly in monetary sense for H-types and D-types to deliver a good of value S_H to their buyers, but only H-types do it voluntarily for non-monetary costs or benefits that they experience while doing so.

The legal system is represented by a minimum 'legal' level of S_j denoted by L and "third parties" who adjudicate disputes arising between buyers and the sellers who deliver a good of value below L. With probability ρ, the third parties find the seller liable and order him/her to compensate the buyer and pay a fine. Crucially, the sellers who fail to comply with the third parties' decision face punishment of such a low probability and severity that, without further incentives, the sellers choose to ignore the third parties' decisions. To emphasize the imperfection of enforcement of the third parties' decisions, I avoid using the terms "judge" or "court" that are often associated with the appropriate administration of decisions. Using the eloquent words of Pollock and Maitland (1895) describing the state of the Anglo-Saxon courts (England before the Normal conquest of 1066), the third parties in this model are "not surrounded with such visible majesty of the laws as in [1895], nor furnished with any obvious means of compelling obedience" (p. 14). Insufficiency of enforcement of the third parties' decisions, to the degree that the undesirable behavior is undeterred, sets this paper's model apart from a large law and economics literature focusing on efficient design of rules under the environment of "seamless web of laws" (see Shavell (2004) for a review).

To encourage sellers to comply with the third parties' decisions, the third parties rely on the following reputational mechanism. Each individual has two distinct episodes of their lives, first as a seller, next as a buyer. The sellers that ignore the third parties' decision and "get away" with it (the decision is not enforced) are denied access to the third parties when taking the role of a buyer. A somewhat similar denial of access arrangement is analyzed by Milgrom, North, and Weingast (1990) whose model differs from mine in two important ways. First, neither individuals' values (e.g. honest vs. dishonest), nor state enforcement have any role in their model. Second, individuals learn about their potential partners' past behavior through querying the third parties, which keep perfect records of identities of individuals that have ever failed to comply with their decisions. This way, unlike this paper's model, individuals condition their decision to enter transactions on their potential partners' reputation, which is built over a long period of time.

Both of these features of the model of Milgrom, North, and Weingast (1990) are rooted in “the true realm of Lawlessness and Economics” where the law is exclusively privately adjudicated. Methods of supporting transactions in such an environment have been analyzed by a vast literature (e.g. Greif 1993, 2002, 2004, 2006, Bernstein 1992, Casella and Rauch 2002, more recently, Takahashi 2010, Wolitzky 2013, Ali and Miller 2013, Acemoglu and Wolitzky 2015, Levine and Modica 2016). In contrast with this body of work, including Milgrom, North, and Weingast (1990), this paper’s model has some rudiments of state enforcement of rules, though imperfect to the extent that the threat of enforcement on its own is incapable of meaningfully influencing individuals’ behavior. This imperfect state enforcement coexists with a rather limited reputational mechanism that relies only on the third parties’ holding information about individuals’ most recent past behavior, without business partners ever learning about each other’s past.

The model demonstrates that a combination of a limited reputation mechanism – created by a rather lenient structure of access to the third parties – and an imperfect state enforcement of the third parties’ decision may be sufficient to achieve the “compliance equilibrium” whereby dishonest sellers voluntarily comply with the third parties’ decisions if found liable. The value of maintaining access to the third parties is the key element underlying the equilibrium. If everyone else complies with the third parties’ decisions, then, depending on the context, the access to the third parties is valuable enough to make compliance with the third parties’ decisions worthwhile for each individual.

The compliance equilibrium can be construed as an environment where legal order is established since the law, L, is being applied by the third parties (through finding ρ share of violators liable), and is obeyed by the entire business community even though a threat of state enforcement is insufficient to achieve compliance. While I use a partial equilibrium model that does not investigate the sources of L, or ρ, or impartiality of the third parties, or enforcers, the respective simplifying assumptions make the model tractable and enable analysis of the types of equilibria that may arise, the conditions under which they may arise, and the interplay between values and laws that they may entail.

Importantly, the compliance equilibrium exists only when the parameters that represent rules (i.e. $L, \rho,$ fines, enforcement probability), and values (i.e. γ_H, denoting the share of H-types, S_H, S_D), are "just right", not too high or too low. Intuitively, a stricter legal system (higher L, or ρ) has two effects in this environment. While it makes compliance with the third parties' decisions costlier and hence less likely to be chosen by individuals in their role as sellers, stricter rules also increase the value of having access to the third parties for individuals in their role as buyers. Interestingly, a higher share of honest individuals in the population may make the compliance equilibrium harder to sustain as it decreases the value of maintaining access to the third parties.

The mechanism underlying the compliance equilibrium also permits multiple equilibria with the possibility of both the compliance and the non-compliance equilibrium, where the latter entails sellers ignoring the third parties' decisions if found liable. This means that two societies that are identical in terms of values and laws may exhibit fundamentally divergent behavioral patterns with significant social welfare implications. This happens because compliance with the third parties' decisions by other sellers convinces each seller to also comply to benefit from maintaining access to the third parties whose decisions are respected. In contrast, as everyone else ignores the third parties' decisions, maintaining access to the third parties is less valuable, making non-compliance a better choice for each seller.

The driving force behind the multiplicity of equilibria in this papers' model is somewhat similar to the common forces employed in the existing literature with an important difference. In the models of Glaeser, Sacerdote and Scheinkman (1996) and Calvó-Armengol and Zenou (2004), for instance, individuals' decisions to behave in a certain way directly affects his/her "neighbor's" decisions to behave in the same way through a direct externality built into individuals' utilities. Ferrer (2010) examines a different externality whereby lawbreaking behavior by others decreases the probability of being punished for lawbreaking, which increases lawbreaking that feeds back onto itself. These two types of externalities work in tandem in the model of Acemoglu and Jackson (2016), which, together with this paper, fits into a relatively new literature analyzing the interplay between values and laws (see also Tabellini 2008a, Benabou and Tirole 2012, Masten and Prufer 2014). In contrast, this paper's model demonstrates that even purely bilateral exchanges may result in a complex feedback loop, which, in its turn, is fueled not through probability of being punished but through the size of that punishment determined by the value of maintaining access to the third parties.

To understand the process by which a society may achieve legal order through the compliance equilibrium while starting off from the non-compliance equilibrium, I analyze a dynamic extension of the model. I employ a replicator dynamic to study evolution of γ_H, the share of H-types in the population, over time. The dynamic version of the model reveals the importance of tailoring the features of the legal system, e.g. L, to the prevailing values to achieve a desirable environment with a high share of honest individuals interacting under the compliance equilibrium.

The rest of the paper is organized as follows. Section 2 presents the model setup defining terms and discussing the reasoning behind each aspect of the formalization. Section 3 analyses the model and examines the types of environments that emerge. Section 4 adds dynamics. Finally, section 5 concludes.

2. Model Setup

The focus of analysis is a voluntary exchange between two "perfect stranger" agents, a seller denoted $\boldsymbol{S}$ and a buyer denoted $\boldsymbol{B}$. Each individual i has two distinct episodes of their lives. In the first episode, each i is a seller, denoted $\boldsymbol{S_i}$**,** and in the second episode each i is a buyer, denoted $\boldsymbol{B_i}$ (note that letters $\boldsymbol{S}$ and $\boldsymbol{B}$ denote roles and subscripts identify individuals). There are as many sellers as buyers during each interaction. I will sometimes refer to individuals in this model as businesspeople, and the exchange as a business interaction.

Businesspeople interact as follows. First each buyer decides whether or not to transact with a seller. Transacting entails giving the seller money in the amount of I to deliver a good. If buyer i decides not to transact with seller j, both parties receive a payoff of 0. If buyer i does transact, the seller j invests the amount I to earn a gross return of rI (with $r > 1$), and delivers the good of value S_j to the buyer i. Note that individuals are denoted with bold letters ($\boldsymbol{S_j}$ is seller j), their actions are denoted with non-bold letters (S_j is the value of the good that seller j delivers to the buyer).

For simplicity, there are two types of businesspeople, H for honest and D for dishonest. H-types return a good of value S_H to the buyer, and D-types return a good of value S_D, with $S_H > I > S_D$. The terms "honest" and "dishonest" reflect the nature of the environment. In particular, by offering exchange to buyers, each seller promises to deliver a good of value S_H. Agreeing to this offer means that the buyer expects with a non-zero probability that the promise will be fulfilled. Consequently, delivering a good of lower value is, at best, an inadvertent deviation from the original agreement; and, at worst, a disregard of the promise. This model assumes the latter, in that the decisions to return the good of value S_H or S_D are assumed to be driven by values that individuals hold.

Without delving into the details of utility functions, the H-types get utility of U^{H_seller} in their role as sellers, where superscript indicates type and role (H and $seller$). And D-types get utility of U^{D_seller}. Note that $U^{H\_seller} < U^{D\_seller}$, meaning that even though H-types feel better fulfilling promise than not fulfilling it, D-types enjoy the advantage of cost savings by delivering good of lower value. Utilities that businesspeople get in their role as buyers are independent of their type. Buyers who receive a good of value S_H from the seller get utility of $U_{S_H}^{buyer}$, and buyers who receive a good of value S_D from the seller get utility of $U_{S_D}^{buyer}$, with $U_{S_H}^{buyer} > 0 > U_{S_D}^{buyer}$.

Denote the share of H-type businesspeople with γ_H. The share of D-type businesspeople is thus $(1 - \gamma_H)$. The parameter γ_H is meant to capture values in the population of businesspeople. This interpretation is reasonable because it is assumed to be equally costly in monetary sense for H-type and D-type businesspeople to deliver a good of value S_H to their respective buyers, but only H-type businesspeople do it voluntarily for non-monetary costs or benefits that they experience while doing so.

The legal system is represented as follows. Before the start of interactions between businesspeople a minimum 'legal' level of S_j – value of goods delivered to a respective buyer – is 'enacted'. This minimum is denoted with L (for law). This L is administered by a distinct kind (not type) of individual, called "third parties". The main role of these individuals is to adjudicate disputes arising between businesspeople in the course of their transactions among each other. Note that I avoid the terms "judge" or "court" to emphasize that this model is intended to capture an environment where sophisticated rules and procedures that are usually associated with these notions are not necessarily present. In particular, a third party might be an arbitrator without much background in law or business, or an examiner that decides whether or not the litigant's complaint is of merit, or simply a randomly selected businessperson who is asked to form an opinion on how to resolve the particular disagreement.

The third parties function as follows. Buyers who receive S_j that falls short of L may or may not involve a third party to dispute the seller's behavior (for some fee). If involved, the third party then may or may not find the seller liable. In the latter case, nothing needs to happen. If the third party does find the seller liable, the seller is ordered to make some material payment (to the buyer, and to the third party, further details on this below). The crucial element of this model is that the third parties' decisions are enforced with a substantial imperfection to the extent that a mere threat of enforcement of the third parties' decisions is not sufficient to encourage compliance. Sellers can and often choose to ignore the third parties' decisions and will often "get away" with it.[1]

Note that several important and complicated components are omitted in this formalization of third parties. In particular, only a small fraction of disagreements ever escalate to the level of even remotely formal procedure that is being analyzed (Hendley 2001), and the complicated process of negotiations that usually occur to avoid this is left as a black box. In addition, the potentially crucial role of legal professionals (Grajzl and Murrell 2006) is completely overlooked even though "the institutions organizing the training, selection, governance, compensation and incentives of lawyers … are fundamental determinants of the cost and efficacy of contract law" (Hadfield 2005, p. 186). Furthermore, there exists a rather severe

[1] To clear all transaction in one period of time, the timing of events is as follows. First every businessperson decides their moves in each of the two roles (as buyer and as seller). In particular, each businessperson j decides (i) whether or not to enter transaction as a buyer, conditional on having access to the third parties; (ii) the amount of S_j to return to the buyer if the transaction where j is a seller occurs; and (iii) whether or not to comply or ignore the third party's decision should the buyer dispute S_j and should the third party find j liable. Next these decisions realize hypothetically for the purposes of finding out which buyers have access to the third parties. Finally, these decisions realize with the corresponding payoffs.

problem of coaxing the disputing parties to agree on the identity of the particular third party, which is also omitted for simplicity (Landes and Posner 1979, Hadfield 2005). It nevertheless is important to understand the workings of the third parties in this rather simplified environment as a first step towards uncovering complex interrelations between these other aspects and the components analyzed here.

This model's portrayal of the legal system helps highlight some of its conceptual aspects. In particular, there are three important elements – enacting of L, deciding on whether a particular behavior is a punishable violation of L, and enforcing that decision. Whether or not the institution that performs the second function, dispute resolution, is also allowed to perform the first, rule formation, has been identified as a crucial point of distinction between Anglo-American and other legal systems (Glaeser and Shleifer 2002). It is unclear however what exactly makes this distinction as crucial for economic development as it seems in some of the empirical studies of the matter (e.g. La Porta et al. 2008). What is clearer is that "adjudication is not dependent on the existence of a state as we would understand the term" (Landes and Posner 1979, p. 242):

> "The governmental institutions of primitive societies are often rudimentary to the point of nonexistence. There may be no legislature, no permanent executive (as distinct from a chief who leads in wartime), no government bureaucracy, no public judges, no public prosecutors or police-indeed, no concept of public law. Yet even in such societies, there will often be adjudication. For example, the Yurok Indians of California had no government at all but they did have a well-developed system of private judging." (ibid, p. 242-243)

A similar argument is made by Hart (1961), a major figure in legal philosophy (Kramer et al 2008). While discussing the elements of law, Hart (1961) distinguishes between repercussions of the violation of rules and the determination that such violation occurred, and claims that the latter is more important than the former:

> "The history of law does … strongly suggest that the lack of official agencies to determine authoritatively the fact of violation of the rules is a much more serious defect; for many societies have remedies for this defect long before the other." (p. 93-94)

In this paper's model, there is no underlying reason to allocate these three functions across different agencies in a specific manner. It is intuitive to expect that the allocation of these and possibly other functions becomes crucial if the analysis shifts from partial to general equilibrium and explores additional topics, such as origins of L or the institution that creates L (see e.g. Greif, Milgrom, and Weingast 1994), behavior of the third parties and whether or not they are impartial in making decisions (see e.g. Glaeser and Shleifer 2002), behavior of the enforcers (see e.g. Acemoglu and Wolitzky 2016), and whether or not everyone is equal before the law. Assuming away these fundamental issues makes the model tractable and allows examination of ways in which legal and non-legal institutions may reinforce each other in the environment where each is fraught with substantial imperfections to the extent of being incapable of meaningfully affecting individuals' behavior if acting separately from the other.[2]

To continue the model setup and fix ideas, assume that the cost to the buyer of involving a third party is K material units. The third party finds $\boldsymbol{S_j}$ liable with

[2] An additional motivation for partial as opposed to general equilibrium analysis of the exchange captured by this model is that even the simplest general equilibrium set of strategies will inevitably be a highly complex interlocking system of interests that keeps all the involved parties unilaterally satisfied. Such a system of agreements and expectations is unlikely to emerge all at once in reality. It is more judicious to think of the origin of this complex general equilibrium through steps represented by partial equilibria.

probability ρ and orders $\boldsymbol{S_j}$ to pay $\left(L - S_j\right)$ material units to the buyer, and to pay a fine in the amount of ϕ material units to the third party. With probability $(1 - \rho)$, S_j is found to be below L for reasons that are not legally punishable. It is worth highlighting that ρ may be a reflection of behavior of the third parties, or be under their control, at least to some extent. If the third parties do exercise some control over ρ, then they wield an important power that was eloquently described by Hart (1961) as part of the analysis of primary and secondary rules as follows:

> "if courts are empowered to make authoritative determination of the fact that a rule has been broken, these cannot avoid being taken as authoritative determinations of what the rules are." (p. 97)

As the model shows, if the third parties do exercise some control over ρ, then they can use ρ, a seemingly subtle instrument, to exercise significant power in shaping individuals' behavior even without participating in the formation of L.

Third parties' decisions are enforced as follows. The sellers who ignore the third party's decision are, with probability e (< 1), forced to pay $\left(L - S_j\right)$ material units to the buyer, and to pay a fine in the amount of $E > \phi$ material units to the enforcing party. Enforcement is limited in that the combination of e and E is such that a mere threat of enforcements is not enough to persuade sellers to follow third parties' decisions. To formalize what this means consider a scenario where $S_H \geq L > S_D$. Facing the probability of e of enforcement is more attractive than paying $(L - S_D)$ and ϕ if the following holds (as shown in the Appendix A-1):

$$e < \frac{(L - S_D) + \phi}{(L - S_D) + E}$$

meaning that the parameters e and E are constrained so that if punishments for ignoring the third parties' decisions are increased (E grows), then the probability of implementation of that more severe punishment must decrease (e falls). Note that this condition assumes that material costs and benefits enter directly and additively to individuals' utility functions, an assumption made for the sake of simplicity. To put the condition differently, an enforcing agency (which, as already mentioned, could be third parties themselves), faces binding constraints in terms of what they can do (E) and how often they can do it (e). For simplicity of exposition, E is considered fixed, and comparative statics is analyzed with regards to e. It is thus convenient to introduce $\overline{e}$ as denoting $\frac{(L-S_D)+\phi}{(L-S_D)+E}$, and focus only on the cases with $e < \overline{e}$.[3]

To encourage D-type sellers who are found liable to voluntarily comply with the third parties' decisions, the following reputational mechanism is used. The sellers that ignore the third parties' decisions and "get away" with it (the decision is not enforced) are denied access to the third parties in their role as buyers. More precisely, if $\boldsymbol{S_j}$ is found liable, ignores the third party's decision, and the decision does not get enforced (which happens with probability $1 - e$), then the businessperson j has no access to the third parties when taking a buyer's role; so $\boldsymbol{B_j}$ cannot involve a third party even if his/her partner returns less than L.

[3] Note that even in the event of unanimous disregard of the third parties' decisions, D-type businesspeople might still find it attractive to deliver a good of value L instead of the preferred S_D to avoid even that limited probability of e of incurring the cost E. This happens if L is so close to S_D that costs of compliance with the law for D-type businesspeople are lower than the costs of facing enforcement, however limited. This is a precarious situation in that the third parties are never used, and is excluded from the main analysis. See Appendix A-1 for discussion of this scenario.

As voluntary compliance with rules is the central aspect of the model, it is instructive to draw parallels between the setup of this model and the inquiry of Lon Fuller, recognized as one of the major contributors to analytical jurisprudence (Hadfield and Weingast 2012), into the origins of a legal or moral duty. Fuller (1964) posits a question "Under what circumstances does a duty, legal or moral, become most understandable and most acceptable by those affected by it?" (p. 22-23), and answers it as follows:

> "I think we may discern three conditions for the optimum efficacy of the notion of duty. First, the relationship of reciprocity out of which the duty arises must result from a voluntary agreement between the parties immediately affected; they themselves "create" the duty. Second, the reciprocal performances of the parties must in some sense be equal in value ... We cannot here speak of an exact identity, for it makes no sense at all to exchange, say, a book or idea in return for exactly the same book or idea. … When … we seek equality in a relation of reciprocity what we require is some measure of value that can be applied to things that are different in kind. Third, the relationships within the society must be sufficiently fluid so that the same duty you owe me today, I may owe you tomorrow – in other words, the relationship of duty must in theory and in practice be reversible ... These, then are the three conditions for an optimum realization of the notion of duty; the conditions that make a duty most understandable and most palatable to the man who owes it. When we ask, "In what kind of society are these conditions most apt to be met?" the answer is a surprising one: in a society of economic traders [Fuller 1964, p. 23-24].

The model's setup satisfies all three of these conditions. In particular, the exchange between buyers and sellers is voluntary; they decide whether or not to exchange resources that have a measurable value; and finally, individuals change roles in the course of their lifetime.[4]

---

[4] The model's setup is also consistent with Fuller (1969) where – in the course of analysis of "ordinary", "customary" and contract law (understood by the author as a law created by contract) –

The reputational mechanism employed in this paper is somewhat similar to the denial of access for the purposes of boosting compliance analyzed by Milgrom, North, and Weingast (1990), with important differences. Apart from not involving individuals' values (e.g. honest vs. dishonest) or state enforcement in their model, Milgrom, North, and Weingast (1990) focus on an institutional structure of the third parties that allows businesspeople to learn about the reputations of their potential partners before entering transactions with them. This way, individuals condition their behavior towards their potential and actual partners on the respective reputation, which, in its turn, is built over a long period of time. In contrast, this paper allows for a substantially weaker reputation mechanism that works exclusively through the third parties: businesspeople never know or learn about reputations of their potential or actual partners. Furthermore, the reputation is built over a short period of time as the third parties rely only on the records from the current period of exchange (consisting of two episodes).

The conceptual differences between this paper's model and that of Milgrom, North, and Weingast (1990) are rooted in the type of environment being analyzed. Milgrom, North, and Weingast (1990) focus on the environment where the law is exclusively privately created and adjudicated without any form of state enforcement. Consequently, they come up with a complex institutional structure of the third parties that fully relies on the power of individuals' reputation. In contrast, this paper's model has some rudiments of state enforcement of rules, though so inadequate that its shadow alone is insufficient to deter the 'undesirable' behavior. The environment

---

Fuller argues that each of these forms of law have "interactional foundations" in that their purpose is to facilitate human interaction. The parameters capturing rules in the model do serve the purpose of facilitating transactions between buyers and sellers.

with imperfect state enforcement of law appears similar to the environment of Europe during the time of the revival of trade in the early Middle Ages. Historical evidence suggests that European monarchs used their power to facilitate contract enforcement. For instance, Reyerson (1985) notes that in the thirteenth century Montpellier, notarial recognitions of debts often submitted the debtor to the jurisdiction of the king of France's specialized commercial court (p. 41, 100-3). In England, as early as the reign of King John (1199-1216),"the machinery of the English exchequer could be used by merchants to levy business debts" (Miller, Postan and Rich 1965, p. 312). Furthermore, King Edward I promulgated legislation in 1285 that delegated enforcement of contracts to local authorities, in practice the towns, while reserving the crown's right to intervene when required (Ogilvie 2011, p. 308, Miller, Postan and Rich 1965, p. 312). Pollock and Maitland (1895) maintain that even before the Norman Conquest (1066), the king exercised "power to do justice of an extraordinary kind" (p. 17) meaning that individuals who failed to obtain justice in their local courts were able to invoke his powers. They continue:

> "After the Norman Conquest, as time went on, the king's justice became organized and regular, and superseded nearly all the functions of the ancient country and hundred courts. But the king's power to do justice of an extraordinary kind was far from being abandoned. … Down to our own time that system preserved the marks of its origin in the peculiar character of the compulsion exercised by courts of equitable jurisdiction. Disobedience to their process and decrees was a direct and special contempt of the king's authority, and a `commission of rebellion' might issue against a defendant making default in a chancery suit, however widely remote its subject-matter might be from the public affairs of the kingdom." (Pollock and Maitland 1895, p. 17-18)

Where monarchs did not provide support to contract enforcement, local institutions sometimes filled the void. Gelderblom (2005) argues that the involvement of local authorities in the settlement of disputes was a "salient constant in commercial litigation in late medieval and early modern Europe", adding that:

> "From the twelfth century onwards town magistrates in Italy, Spain, Germany, the Low Countries and England acted as third party enforcers in conflicts between merchants. Initially some local courts may have discriminated against aliens but by 1300 legal services were offered to the merchant community at large. In following centuries the involvement of local authorities increased."(Gelderblom 2005, p.4)

Alternatives to state courts existed as well. The medieval church operated canon law-courts which imposed and enforced a wide range of penalties from fines to excommunication and, as shown in the records dating from the twelfth century, also covered commercial contracts (Ogilvie 2011). Pollock and Maitland (1895) maintain that during Anglo-Saxon period (from 410 to 1066) the ecclesiastical and the secular courts co-existed in England with virtually no separation and largely overlapping jurisdictions. In sum, at least some parts of the medieval Europe had some state support for enforcement of business transactions, most likely of varying quality. By focusing on a similar, albeit simplified, environment, this paper's model may provide useful insights into Europe's history.

3. Model Analysis

It is illustrative to start in an environment without third parties. Since each interaction is one-shot without any information about the partner, the decision-making is the same across the two episodes of each individual's life. The two episodes are linked together only when third parties exist and can deny access to some businesspeople based on their behavior in the first episode of their lifetime. In the absence of third parties, buyers transact if and only if the following holds:

$$EU^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1-\gamma_H) \cdot U_{S_D}^{buyer} \geq 0$$

Denote the level of γ_H at which $EU^{buyer} = 0$ with $\underline{\gamma_H}$.[5] Whenever γ_H falls short of $\underline{\gamma_H}$, transactions cease in the absence of third parties.

Adding to this environment third parties and an L that is below S_D changes nothing since no buyer will be in a position to dispute S_D. The passage of an L that is above S_D however does have a potential of significant impact. Consider first the case when $S_H \geq L > S_D$. D-type individuals now face the following choice set (with corresponding utilities given in the Appendix A-1):

A. deliver the good of value L to the buyer,
B. deliver the good of value S_D to the buyer, and comply with the third parties' decision if disputed and found liable,
C. deliver the good of value S_D to the buyer, and ignore the third parties' decision if disputed and found liable.

Given the above choice set for D-type businesspeople, notation is slightly amended as follows. The utility that a D-type individual derives as a seller after delivering the good of value L is denoted with $U_L^{D\_seller}$, and the utility after delivering the good of value S_D with $U_{S_D}^{D\_seller}$ $\left(U_L^{D_{seller}} < U_{S_D}^{D_{seller}}\right)$.

---

[5] So, $\underline{\gamma_H} = \frac{-U_{S_D}^{buyer}}{U_{S_H}^{buyer} - U_{S_D}^{buyer}}$, which is in the interval $(0,1)$ because $U_{S_D}^{buyer} < 0 < U_{S_H}^{buyer}$.

3.1. Compliance equilibrium

The "compliance equilibrium" is one where D-type businesspeople deliver goods of value S_D to the buyers, and voluntarily comply with the third parties' decisions if found liable. In other words, D-type businesspeople choose option B from the above in compliance equilibrium. Recall that a mere threat of enforcement of the third parties' decisions is not enough to coax D-type sellers to comply with their decisions (i.e. $e < \overline{e}$). Compliance may become attractive for D-type sellers if maintaining access to the third parties is sufficiently valuable. The value of having access to the third parties depends on the context as given below and is denoted by ΔEU_{CE}^{buyer} (with subscript CE denoting compliance equilibrium). The following outlines conditions for the compliance equilibrium (derivations are in the Appendix A-1).

Observation 1: When $e < \overline{e}$, the compliance equilibrium exists if and only if:

$$\overline{e} > e \geq \frac{\alpha\big((L - S_D) + \phi\big) - \Delta EU_{CE}^{buyer}}{\alpha\big((L - S_D) + E\big) - \Delta EU_{CE}^{buyer}} \equiv \underline{e}^{comply} \qquad (Obs\ 1.1)$$

$$U_{S_D}^{D\_seller} - U_L^{D\_seller} > \alpha\rho\big((L - S_D) + \phi\big) \qquad (Obs\ 1.2)$$

$$\rho(L - S_D) \geq K \qquad (Obs\ 1.3)$$

$$\gamma_H \geq \underline{\gamma_H}^{comply} \text{ if } \underline{\gamma_H} > \gamma_H \qquad (Obs\ 1.4)$$

where

- $\Delta EU_{CE}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$ if $\gamma_H < \underline{\gamma_H}$, and $\Delta EU_{CE}^{buyer} = (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$ if $\gamma_H \geq \underline{\gamma_H}$

- $\underline{\gamma_H}^{comply} = \frac{-U_{S_D}^{buyer} - \alpha(\rho(L - S_D) - K)}{U_{S_H}^{buyer} - U_{S_D}^{buyer} - \alpha(\rho(L - S_D) - K)} < \underline{\gamma_H}$.

The key role of the value of having access to the third parties, ΔEU_{CE}^{buyer}, is clear from Obs 1.1, with $\underline{e}^{comply}$ approaching $\overline{e}$ as ΔEU_{CE}^{buyer} approaches 0. This condition ensures that D-type businesspeople prefer complying with the third parties' decisions as opposed to ignoring it. Obs 1.2 ensures that D-type businesspeople prefer delivering the good of value S_D with the risk of being found liable to delivering the good of value L. This condition takes into account the fact that under compliance equilibrium the good of value S_D is disputed with probability 1. This is because compliance grants all D-type businesspeople access. Finally, Obs 1.3 and Obs 1.4 ensure, respectively, that the buyers with access to the third parties are not dissuaded by fees to lodge a complaint if delivered the good of value S_D, and that they find transactions attractive.

The conditions Obs 1.1-Obs 1.4 depict an environment where rules – represented by parameters L, ρ, ϕ, K, e and E – and values – represented by γ_H and indirectly by α, S_H, S_D – must be "just right", not too high or too low, for the compliance equilibrium to exist. The following set of comparative statics explores inter-connections between these parameters in delineating the boundaries of the compliance equilibrium.

Comparative Statics 1.A.: as laws get stricter (L grows), or probability of being found liable (ρ) *increases, or access to the third parties is cheaper (K* *drops), ceteris paribus, the minimum share of H-type individuals that is required to sustain the compliance equilibrium ($\underline{\gamma_H}^{comply}$) decreases.*

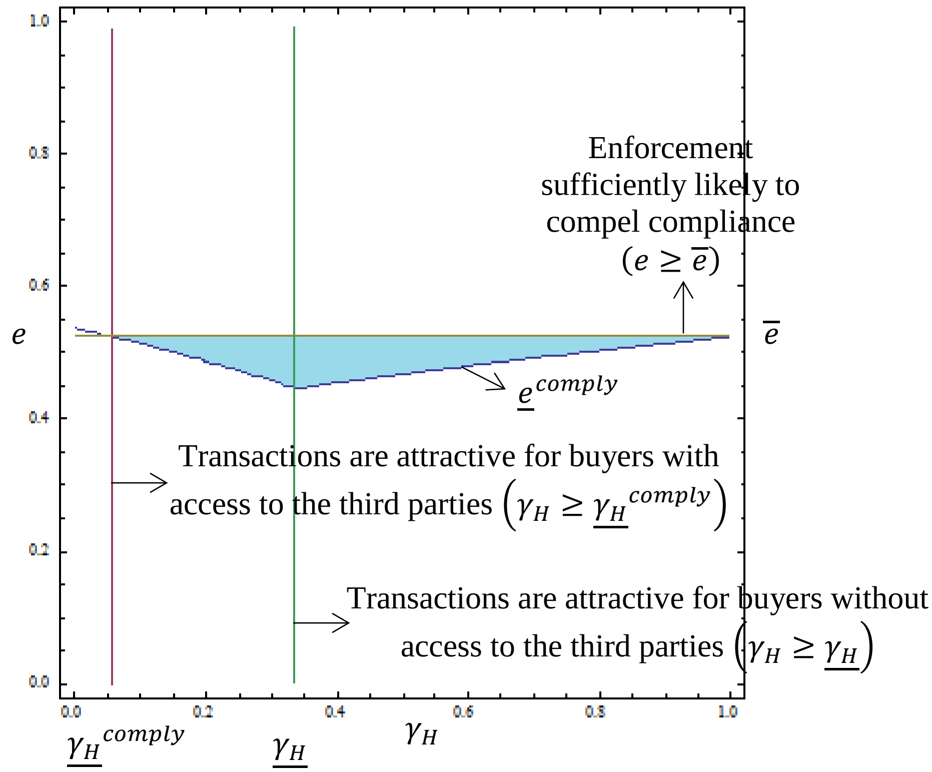
Comparative Statics 1.B: in a population with a higher share of H-type businesspeople (higher γ_H) the minimum probability of enforcement that is required to sustain the compliance equilibrium ($\underline{e}^{comply}$) may be higher. $\underline{e}^{comply}$ is decreasing with ρ, E, and is increasing with L, ϕ, K.

Intuition behind *Comparative Statics 1.A* is fairly clear. With stricter laws, or better fact-finding that result in a higher likelihood of finding cheaters liable, or more affordable third parties, the transactions are more attractive from the buyers' standpoint, even with a lower share of honest businesspeople (lower γ_H). More appealing prospects convinces D-type sellers to maintain access to the third parties and comply with the third parties' decisions. The laws cannot get too strict however, as *Comparative Statics 1.B* suggests. This is because, while making transactions more appealing from buyers' standpoint, stricter L also makes compliance with the third parties' decisions costlier for D-type sellers. As L increases, the former overcomes the latter and D-type sellers stop complying with the third parties' decisions unless incentivized through stricter enforcement (higher e or E or both). It is instructive to highlight how this effect of stricter L differs from the effect of a stricter law in the model of Acemoglu and Jackson (2016) which also studies the interplay between values and laws. In their model, once a lawbreaking – violation of L – is reported, the rules are perfectly enforced. Law-abiding individuals report their partners' lawbreaking behavior because of the behavioral externalities by which each individual's behavior affects utilities of everyone else. As a consequence, in the model of Acemoglu and Jackson (2016), a stricter law results in a higher prevalence of lawbreaking unless behavioral externalities are strong. This is because a stricter L is costlier to follow, and benefits of following it arise solely through behavioral externalities since only law-abiding individuals may report their partner's lawbreaking and thus guarantee law enforcement. In contrast, this paper's model suggests that stricter law may be beneficial even in the environment of pure bilateral exchanges. This is because stricter L means better average outcomes for individuals in their role as buyers, which incentivizes individuals to comply with the third parties decisions in their role as sellers.

Comparative Statics 1.B highlights a less intuitive relation between laws and values. It states that in a society with higher share of honest businesspeople (higher γ_H), it may be harder to sustain the compliance equilibrium ($\underline{e}^{comply}$ may be higher). This happens when γ_H exceeds the level where transactions are attractive even for buyers without the access to third parties ($\underline{\gamma_H}$), and the value of this access dissipates. Since with higher γ_H, buyers are more likely to encounter a seller that is honest and will deliver the good of value S_H, they are less likely to need access to a third party to dispute the sellers' behavior. With less interest in maintaining the access to the third parties, the D-type sellers are more inclined to ignore the third parties' decisions altogether, unless those decisions are backed with stronger enforcement. Changes in other parameters have more intuitive effects. An improvement in third parties' fact-finding abilities (higher ρ) decreases $\underline{e}^{comply}$ as access to the third parties gets more valuable and enforcement through e is less important. An increase in fines imposed by the third parties (higher ϕ) makes it less attractive for D-type businesspeople to comply with the third parties' decisions as risking the cost of enforcement becomes relatively more palatable.

Figure 1-1 provides an illustration of *Observation 1* by visualizing potential behavioral patterns and respective regions defined by e and γ_H. In particular, whenever the probability of enforcement of third parties' decisions exceeds $\overline{e}$, the threat of enforcement is sufficient to compel D-type businesspeople to comply with the third parties' decisions. This study focuses on the region where e falls short of $\overline{e}$. For the compliance equilibrium to exist there, the share of H-type businesspeople must exceed $\underline{\gamma_H}^{comply}$. Otherwise transactions do not take place at all since even the buyers with access to the third parties do not find transactions attractive. This is Obs 1.4. As γ_H grows beyond $\underline{\gamma_H}^{comply}$, the minimum level of enforcement necessary to compel D-type businesspeople to comply with the third parties' decisions ($\underline{e}^{comply}$) drops. As γ_H reaches $\underline{\gamma_H}$, transactions become attractive even for those buyers that do not have access to the third parties. After this point, further growth of γ_H dissipates the value of having access to the third parties and $\underline{e}^{comply}$ grows. This is an illustration of *Comparative Statics 1.B*, namely that the compliance equilibrium becomes harder to sustain as the share of honest businesspeople increases. All conditions for the existence of the compliance equilibrium are met in the shaded region of Figure 1-1. Note that parameters are set to ensure that Obs 1.2 and Obs 1.3 are satisfied, meaning that D-type businesspeople do not prefer delivering the good of value L to delivering the good of value S_D with the risk of being found liable, and the buyers with access to the third parties are not dissuaded by fees to lodge a complaint if delivered the good of value S_D.

Figure 1-1: Compliance Equilibrium



Parameters for this figure are set as follows: $\alpha = 1,\ r = 2,\ I = 100, S_D = 75, S_H = 150,\ U_{S_H}^{buyer} = \alpha(-I + S_H) = 50, U_{S_D}^{buyer} = \alpha(-I + S_D) = -25,\ U_{S_D}^{D_{seller}} = \alpha(rI - S_D) = 125,\ L = 115, U_{S_L}^{D_{seller}} = \alpha(rI - L) = 85,\ K = 2,\ \rho = 0.6,\ \phi = 15,\ E = 65.$

Analysis of *Observation 1* offers additional insights into an idea that 'better' economic opportunities beget 'better ' institutional environment. This idea was perhaps most directly expressed by Lipset (1960) who suggested that economic growth improves human capital which in its turn improves the quality of institutions. While Lipset (1960) focused on political institutions, he also discussed effects of economic growth on the functioning of courts.[6] In my model, 'better' economic opportunities are represented by an increase in r, gross return on investment I. Note that a change of r, without being reflected in changes of S_H or S_D or L merely

[6] For empirical support of Lipset's hypothesis, see e.g. Barro (1999), for opposite findings see e.g. Acemoglu, Johnson, Robinson, and Yared (2009).

increases sellers' utilities, of which only $U_{S_D}^{D_{seller}}$ enters the conditions for compliance equilibrium. In particular, it affects $(Obs\ 1.2)$ which ensures that that D-type businesspeople prefer delivering the good of value S_D with the risk of being found liable to delivering the good of value L.[7] Consequently, a ceteris paribus change in r can be inconsequential for existence of the compliance equilibrium. It is through S_H, S_D, L, and their effects on ΔEU_{CE}^{buyer}, the value of access to the third parties, that r shapes the environment. ΔEU_{CE}^{buyer} is likely to increase with r, and hence reduce $\underline{\gamma_H}^{comply}$, if L and S_H increase with r more than S_D does. And $\underline{e}^{comply}$ is likely to also increase with r, making the compliance equilibrium harder to sustain, if L increases more than S_H or S_D do. Overall in this model, 'better' economic opportunities, e.g. higher gross return on investments (r), do not necessarily translate to higher likelihood of observing the compliance equilibrium.

Further examination of the compliance equilibrium clarifies its meaning and relates it with the concepts of law and legal system in general. In the compliance equilibrium as envisioned by *Observation 1*, there exist H-type businesspeople that abide by L voluntarily and without the need to invoke a threat of punishment (through the assumption that $S_H \geq L$). There are also D-type businesspeople who do not choose a behavior consistent with L unless there is a specific external incentive for doing so. Then there are third parties' whose decisions are respected by D-type businesspeople due to the combination of two distinct factors. First, the third parties'

[7] Note that somewhat paradoxically, decreases in r resulting in the decrease of $U_{S_D}^{D\_seller}$, ceteris paribus, encourages the D-type businesspeople to avoid violating the law altogether and deliver the good of value L instead. While this constitutes breakdown of the compliance equilibrium, it gives rise to an equilibrium where third parties are never used and yet are relied upon, which is analyzed in more detail in Appendix A-1 and is a precarious scenario omitted here for the sake of brevity.

decisions are enforced; and second, respect that other D-type businesspeople pay to the third parties' decisions increases the value of doing the same. Importantly, none of these two factors can work alone in this model; it is through their combined effect that the compliance equilibrium is achieved.

This depiction of the compliance equilibrium highlights the aspects that make it consistent with the notion of legal system as conceptualized by Hart (1961).

> "So long as the laws which are valid by the system's tests of validity are obeyed by the bulk of the population this surely is all the evidence we need in order to establish that a given legal system exists." (p. 114)

In the model, L passes the "tests of validity" in that the third parties operationalize it by finding some businesspeople liable after delivering the good of value less than that. The law is "obeyed by the bulk of the population" in two ways. First, some sellers (γ_H) deliver the good of value above L. And second, those that deliver the good of lower value comply with the third parties' decisions if found liable. The compliance equilibrium thus is an environment where it can be said that the "legal system exists".

3.2. Multiple equilibria

The compliance equilibrium is not the only equilibrium that the model admits. There also may exist a "non-compliance equilibrium" whereby D-type businesspeople deliver goods of value S_D to the buyers and ignore the third parties' decisions if found liable. Analysis of the conditions underlying each of these two equlibria reveals the following:

Observation 2: When $e < \overline{e}$, either the compliance or non-compliance equilibrium is possible if and only if:

$$\bar{e}^{non-comply} > e \geq \underline{e}^{comply} \qquad (Obs\ 2.1)$$

$$U_{S_D}^{D\_seller} - U_L^{D_{seller}} \qquad (Obs\ 2.2)$$

$$> \max\{\alpha\rho\big((L - S_D)$$

$$+ \phi\big), P(dispute)\big[\rho e\alpha\big((L - S_D) + E\big)$$

$$+ \rho(1 - e)\Delta EU_{NCE}^{buyer}\big]\}$$

$$\rho e(L - S_D) \geq K \qquad (Obs\ 2.3)$$

$$\gamma_H > \underline{\gamma_H}^{non-comply} \geq \underline{\gamma_H}^{comply} \qquad (Obs\ 2.4)$$

where

- as before, $\underline{e}^{comply} = \frac{\alpha\big((L-S_D)+\phi\big)-\Delta EU_{CE}^{buyer}}{\alpha\big((L-S_D)+E\big)-\Delta EU_{CE}^{buyer}}$,

- $\bar{e}^{non-comply} = \frac{\alpha\big((L-S_D)+\phi\big)-\Delta EU_{NCE}^{buyer}}{\alpha\big((L-S_D)+E\big)-\Delta EU_{NCE}^{buyer}}$, with $\overline{e} > \bar{e}^{non-comply} > \underline{e}^{comply}$

- if $\gamma_H < \underline{\gamma_H}$, then

$$\Delta EU_{CE}^{buyer}$$

$$= \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H)$$

$$\cdot \alpha(\rho(L - S_D) - K)$$

$$\Delta EU_{NCE}^{buyer}$$

$$= \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H)$$

$$\cdot \alpha(\rho e(L - S_D) - K)$$

$$P(dispute) = 1$$

– if $\gamma_H \geq \underline{\gamma_H}$, then

$$\Delta EU_{CE}^{buyer} = (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$$

$$\Delta EU_{NCE}^{buyer} = (1 - \gamma_H) \cdot \alpha(\rho e(L - S_D) - K)$$

$$P(dispute) = \frac{1}{1 + (1 - \gamma_H)\rho(1 - e)} < 1$$

– as before, $\underline{\gamma_H}^{comply} = \frac{-U_{S_D}^{buyer} - \alpha(\rho(L - S_D) - K)}{U_{S_H}^{buyer} - U_{S_D}^{buyer} - \alpha(\rho(L - S_D) - K)} < \underline{\gamma_H}$, and $\underline{\gamma_H}^{non-comply} = \frac{-U_{S_D}^{buyer} - \alpha(\rho e(L - S_D) - K)}{U_{S_H}^{buyer} - U_{S_D}^{buyer} - \alpha(\rho e(L - S_D) - K)} < \underline{\gamma_H}$.[8]

Observation 2 suggests that two identical societies, with the same values as well as the same legal system, may exhibit very different behavioral patterns. Businesspeople in these two distinct behavioral patterns behave the way they do solely because other people behave that way, and this is not simply copying others' behavior, but rather a rational best response to the environment. More precisely, as other D-type businesspeople comply with the third parties' decisions, it is more valuable to have access to the third parties, which convinces each D-type businessperson to comply. Importantly, both these equilibria are stable, and there is nothing "fundamental" that makes one or the other more or less likely to appear.

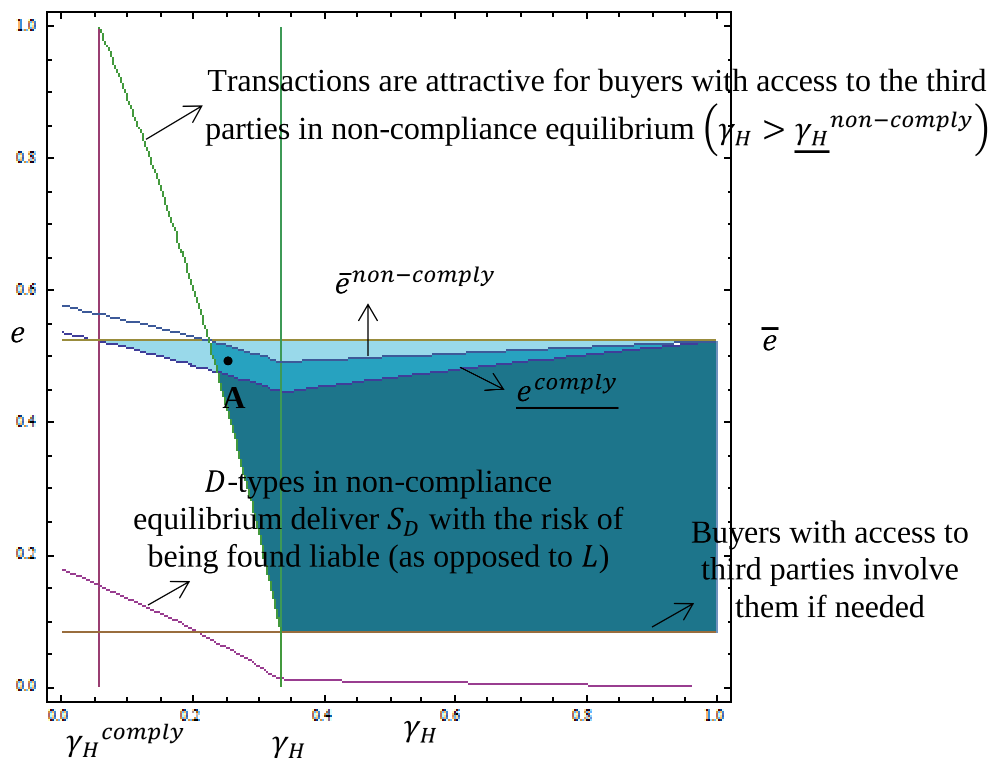
The two equilibria of *Observation 2* can be Pareto ranked if $\gamma_H < \underline{\gamma_H}$. In this region, only buyers that have access to the third parties find transactions attractive,

[8] Note that while higher γ_H is better as it allows more transactions (which are socially beneficial as $r > 1$), once transactions are attractive enough to be made further increase in γ_H does not affect social welfare.

while all transactions in the model are welfare enhancing (gross return on investments, r, is above 1). Thus, when $\gamma_H < \underline{\gamma_H}$, only in the compliance equilibrium do all potential transactions materialize. In contrast, in the non-compliance equilibrium, some of the D-type sellers who did not comply with the third parties' decisions no longer have access to the third parties and hence refuse to transact as buyers. Consequently, if $\gamma_H < \underline{\gamma_H}$, the compliance equilibrium is Pareto superior to the non-compliance equilibrium. If $\gamma_H \geq \underline{\gamma_H}$, the two equilibria are associated with identical social welfare because all potential transactions materialize in both equilibria and the repercussions of non-compliance are transfers from some individuals to others. The Pareto ranking of the two equilibria confer an additional significance to *Observation 2*. In particular, under special circumstances (as outlined in *Observation 2*), the business interactions of this model transform into a coordination game where each individual is better off behaving just like others do, and this happens even as the subsequent population behavior may not be the best for the population as a whole.

Figure 1-2 illustrates *Observation 2* by overlaying the conditions underlying existence of each of the two (compliance and non-compliance) equilibria and highlighting potential behavioral patterns in the respective regions. The lightest shade represents the conditions where, in the event of $e < \overline{e}$, only the compliance equilibrium exists. The second lightest shade highlights the environment where both the compliance and non-compliance equilibrium are possible. And the darkest shade highlights the conditions where only the non-compliance equilibrium exists. In the unshaded regions where $e < \overline{e}$, either transactions are unattractive for buyers and hence are not made, or D-type businesspeople prefer to deliver the good of value L to avoid third parties, or e is so low that it is not even worth for buyers to lodge a complaint to third parties.

Figure 1-2: Multiple equilibria

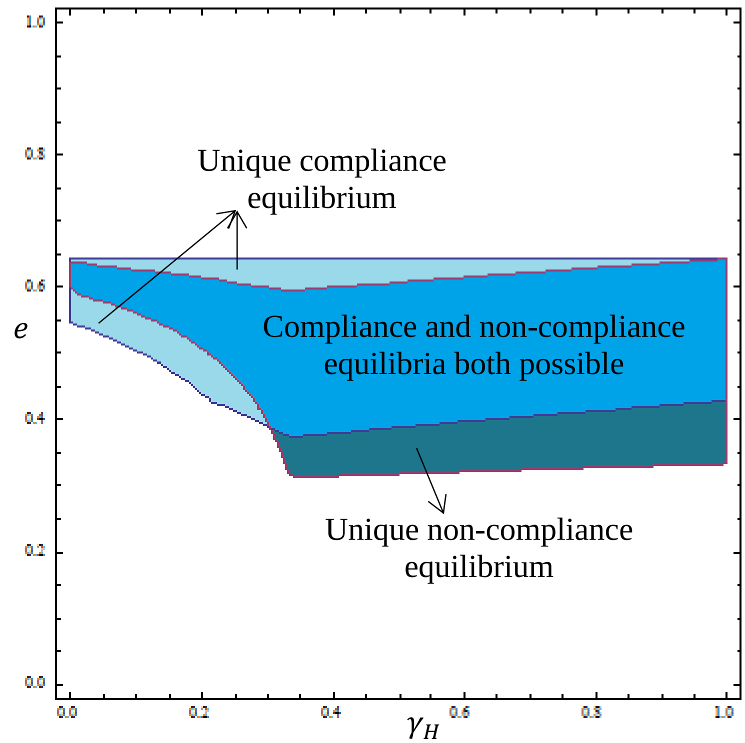


Parameters for this figure are the same as on Figure 1-1.

Consideration of point A on Figure 1-2 helps understand some of the intuition behind *Observation 2*. Both the compliance and the non-compliance equilibrium are possible at point A. In addition, point A is in the region where $\gamma_H < \underline{\gamma_H}$, so the non-compliance equilibrium is Pareto inferior to the compliance equilibrium (because only in the compliance equilibrium are all potential transactions made). If, at point A, the society is in non-compliance equilibrium, the easiest way to move to the Pareto superior equilibrium may be, rather counter-intuitively, to reduce the share of honest businesspeople. This is because with lower γ_H from point A, ceteris paribus, transactions are no longer attractive even for buyers with access to the third parties if all D-type sellers ignore the third parties' decisions. Consequently, all transactions cease and the non-compliance equilibrium breaks down. Compliance with the third parties' decisions is advantageous however since transactions are attractive for buyers with access to the third parties in the environment where other D-type sellers comply with the third parties' decisions. Consequently, at point A, it is welfare enhancing to have less honest business people in the population as lower γ_H forces the population from the non-compliance to the compliance equilibrium with the corresponding increase in the number of transactions.

Figure 1-1 and Figure 1-2 illustrate *Observation 1* and *Observation 2* for fixed values for the model parameters. A natural next step is to examine whether or not tailoring rules to specific contexts may help improve the social welfare. Figure 1-3 provides an example of this added flexibility. Instead of setting L at a fixed value as in figures 1-1 and 1-2, Figure 1-3 allows L to vary with e and γ_H. More precisely, at each point on Figure 1-3, L is set at the maximum level permitted by the compliance equilibrium at that point, while all other parameters are set as in figures 1-1 and 1-2. Figure 1-3 illustrates that this added flexibility in L considerably increases the region where the compliance equilibrium is possible. It also notably decreases the region where only the non-compliance equilibrium is possible. Figure 1-3 thus highlights the importance of processes that govern L for the type of equilibrium that prevails with the corresponding social welfare. Added flexibility in other parameters representing rules, e.g. E or ϕ or ρ, further reshapes the shaded regions.

Figure 1-3: Multiple equilibria with flexible *L*



Parameters for this figure are the same as on Figure 1-1 and Figure 1-2, except L which equals the following: $S_D + \frac{\alpha(eE-\varphi)+(1-e)\left(I(\gamma_H<\underline{\gamma_H})\cdot\left(\gamma_H\cdot U_{S_H}^{buyer}+(1-\gamma_H)\cdot U_{S_D}^{buyer}\right)-(1-\gamma_H)\alpha K\right)}{\alpha(1-(1-\gamma_H)\rho)(1-e)}$, with $S_D \leq L \leq S_H$ restriction.

4. Dynamics

This section adds time a dimension to the model setup and examines the evolution of γ_H using a replicator dynamics (Gintis 2000). H-type and D-type businesspeople are viewed as replicators in the sense that the types with higher average payoff are more likely to replicate themselves than the types with lower average payoff. Note that the total size of population remains the same over time; it is the distribution of types, captured with γ_H, that evolves. Put differently, at the end of each t, businesspeople switch their types depending on whether H-types or D-types earn higher utility on average.

Each time period t unfolds as described in the static version of the model. Denote the average utility that H-type and D-type businesspeople earn over the two episodes of their lives at time t by, respectively, $\overline{U}_t^H$ and $\overline{U}_t^D$, and the average utility of the population by $\overline{U}_t$.[9] Following the standard logic of replicator dynamic, suppose that the frequency of H-type businesspeople increases if H-types have above average payoffs, and decreases if H-types have below average payoffs. In particular, this dynamic can be expressed as follows:

$$\gamma_{H_{t+1}} = \gamma_{H_t} \cdot g\left(\overline{U}_t^H - \overline{U}_t\right)$$

where $g(\cdot)$ is an increasing continuous function with $g(0) = 1$.[10] The equilibrium level of γ_H then is reached if $\overline{U}_t^H$ and $\overline{U}_t^D$ are the same, meaning that H-type and D-type businesspeople earn the same utilities on average at time t.[11] Importantly, in the absence of third parties, $\overline{U}_t^H$ is always below $\overline{U}_t^D$ because even though the two types of businesspeople earn the same utilities as buyers, H-types earn less as sellers: $U_{S_H}^{H_{seller}} < U_{S_D}^{D_{seller}}$. While the closed-form solution of the equilibrium level of γ_H is intractable, numerical examples based on the values of parameters as given on figures 1-1, 1-2, and 1-3 offer interesting insights.

Figure 1-4 illustrates possible scenarios highlighting that (i) a continued failure to tailor L to the context may have long-lasting repercussions on both, the equilibrium level of γ_H and the type of equilibrium that prevails, and (ii) small

[9] More precisely, $\overline{U}_t = \gamma_{H_t}\overline{U}_t^H + \left(1 - \gamma_{H_t}\right)\overline{U}_t^D$.

[10] For instance, $g(x) = 1 + k \cdot \frac{1-e^{-x}}{1+e^{-x}}$ with $k \in (0,1)$ determining the speed of change.

[11] Note that $\overline{U}_t^H - \overline{U}_t = (1 - \gamma_{H_t})\left(\overline{U}_t^H - \overline{U}_t^D\right)$.

divergence in environments may set societies on fundamentally divergent paths. Before examining the scenarios of Figure 1-4 in detail, it is instructive to consider four important and common features of the corresponding societies. First, the societies start and remain in the environment where enforcement itself is not sufficient to compel D-type businesspeople to comply with the third parties' decisions. Second, mimicking a widespread historical path, the societies in the simulation start in the non-compliance equilibrium.

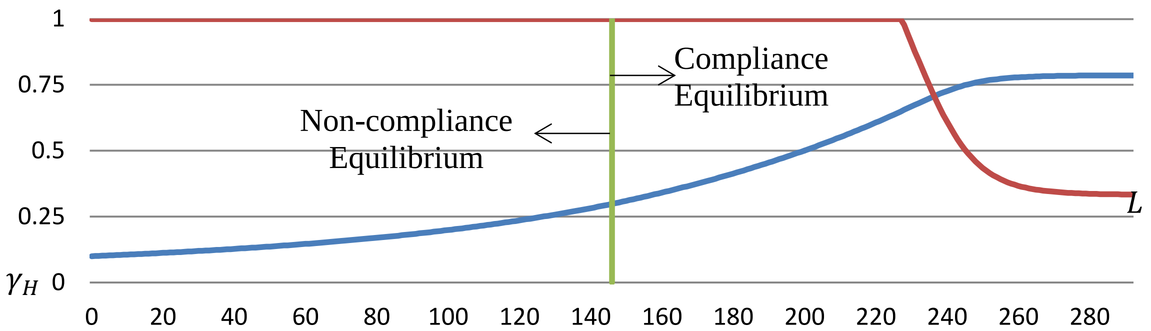
Third, to examine potentially significant changes in the population behavior, initial conditions also allow existence of the compliance equilibrium. In addition, D-type businesspeople earn lower average utility than H-type businesspeople at t_0. Without these added advantages at the start, there is very little a society can do in the model to get out of the non-compliance equilibrium, apart from overcoming the limitations of enforcement (e or E or both). Importantly, recall that H-types in their role as sellers prefer delivering the good of value S_H to delivering the good of lower value, S_D, and in doing so earn lower utility than the D-type sellers that prefer delivering the good of value S_D. More precisely, $U_{S_D}^{H_{seller}} < U_{S_H}^{H_{seller}} < U_{S_D}^{D_{seller}}$ so that even though H-types feel better fulfilling promise than not fulfilling it (the first inequality), D-types enjoy the advantage of cost savings by delivering a good of lower value (the second inequality). Nevertheless, D-type businesspeople earn lower average utility than H-type businesspeople at t_0 because (i) only the buyers with access to the third parties enter transactions, so every D-type seller that gets a transaction faces third parties and a possibility of enforcement; and (ii) some D-types do not have access to the third parties and hence cannot enjoy the benefits of transactions as buyers. To paraphrase this condition, at t_0, if there were no third parties, D-types would outperform H-types (because $U_{S_H}^{H_{seller}} < U_{S_D}^{D_{seller}}$), but in the presence of third parties, even as all D-types ignore the decisions of the third parties, H-types outperform D-types in terms of the average utility that they earn.

The final feature of the societies illustrated on Figure 1-4 is that, mimicking the practical difficulty that even small groups of individuals face in changing the group behavior, the non-compliance equilibrium persists unless the society goes through a phase where the non-compliance equilibrium breaks down and only the compliance equilibrium is possible. After this first transition, the compliance equilibrium persists unless the non-compliance equilibrium is the unique equilibrium. Put differently, even if two equilibria are possible, societies do not switch the type of equilibrium unless there is no alternative.

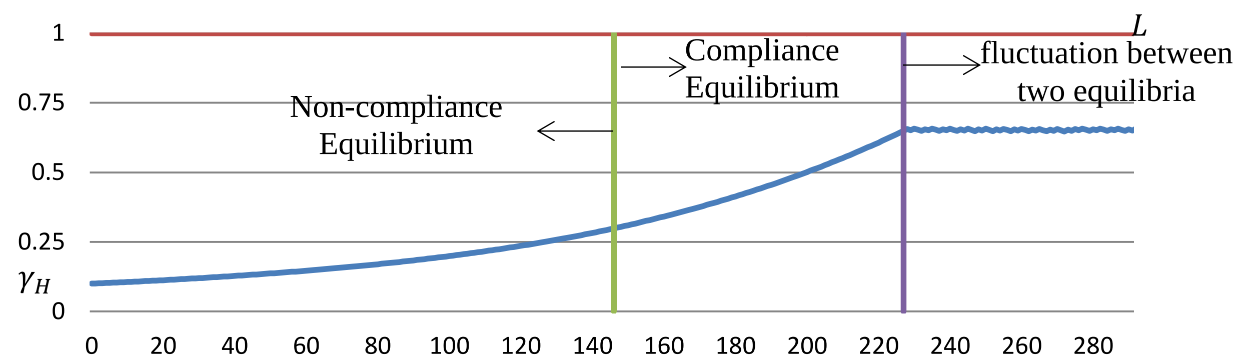
Panel A and Panel B of Figure 1-4 illustrate the importance of a sustained tailoring of L to the relevant context. On Panel A, as on Figure 1-3, the level of L (red line) is set at the start of each t at the maximum level permissible for the compliance equilibrium in the corresponding context. In contrast, on Panel B, L is set at this level at t_0 and kept constant thereafter regardless the context of each t. Consequently, Panel A and Panel B have identical L at t_0 ($L = S_H$ for both at the start), but not necessarily so thereafter. As the paths of L happen to largely coincide for the two scenarios, the two societies share a phase of compliance equilibrium which they enter at $t = 147$. This is where compliance equilibrium is the unique equilibrium given the conditions at the time.

Figure 1-4: γ_H and L over time

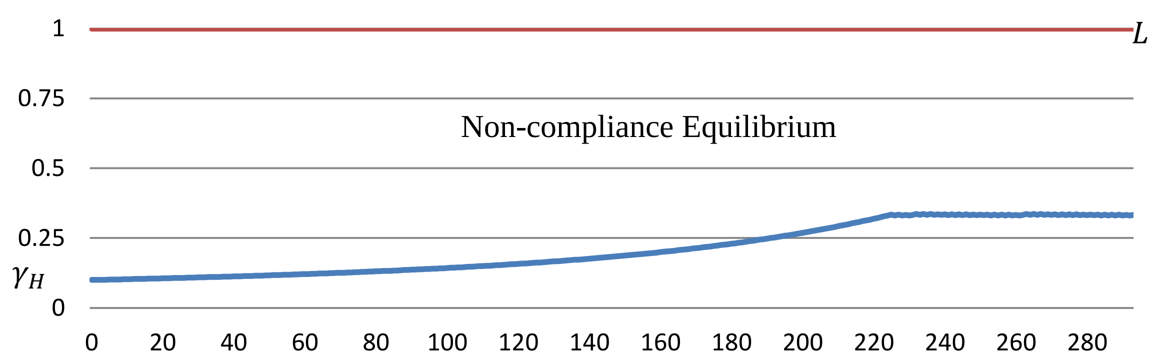
Panel A: $e = 0.6$ and L set at the start of each t



Panel B: $e = 0.6$ and L is set at $t = 0$



Panel C: $e = 0.59$ and L set at the start of each t



Parameters are the same as on figures 1-1, 1-2 and 1-3, namely: $\alpha = 1$, $r = 2$, $I = 100$, $S_D = 75$, $S_H = 150$, $U_{S_H}^{buyer} = \alpha(-I + S_H) = 50$, $U_{S_D}^{buyer} = \alpha(-I + S_D) = -25$, $U_{S_D}^{D seller} = \alpha(rI - S_D) = 125$, $U_{S_L}^{D seller} = \alpha(rI - L)$, $K = 2$, $\rho = 0.6$, $\phi = 15$, $E = 65$. In addition, $U_{S_H}^{H seller} = \alpha(rI - S_H + H) = 75$ with $H = 25$ (note $U_{S_H}^{H seller} < U_{S_D}^{D seller}$). Furthermore, $\gamma_{H_0} = 0.1$ and $k = 0.01$ (in $g(\cdot)$).

The paths of L on panels A and B diverge at $t = 228$ (the point where red line tracing L starts descending on Panel A), where γ_H has grown to the extent that keeping access to the third parties is less valuable than before and lower L is needed to convince D-type businesspeople to pay $(L - S_D)$ to the buyer and fine ϕ to the third parties rather than ignore the third parties' decision. This pressure on L also illustrates a conclusion from *Observation 1* that the law cannot get too strict or it may jeopardize the existence of the compliance equilibrium. As Panel A society lowers L to sustain the compliance equilibrium, γ_H grows further to settle at $\gamma_H \approx 0.78$. In contrast, Panel B society keeps L constant, fails to sustain the compliance equilibrium and enters a phase where the society fluctuates between the two types of equilibria around $\gamma_H \approx 0.65$. More precisely, the non-compliance equilibrium after $t = 228$ entails lower average utility for H-types than for D-types. This forces γ_H to drop for the next period. This lower γ_H is associated with the unique compliance equilibrium where H-types outperform D-types, pushing γ_H up again for the next period. The process then repeats as higher γ_H again brings about the unique non-compliance equilibrium.

Panel C illustrates the potential long-term repercussions of a small divergence in environments. It exactly replicates the environment of Panel A with one small exception: the third parties' decisions are enforced with 1 percentage point less likelihood on Panel C, i.e. e is 0.59 on Panel C instead of 0.60 as on Panel A. This small discrepancy in the environment leads to a massive divergence in the long term as the society of Panel C never goes through a phase where the compliance equilibrium is unique and hence never escapes the non-compliance equilibrium. The equilibrium level of γ_H here is approximately 0.33, less than half of that achieved on Panel A, and social welfare is significantly lower with only around 85% of all potential transitions actually materializing.

Importantly, the numerical examples illustrated on Figure 1-4 keep all parameters fixed except L on panels A and C. If societies are able to tailor other parameters representing rules, e.g. E or ϕ or ρ, to the relevant contexts, then a wider range of disadvantageous conditions may be overcome, and societies may be led to the compliance equilibrium with a high equilibrium level of γ_H (e.g. setting $\varphi = 10$ on Panel C achieves this). While this means that small divergences in environments do not necessarily lead to fundamentally divergent paths, Figure 1-4 highlights the importance of tailoring the features of legal system to the existing context defined by values and history.

5. Conclusions

This paper examines the origins of legal order in an environment where neither legal nor non-legal institutions, taken separately, are capable of supporting transactions. The model focuses on voluntary business exchange between pairs of "perfect strangers", with each individual's life spanning two distinct episodes, one as a seller, and another as a buyer. By entering a transaction, each buyer exposes him/herself to the risk of suffering losses if their partner is dishonest and delivers the good of value that falls short of the buyer's original investment. The share of honest individuals in the population provides a measure of values of the population. The legal system is represented in the model by the minimum quality of goods that sellers may deliver below which buyers may invoke "third parties" to dispute the sellers' behavior. The crucial element of this model is that the third parties' decisions regarding liability of the seller and the corresponding payments required of him/her are enforced so imperfectly that a threat of enforcement is not sufficient to encourage sellers to comply with the third parties' decisions. Sellers can and often choose to ignore the third parties' decisions, and those decisions often go unenforced.

To compel dishonest sellers to comply with the third parties' decisions, the sellers that ignore the third parties' decision and "get away" with it (the decision is not enforced) are denied access to the third parties when taking the role of a buyer. The value of maintaining this access to the third parties, coupled with the state enforcement, may be sufficient to achieve the "compliance equilibrium" whereby dishonest sellers behave dishonestly but voluntarily comply with the third parties' decisions if found liable. Furthermore, two identical societies, with exactly the same values and laws, may exhibit fundamentally divergent behavioral patterns, with one enjoying the compliance equilibrium while the other languishing in the "non-compliance" equilibrium where everyone ignores the third parties' decisions with only a fraction, if any, transactions being made, even though each transaction is potentially mutually beneficial. This divergence in behavioral patterns is possible because the value of maintaining access to the third parties feeds onto itself. If everyone else values this access, individuals comply with the third parties' decisions thus further increasing the value of this access.

The model shows that in a society with higher share of honest individuals, it may be harder to sustain the compliance equilibrium. This happens because a higher share of honest individuals means that buyers are more likely to encounter a seller that is honest and will deliver the good of desirable quality. Consequently, buyers are less likely to need access to a third party to dispute the sellers' behavior. With less interest in maintaining the access to the third parties, the sellers are more inclined to ignore the third parties' decisions altogether, unless they are backed with stronger enforcement.

Analysis of evolution of values over time reveals that failure to closely tailor the features of legal system to the prevailing values may have long-lasting repercussions on both, the steady-state level of honest individuals in population, and the type of equilibrium that prevails in that steady-state. Furthermore, small divergence in contexts may set societies on fundamentally divergent paths that may be hard to alter without drastic measures.

Chapter 2: Institutions, social structure and human capital as determinants of culture

1. Introduction

The process of learning is increasingly recognized in economic analysis as an important determinant of individual and population behavior (e.g. Fudenberg and Levine 2016). Building on the widespread agreement that culture is learned socially, I develop a model of learning that uncovers new ways in which institutions, human capital, and social structure may shape culture. Interconnections between institutions, social structure and culture have been documented empirically (e.g. Tabellini 2010, Alesina and Giuliano 2011), and a number of underlying causal mechanisms have been considered (e.g. Banfield 1958, Almond and Verba 1963, Putnam, Leonardi and Nanetti 1993, Tabellini 2008b). The role of the process of learning in forming these interconnections has received scant attention.

I embed the process of learning about cultural beliefs, attitudes, values, behavioral rules, or simply cultural traits in the following context. Through regularizing behavior, institutions determine the uncertainty of payoffs from cultural traits. Social structure shapes the nature, frequency and intensity of social interactions, and thus determines the strength of information flows from family and peers (e.g. Bandura 1986). Finally, the stock of competencies, abilities, expertise, and innovativeness, or the level of human capital, determines the productiveness of asocial learning (e.g. Nelson and Phelps 1966).

Following experimental findings on the process of learning (see Erev and Haruvy (2012) for an excellent review), I assume that individuals have limited memory and estimate expected payoffs of different cultural traits by calculating the corresponding averages. Next, individuals in the model internalize the cultural trait with the highest estimated expected payoff. The way in which individuals analyze information gives rise to two types of effects of the environment that have direct analogs in regularities observed in behavioral experiments. I call these the "consideration effect" and the "precision effect". The consideration effect refers to the fact that adding an item to the set of possible alternatives increases the chance of that item being chosen even if it is not the best among the alternatives.[12] Stutzer, Goette and Zehnder (2011) provide evidence of this effect. The precision effect refers to the fact that additional or more precise information alters the outcomes of learning and subsequent behavior. Myers and Sandler (1960) is among the first to document its existence in an experiment.[13]

This process of learning and internalizing cultural traits is analytically described by a replicator dynamic. I establish that a steady state of culture emerges and that it is always unique and stable. Institutions, social structure and human capital are found to determine equilibrium culture through combinations of the consideration and precision effects. The model establishes that institutions can influence the spread of cultural traits even without affecting the expected value of payoffs. Previous research primarily relies on institutions altering payoffs or expectations thereof and

[12] The main source of the consideration effect in this paper's model is that individuals may internalize only the cultural traits that they are aware of, or alternatively, the cultural traits that attract sufficient amount of attention from learners. Modica and Rustichini (1994) appear to be among the first to study awareness in the economics literature. The importance of attention has been recognized at least since Simon (1957). For models incorporating awareness or attention, please see, e.g. Li (2009), Tirole (2009), Masatlioglu, Nakajima, and Ozbay (2012), Filiz-Ozbay (2012); for an empirical investigation see, e.g. Goeree (2008).

[13] Busemeyer and Townsend (1993) coined the term "payoff variability effect" to describe this behavioral regularity.

subsequently altering the prevalence of different cultural traits.[14] My model, in contrast, finds that, through modifying the uncertainty of payoffs, institutions determine the degree of precision of the information about cultural traits that individuals acquire in the course of learning. This, through the precision effect, influences the outcomes of learning and is subsequently reflected in equilibrium culture. Uncertainty of payoffs associated with cultural traits is an important and previously underexplored channel through which institutions shape culture.

Similarly, the model offers a new mechanism behind the existing findings that strong family ties often hinder the spread of beneficial cultural traits. Banfield (1958) and Putnam, Leonardi and Nanetti (1993) argue that strong family ties breed exclusive trust in one's immediate family, which, by decreasing the payoffs from interacting outside of family, lower the benefits of civic engagement. Consequently, strong family ties are associated with low civic participation. In contrast, this paper's model abstracts away from the effects of family ties on payoffs and focuses on its effect on the availability of information about the cultural traits that family members have. The level of access to this additional information alone is able to influence the dynamics of culture and the subsequent equilibrium. The model thus demonstrates that the strength of information flows is an important new channel through which social structure is related with culture.

[14] For theory see e.g. Milgrom, North and Weingast (1990), Greif (1994), Bowles (1998), Tabellini (2008). For empirical evidence on historical institutions shaping values, see e.g. Tabellini (2010), Guiso, Sapienza and Zingales (2008a), Grosjean (2011). For empirical evidence on current institutions shaping values, see e.g. Agion, Algan, Cahuc and Shleifer (2010), Di Tella, Galiani and Schargrodsky (2007), Alesina and Fuchs-Schündeln (2007).

The model demonstrates that human capital promotes the spread of beneficial cultural traits. That both institutions and human capital shape culture potentially reconciles the findings of Acemoglu, Johnson and Robinson (2001) and Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004). Acemoglu, Johnson and Robinson (2001) claim that improvements of institutions cause economic growth, while Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004) disagree and argue that human capital accumulation causes both economic growth and improvements of institutions. If culture is a channel through which institutions and human capital affect economic performance then these two claims are complementary in the light of this model's finding. In particular, if the particular measures of human capital capture more of the influence of culture than the particular measures of institutions, as Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004) indirectly suggest, the empirical effect of institutions might look insignificant when one controls for human capital, even though institutions are independently important.

The model sheds light on the joint effects of institutions, social structure and human capital on culture. Institutions and human capital mostly substitute for each other in promoting the spread of beneficial cultural traits. Put in terms of the underlying parameters, this means that outcomes of individual deliberation are less important as the uncertainty of payoffs drops. While simple intuition would suggest that more precise information should have a larger impact on the corresponding choices than less precise information, the model reveals that interplay of the consideration and precision effects reverses this intuition. The model also exposes complex interactions of institutions and social ties in shaping culture and establishes that better institutions generally mute the effects of social ties, whether positive or negative.

In studying the relation of institutions, social structure and human capital with culture, this paper is related to empirical work by Alesina and Fuchs-Schündeln (2007), Tabellini (2010), Aghion, Algan, Cahuc and Shleifer (2010), Alesina and Giuliano (2011) and analytical research by Banfield (1958), Almond and Verba (1963), and more recent work by Putnam, Leonardi and Nanetti (1993), Bowles (1998), Guiso, Sapienza and Zingales (2008a), Dessi (2008), and Tabellini (2008b). The latter three papers are the most closely related in that they too are learning models. They are a part of the distinct branch of the economics literature initiated by Bisin and Verdier (1998, 2000, 2001a) that combine evolutionary models of anthropology and biology with optimization by parents in efforts to inculcate cultural traits in their children.[15] This focus on parental decisions appears to be a hallmark of most research into cultural transmission in the economics literature. A common mechanism underlying the dynamics of culture is the difference between parents' and children's preferences and beliefs (e.g. parents are assumed to be imperfectly emphatic in that parents use their own values to assess the child's wellbeing even if the child has different values). In contrast with this focus on parental decisions about inculcating cultural traits in their children, I analyze the process of learning by individuals themselves. While doing so, I also abstract away from the differences between parents' and children's preferences and beliefs.

[15] See Bisin and Verdier (2011) for an excellent review of the literature on cultural transmission and socialization.

In focusing on the process of learning and examining the subsequent individual or population behavior, this paper is related to a vast literature on social learning that spans the fields of economics, anthropology, and biology. The majority of this literature in economics, which includes research into social networks, analyzes the population-level consequences of various decision rules or network topologies.[16] A large part of the social learning literature in anthropology and biology explores which decision rules are evolutionarily adaptive under which conditions.[17] This paper's model also relates to a large literature on diffusion of innovations, in particular Rogers' seminal work on factors that influence the spread of new ideas (Rogers 1995). Considering only the process of evaluating cultural traits – abstracting away from the process by which the relevant information is collected – models of stochastic choice are also relevant to this paper's model. Following the classification of stochastic choice models by Agranov and Ortoleva (2017), the models of bounded rationality are most relevant. These models assume that individuals have well-defined and stable preferences over available options but their choice depends on the realization of noisy signals regarding which options are preferable (e.g. Ratcliff and McKoon, 2008).

This paper builds on all these contributions in terms of the model's analytics. The emphasis on factors that might influence the process of learning, albeit with modified interpretation, is borrowed from Rogers (1995); the distinction between

[16] For Bayesian decision rules see, for example, Bikchandani, Hirshleifer, and Welch (1992), Banarjee and Fudenberg (2004), Smith and Sorensen (2008), Acemoglu, Dahleh, Lobel, and Ozdaglar (2011), Gale and Kariv (2003). For non-Bayesian decision rules see, for example, Ellison and Fudenberg (1993, 1995), DeMarzo, Vayanos and Zwiebel (2003), Golub and Jackson (2010).
[17] See, for example, Boyd and Richerson (1985, 2005), Henrich and Boyd (1998), McElreath and Strimling (2008), Kendal et al. (2009), Rendell et al. (2010).

social interactions with family and with peers is based on the finding of research in biology that different modes of cultural transmission give rise to different dynamics of culture (e.g. Cavalli-Sforza and Feldman 1981); and the population-level consequences of a simple rule of forming estimates of payoffs are studied in the spirit of the economics literature. This diversity of sources underlying the mechanics of this model, and its application to the topics of institutions, social structure, human capital and culture complicates the precise positioning of this research. Analytically the model is closer to studies of social networks (e.g. Golub and Jackson 2010, Acemoglu, Dahleh, Lobel, and Ozdaglar 2011, Acemoglu, Ozdaglar, and ParandehGheibi 2010) and social learning in general (e.g. Ellison and Fudenberg 1995, Banerjee and Fudenberg 2004) than anything else within the economics literature. In contrast with these contributions I analyze learning from multiple kinds of information sources which gives rise to qualitatively distinct results.

The rest of the paper is organized as follows. Section 2 sets up the model. Section 3 looks at the equilibrium culture and describes the consideration and precision effects. Section 4 presents results. The final section briefly concludes. Detailed derivations and proofs are deferred to Appendix B-1.

2. Model Setup

Consider two populations of individuals, the parental generation and the younger generation. The younger generation begins learning about cultural traits having inherited a cultural trait from their family (from the parental generation).[18] In

[18] The results are unaffected if individuals from the younger generation start off with other cultural traits. As shown below, a unique equilibrium culture is independent of the culture among the younger generation at $\tau = 0$.

each learning period τ, illustrated in Figure 2-1, individuals from the younger generation learn about cultural traits and may adopt one different from their own. For simplicity, individuals from the parental generation have stopped learning and keep their own cultural trait. The process of learning by individuals from the younger generation unfolds as follows. Individuals potentially learn about cultural traits of their family (from the parental generation) and peers (from the younger generation), denoted by c_F and c_P respectively, through social interactions with them. It is instructive to think about c_F and c_P as envelopes that individuals from the younger generation may receive, respectively, from family and peers. The content of these envelopes are determined by the culture of the corresponding population, as discussed below. Social structure determines the strength of information flows, captured by probabilities p_F and p_P that the corresponding envelopes are received in the course of social interactions.

In addition to information that individuals from the younger generation potentially receive from their family and peers, they receive information through experimentation and deliberation. This envelope, denoted with c_A (subscript A for asocial learning), is received with certainty. Its content however is determined by the level of human capital, captured with probability ρ that the envelope c_A contains information about the cultural trait with the best expected outcome. Intuitively, better human capital (higher ρ) leads to a higher likelihood of encountering the most desirable cultural trait through experimentation and deliberation. Finally, individuals learn about their own cultural trait at time τ, c_τ, through their own experience.

Institutions define outcomes, y, associated with each cultural belief, attitude, value, or behavioral rule. Thus, by the end of each learning period τ, individuals from the younger generation hold information $\{c_A, y_{c_A}\}$ and $\{c_\tau, y_{c_\tau}\}$ that was received, respectively, from deliberation and own experience, and may also hold information $\{c_F, y_{c_F}\}$ and $\{c_P, y_{c_P}\}$ received, respectively, from family (with probability p_F) and peers (with probability p_P). Individuals then analyze this set of information acquired in the course of learning and may adopt a behavioral pattern different from their own.

The next learning period, $\tau + 1$, unfold in the same way, except that individuals from the younger generation may have a cultural trait that differs from what they had at the learning period τ. Note that each τ is a learning period of individuals in the younger generation, and the passage of time does not mean that the younger generation becomes the parental generation. It is instructive to think of the two generations of individuals in the model as two groups of infinitely lived individuals, with one group – called the younger generation – engaged in learning about cultural traits. Importantly, infinite life span is not necessary for the model as a unique and stable equilibrium is obtained rather quickly. The designation of the parental generation as a (static) separate source of information about cultural traits follows the classic study of Cavalli-Sforza and Feldman (1981), who demonstrate that each of the three major modes of cultural transmission – vertical (from parents), oblique (from non-parents of the parental generation), and horizontal (from peers) – gives rise to different dynamics of culture.[19] An empirical evidence of importance of this distinction between the sources of information in the process of learning about

[19] Oblique cultural transmission is not considered in this model for analytical tractability.

cultural traits is provided by Giuliano and Nunn (2017) who find that a more stable climate between 500 and 1900 AD is associated with more reliance on information from the parental generation, and also more persistence of culture.

In this paper's model, the process of learning and adoption of cultural beliefs, attitudes, values, or behavioral rules leads to changes over learning periods τ in the cultural composition of the younger generation until a unique equilibrium is reached. The model aims at understanding characteristics of equilibrium, and its determinants.

The following subsections detail each aspect of the process of learning in turn.

2.1. Culture

The concept of cultural trait helps formalize the process of learning about beliefs, attitudes, values, or behavioral rules. A cultural trait is one of a set of mutually exclusive behavioral patterns (or beliefs or attitudes or values or behavioral rules) that an individual could possibly hold concerning a particular phenomenon.[20] Let C represent the corresponding set of all possible cultural traits, of which each individual holds exactly one at each point in time. For simplicity I assume that $C = \{c_1, c_2\}$.

Through social interactions with family and peers, individuals from the younger generation may receive envelopes c_F and c_P. Subscripts F (for family) and P (for peers) denote the source of information about cultural traits, not their specific content. The probability that these envelopes contain information about a particular

[20] For arguments of using discrete models to analyze social formation of culture despite the fact that mental representation are rarely discrete, see Henrich, Boyd and Richerson (2008). They also show that neither the existence of memes, or gene-like elements, nor their accurate replication is necessary for fruitful application of evolutionary dynamics to the study of culture.

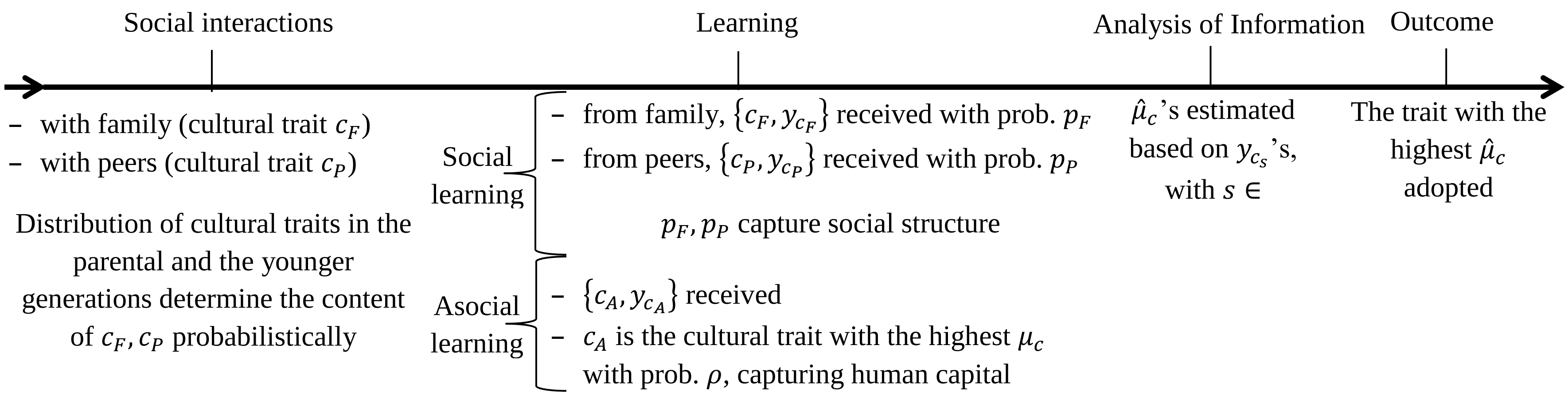
cultural trait, e.g. whether c_F is c_1 or c_2, is a function of the prevalence of that cultural trait in the corresponding generation. For simplicity, I assume the simplest function whereby these probabilities exactly reflect the respective distribution of cultural traits. Denote the share of individuals of c_1 among the younger generation at time τ with q_τ, and that among the parental generation with q_F. Since individuals from the parental generation are assumed to have stopped learning about cultural traits, and τ denotes learning periods, not births of new generations, q_F remains the same across τ. Thus:

$$c_F = \begin{cases} c_1 \text{ with probability } q_F \\ c_2 \text{ with probability } (1 - q_F) \end{cases}$$

$$c_P = \begin{cases} c_1 \text{ with probability } q_\tau \\ c_2 \text{ with probability } (1 - q_\tau) \end{cases}$$

The distributions of cultural traits, q_F and q_τ, are meant to represent culture of the corresponding population, as in Cavalli-Sforza and Feldman (1981), Boyd and Richerson (1985), Bisin and Verdier (2000, 2011), Dixit (2009), Tabellini (2008b), Axelrod (1997), and many more studies that use discrete cultural traits as a unit of analysis. While culture is a complex, multifaceted concept that has been defined and analyzed based on multitude of dimensions, there is a widespread agreement that it is acquired socially. This process of social formation of culture constitutes the main focus of this study.

Figure 2-1: Timing of events in each learning period τ



2.2. Social structure

Social structure determines whether or not the envelopes c_F and c_P are received from, respectively, family members and peers by individuals in the process of learning. More precisely, the extent to which individuals are exposed to and are willing to consider cultural traits of family members (c_F) and peers (c_P) is captured by parameters p_F and p_P, respectively. These probabilities are exogenous for simplicity.[21]

The link between the strength of flows of information about traits and social structure of a society has been noted by anthropologists and social psychologists. As Boyd and Richerson (1985) and Richerson and Boyd (2005), among others, argue, information about cultural traits can flow between individuals through observation, demonstration, persuasion, instruction, assistance, and other forms of social interaction. Bandura (1986) emphasizes the importance of the frequency of social interactions for understanding all the subtleties of cultural traits, especially when these subtleties "are not observable or easily described" (p. 65). By determining social ties and concomitant incentives, social structure influences, among other things, the willingness and ability of the cultural models to communicate their own traits, the willingness and ability of the individuals who are learning to understand and potentially adopt the cultural trait being observed or communicated. Stout (2005, 2011) provides evidence that some societies exploit this link by modifying social

[21] Unlike in Bisin and Verdier (2001a) and Tabellini (2008), for instance, where similar probabilities are objects of decision-making by individuals that are trying to communicate their cultural traits to others. Note that this potentially intensifies the link between p_F and p_P and social structure, since the latter influences the degree to which individuals care about those to whom they are trying to communicate information.

structure for the purposes of facilitating a flow of information about the traits that are deemed important.

Note that social structure is often formalized as the benefits or costs of potential interactions between individuals (see for instance Bowles and Gintis 1998, Bowles 1998, and Henrich et al. 2005). In focusing on the link between social structure and flow of information, this model is analytically closer to models of social networks, and social learning in general (e.g. Golub and Jackson 2010, Banerjee and Fudenberg 2004). These models however mostly focus on how learning from within the social contacts unfolds. In contrast, individuals in this model learn from multiple distinct kinds of sources of information: from their peers (which can be reformulated as a random graph network), from their family (which can be reformulated as a separate random graph network), as well as from individual experimentation and own experience.

2.3. Institutions

Cultural traits c_1 and c_2 are associated with expected payoffs of μ_1 and μ_2, respectively. The expected payoffs are exogenously fixed and unknown to individuals. Without loss of generality, I assume that $\mu_1 > \mu_2$, meaning that in terms of the expected payoffs c_1 is a superior cultural trait. The payoff of an individual i with cultural trait c_k ($k \in \{1,2\}$) is denoted by $y^i_{c_k}$ and is given by $\mu_k + \varepsilon^i$, where ε is an independent and identically distributed random variable with distribution $F(\varepsilon)$, mean zero, and precision ω (variance of ε is $\sigma = \frac{1}{\omega}$).[22,23] The level of ω captures a

[22] Allowing for $\varepsilon^i_{c_k}$ instead of simply ε^i complicates the model without much additional insight.

dimension of institutions that has received little attention in theoretical models of institutions, namely uncertainty of outcomes of individuals' actions. Institutions regularize behavior thus making it more predictable, and higher quality institutions do so to a larger extent. Institutions naturally influence more than the variability of payoffs, and they have often been modeled as determinants of μ_k, but I focus on their less explored effects on ω, which has direct ramifications on the process of learning.

Institutions have been defined and analyzed in various ways. Many of the existing conceptualizations of institutions highlight that the predictability of outcomes of individuals' actions is a central aspect of institutions. After analyzing numerous conceptualizations, Crawford and Ostrom (1995) conclude that institutions produce observed regularities in human behavior. These regularities enable individuals to develop informed predictions about the consequences of their actions. For Hayek, institutions enable the greatest possible number of individual expectations to be satisfied with the least costs and a minimum of unwanted outcomes (as summarized by Cubeddu 2002). North (1990) goes one step further and argues that "institutions exist to reduce uncertainties involved in human interaction" (p. 25). He goes on to clarify that:

> "[U]ncertainties arise from incomplete information with respect to the behavior of other individuals in the process of human interaction. The computational limitations of the individual are determined by the capacity of the mind to process, organize, and utilize information. From this capacity taken in conjunction with the uncertainties involved in deciphering the environment, rules and procedures evolve to simplify the process." (p. 25)

---

[23] Note that this setup represents an example of a pure information externality (Gala and Kariv 2003), in that each individual's payoff is independent of actions of others, and actions of others may reveal useful information for deciding what action to take.

In a similar vein, Williamson (1979, 1985, 1998) identifies uncertainty, stemming from bounded rationality or opportunism, as one of the critical dimensions of transactions. He argues that institutions such as contracts or hierarchies are the "means by which *order* is accomplished in a relationship" (p. 37, original emphasis). Institutions thus curb uncertainty and make mutually beneficial exchange possible. For Greif (2006), "[i]nstitutions span the domain that individuals understand, within which they can predict others' behavior, determine their interest and specify the morally appropriate" (p. 383). Relatedly, among the three institutional improvements that "eventually led to the rise of the Western world" (p. 126) North (1990) includes the transformation of uncertainty into risk enabling "the provision of a hedge against variability" (p. 127). The importance of reduction in uncertainty that higher quality institutions engender was perhaps expressed most forcefully by Max Weber as follows:

> "As a rule, the negative aspect of this arbitrariness [of ruler's unrestricted discretion] is dominant, because – and this is the major point – the patrimonial state lacks the political and procedural *predictability*, indispensable for capitalist development, which is provided by the rational rules of modern bureaucratic administration." (Economy and Society, 1968, p. 1095, original emphasis)

That better institutions are understood to be associated with less uncertainty is also visible from various ways that quality of institutions has been measured. Consider, for instance, the often used measure of the rule of law suggested by Kaufmann, Kraay and their co-authors.[24] It is based on perceptions of the

[24] See, for example, Rodrik, Subramanian and Trebbi (2004), Easterly, Ritzen and Woolcock (2006), Sala-i-Martin and Subramanian (2003), Nunn (2007), Easterly and Levine (2003), Alesina and Wagner (2006).

predictability of rules as well as their enforcement. Kaufmann, Kraay and Zoido-Lobaton (1999) maintain that "[t]ogether, these indicators measure the success of a society in developing an environment in which fair and predictable rules form the basis for economic and social interactions" (p. 8).

Just as theoretical models of institutions have typically sidestepped the effects of institutions on the variability of payoffs, ω in this model's notation, and mostly focused on their effects on μ_k's, uncertainty of this type has received scant attention in the social learning literature. There the focus has mainly been on variability of μ_k over time, which is particularly relevant for studying genetic evolution, or aggregation of individual-level information, or analyses of parental incentives to influence their children through transmission of information about the state of the environment.[25] Among the few studies that consider the form of cross-sectional uncertainty maintained here are Banerjee and Fudenberg (2004), Golub and Jackson (2010) and Ellison and Fudenberg (1995), but they focus primarily on other aspects of the process of learning and subsequent evolution. In particular, Banerjee and Fudenberg (2004) investigate efficiency of a range of sampling rules and use individual noise terms to interpret the signals that individuals are getting about the (changing) state of the environment; Golub and Jackson (2010) study which social networks are best at aggregating information and use idiosyncratic uncertainty to make sure that nobody in the social network is fully informed; Ellison and Fudenberg (1995) combine idiosyncratic and aggregate uncertainty and examine the effects of

[25] For aggregation of individual-level information, see for instance, Acemoglu, Bimpikis and Ozdaglar (2010), Acemoglu, Dahleh, Lobel and Ozdaglar (2011). For analyses of parental incentives, see for instance, Guiso, Sapienza and Zingales (2008a), Dessi (2008).

the number of peers sampled in the course of learning on the process of information aggregation. As my model demonstrates, allowing only idiosyncratic uncertainty makes the model tractable and generates new insights into the process of learning.

2.4. Human capital

I formalize human capital with a parameter ρ which represents the probability that learning through means other than social interactions with family and peers results in the information about the cultural trait with the highest expected payoff. This kind of learning takes place through deliberation, experimentation with alternatives, consideration of advantages and disadvantages of each alternative, and many more similar activities that are not necessarily social in nature. I call these activities asocial learning to distinguish them from learning that takes place mainly through social interactions. In the model, parameter ρ governs the content of c_A – information obtained through asocial learning. More precisely:

$$c_A = \begin{cases} c_1 \text{ with probability } \rho \\ c_2 \text{ with probability } (1-\rho) \end{cases}$$

Recall that $\mu_1 > \mu_2$, and therefore better human capital (higher ρ) leads to a higher likelihood of encountering the most desirable cultural trait through experimentation and deliberation. Asocial learning is a very complex process, as demonstrated, for instance, by Callander (2011), but it is likely that an individual's stock of competences, abilities, expertise, and innovativeness, in short the level of human capital, has a positive effect on its outcome.

A number of cultural evolutionary theorists (e.g. Boyd and Richerson (1985), Rogers (1988), Henrich and Boyd (1998), McElreath and Strimling (2008)) have modeled asocial learning similarly. These studies investigate the genetic evolution of reliance on asocial as opposed to social learning and analyze the conditions under which natural selection favors more or less asocial learning. In this model's notation, their endeavors are mainly aimed at understanding what levels of ρ are most fitness enhancing in different environments. In contrast, I take ρ to be exogenous and study its effects on the equilibrium culture formed within a single generation.

2.5. Analysis of information about cultural traits

Individuals use the information that they obtain through social and asocial learning alongside their own current experience to estimate the payoffs of cultural traits. These estimates, denoted by $\hat{\mu}_k$ ($k \in \{1,2\}$), are formed by averaging the corresponding payoffs that have been learned in the current learning period. Individuals then internalize the cultural trait that, from their perspective, has the highest estimated expected payoff, or the highest $\hat{\mu}_k$. Note the qualitative similarities of this model and models of stochastic choice, in particular two-step conceptualizations of the act of choice by, for instance, Masatlioglu, Nakajima and Ozbay (2012), and Manzini and Mariotti (2014). In these models, individuals devote attention to a sub-set of all possible alternatives, called consideration set following the extensive literature in marketing (see Wright and Barbour (1977) and subsequent research). Individuals then choose from the consideration set. Importantly, models of stochastic choice are typically aimed at inferring individuals' preferences from their choices and are intentionally general and vague on the details regarding the process of formation of the relevant information sets (e.g. general "attention filter" mapping employed in Masatlioglu, Nakajima and Ozbay, 2012). In contrast, I explicitly model the learning process starting from the collection of information regarding cultural traits from various sources, and including the specific learning rule by which the information is utilized. I do so for the purposes of understanding the effects of strength of information flows (capturing social structure), payoff variability (capturing institutions), and productiveness of asocial learning (capturing human capital), on the equilibrium culture.

Two important elements of the learning rule are worth noting. First, individuals have limited memory as they take into account the information acquired only in the current learning period. Several behavioral regularities that have been reliably replicated in a wide range of laboratory experiments on learning suggest that individuals do have a rather limited memory and rely on a small sample of observations. In an excellent review of behavioral experiments aimed at studying the process of learning, Erev and Haruvy (2012) conclude that models assuming that individuals rely on small samples of observations are the best predictors of individual behavior. While these and other similar findings do not prove that individuals do rely on small samples of observations, they point to the advantage of models that assume that they do in replicating and understanding behavior.

Second, individuals in the model are not necessarily Bayesian. Non-Bayesian behavior is also commonly identified in laboratory experiments. Çelen and Kariv (2005), for instance, demonstrate that subjects substantially deviate from Bayesian behavior even in a simple learning environment. They also find that individuals move further away from Bayesian learners as the environment gets more complex. Consequently, simplicity of the learning rule may be interpreted as capturing a combination of bounded rationality of individuals and the complexity of the environment that they face. And the environment that individuals face when learning about cultural traits is possibly highly complex. In particular, information about the shape of uncertainty associated with payoffs is rarely known, which complicates the task of coming up with a rule that reliably identifies superior alternatives in a small sample of observations. In addition, individuals are frequently uninformed about the distribution of cultural traits in the entire relevant population, or about why and how their cultural models acquired the respective cultural traits. Moreover, individuals rarely comprehend the intricate effects of social structure on the content of information that they receive from the environment. In complex environments like these, not only are individuals likely to deviate from Bayesian behavior by applying simple and intuitive rules of thumb, but they may even be better off in doing so. Rendell et al. (2010) demonstrate that simple learning rules might even outperform highly sophisticated ones in discerning the best course of action in terms of benefits.

Notice that despite the effects of the limitations on memory and sophistication on the way that information is analyzed, the learning rule employed here makes the process of learning cumulative on average. This is because individuals enter each learning period with the cultural trait that they deemed best in the previous learning period. Even though one's own cultural trait is not a sufficient statistic about past learning periods, it turns out to be sufficiently informative on average and retains, on the population level, important information about previous experiences, even as they are forgotten.

3. Equilibrium Culture

The equilibrium culture of the younger generation, denoted with q^*, is defined as the level of q, i.e. the share of individuals with c_1 among the younger generation, that does not change with learning periods τ. To find q^*, it is useful to express the share of individuals with c_1 at $\tau + 1$, denoted with $q_{\tau+1}$, as a function of τ. Note that this group of individuals consist of: (i) individuals entering τ with c_1 and retaining the same trait; and (ii) individuals entering τ with c_2 and switching to c_1 by the end of τ. Denote the conditional probability that an individual with c_k switches to c_m as P_{km} $(k, m \in \{1,2\}, k \neq m)$. Then the dynamics of culture is described as follows:

$$q_{\tau+1} = q_\tau\big(1 - P_{12}(q_\tau)\big) + (1 - q_\tau)P_{21}(q_\tau) \qquad (1)$$

The first term on the right-hand-side of (1) accounts for the individuals in (i), and the second term accounts for the individuals in (ii). These switching probabilities P_{12}, and P_{21} are themselves functions of q_τ because the existing culture determines the content of envelopes that individuals may receive in the process of social learning. [26]

Exact derivations of the conditional switching probabilities P_{12} and P_{21} are deferred to Appendix B-1. The intuitive steps are as follows. Each individual has a specific set of information to analyze. In particular, individuals from the younger generation hold information $\{c_A, y_{c_A}\}$ and $\{c_\tau, y_{c_\tau}\}$ from, respectively, deliberation and their own experience at time τ. The content of c_A is probabilistic, governed by ρ, a

[26] Equation (1) cannot be solved using standard techniques because the process it describes cannot be reduced to a stationary Markov chain (see Appendix B-1 for proof of this claim), unlike most of the models that analyze propagation of information in social networks.

measure of human capital. They may also hold information $\{c_F, y_{c_F}\}$ and $\{c_P, y_{c_P}\}$ from, respectively, family (with probability p_F) and peers (with probability p_P). The content of c_F and c_P are also probabilistic, governed by, respectively q_F and q_τ (recall that individuals from the parental generation are assumed to have stopped learning about cultural traits fixing q_F across τ). The realizations of payoffs $y_{c_A}, y_{c_\tau}, y_{c_F}$ and y_{c_P} vary depending on which cultural trait they pertain to and on the quality of institutions. In particular, if c_A is c_1 (which happens with probability ρ), then $y_{c_A} = \mu_1 + \varepsilon^{i,c_A}$ where ε is an independent and identically distributed random variable with distribution $F(\varepsilon)$, mean zero, and precision ω. Similarly, if c_F is obtained (which happens with probability p_F), and is c_2 (which happens with probability $1 - q_F$), then $y_{c_F} = \mu_2 + \varepsilon^{i,c_F}$.

Consequently, whether or not an individual's estimate of μ_1 (denoted with $\hat{\mu}_1$) is higher or lower than that of μ_2 (denoted with $\hat{\mu}_2$) is determined by the specific configuration of information that was obtained during τ. Let Θ represent the complete list of configurations of information that each individual may have.

Denote the probability that an individual with c_1 switches to c_2 (i.e. from his/her perspective $\hat{\mu}_1 < \hat{\mu}_2$) given the configuration $\theta \in \Theta$ by $\Pr(\hat{\mu}_1 < \hat{\mu}_2 | c_\tau = c_1, \theta)$. Similarly, denote the probability that an individual of c_2 switches to c_1 with $\Pr(\hat{\mu}_1 > \hat{\mu}_2 | c_\tau = c_2, \theta)$. The switching probabilities can thus be expressed as follows:

$$P_{12} = \sum_{\theta \in \Theta} \Pr(\hat{\mu}_1 < \hat{\mu}_2 | c_\tau = c_1, \theta) \cdot \Pr(\theta)$$

$$P_{21} = \sum_{\theta \in \Theta} \Pr(\hat{\mu}_1 > \hat{\mu}_2 | c_\tau = c_2, \theta) \cdot \Pr(\theta)$$

Note that the conditional switching probabilities P_{12} and P_{21} are functions of q_τ because q_τ determines $\Pr(\theta)$.

The existence, uniqueness, and stability of the equilibrium culture q^* are established next.

Proposition*: The difference equation* (1) *has a unique and stable steady state* $q^* \in [0,1]$. *The steady state is independent of the initial condition (*q_0*).*

The proof is in Appendix B-1.

Interestingly, the equilibrium (q^*) is a non-homogeneous culture – with both c_1 and c_2 present in the population – as long as parameters ρ, p_F, p_P take non-extreme values (i.e. values except 0 or 1) and $\sigma \neq 0$. Institutions (ω), social structure (p_F, p_P), and human capital (ρ) determine equilibrium culture (q^*) through a combination of the two effects that I call the "consideration effect" and the "precision effect". The next two subsections discuss these effects in turn for the purposes of exposition of the intuition behind the results of the model.

3.1. Consideration effect

The consideration effect arises when considering a cultural trait as a possible option increases the chances that individuals end up internalizing that cultural trait even if it is not the most beneficial among the possible options. To understand the intuition behind this effect it is helpful to classify individuals into three mutually exclusive and exhaustive subpopulations: individuals that experience and learn only about c_1; individuals that experience and learn only about c_2; and the rest of the individuals, who are exposed to both c_1 and c_2.

Consider the population level consequences of more exposure to c_2, for instance, ceteris paribus. Some of the individuals who would otherwise experience and learn only about c_1 now consider c_2 as a possible option. At least some of these individuals will face a configuration of information that makes them switch to c_2. Consequently, more exposure to c_2 increases the probability of switch to c_2, P_{12}, by increasing the share of individuals that consider both c_1 and c_2 as possible options.

In sum, more (less) exposure to a cultural trait has a consideration effect on learning in that it increases (reduces) the rate of switches to the corresponding cultural trait.

Evidence for the existence of such a consideration effect is provided by Stutzer, Goette and Zehnder (2011). They find that individuals who have not reflected upon the importance of donating blood are very likely to donate blood if presented with an opportunity, unlike individuals who had previously engaged in such deliberation. The opportunity of donating blood leads to consideration of blood donation as a possible option, which in its turn changes individuals' behavior. Similarly in this paper's model, putting c_1 or c_2 in the thought-process of individuals can increase the chance that they end up internalizing the corresponding cultural trait.

3.2. *Precision effect*

The precision effect describes a scenario where an outcome of learning is altered by a more precise evaluation of alternatives. The expected payoffs μ_1 and μ_2 are more precisely estimated by individuals if (i) the variability of outcomes associated with cultural traits (σ) decreases, or (ii) individuals have access to more items of information about the cultural traits that they are already considering (e.g. flows of information get stronger, i.e. p_F or p_P or both increase).

The precision effect refers to two related immediate consequences of availability of more precise or additional pieces of information. First, individuals with the cultural trait that has lower expected payoff (c_2, recall that $\mu_2 < \mu_1$) are more likely to realize that their trait is inferior in terms of the possible outcomes. This leads to a (weakly) higher conditional likelihood of switching to c_1 under any possible configuration of information. More specifically, due to a more precise or an additional piece of information, $\Pr(\hat{\mu}_1 > \hat{\mu}_2 | c_\tau = c_2, \theta)$ increases for all $\theta \in \Theta$ that contain c_1, and remains at 0 otherwise (because if c_1 is not part of θ and $c_\tau = c_2$, then individuals do not consider c_1 at all). Consequently, the conditional probability of switching to c_1 (P_{21}) grows.

Second, higher precision makes individuals whose current trait has the highest expected payoff (c_1) less likely to conclude that the alternative trait is superior. This leads to a (weakly) lower conditional probability of switching to c_2 under any possible set of information. More specifically, due to a more precise or an additional piece of information, $\Pr(\hat{\mu}_1 < \hat{\mu}_2 | c_\tau = c_1, \theta)$ decreases for all $\theta \in \Theta$ that contain c_2, and remains at 0 otherwise; as a result the total conditional probability of switches to c_2 (P_{12}) decreases.

In sum, the level of σ or the strength of information flows have a precision effect on learning in that more (less) precision increases (decreases) the rate of switches to the superior trait, c_1, and decreases (increases) the rate of switches to the inferior trait, c_2.

Evidence for the existence of the precision effect in the process of learning has been repeatedly provided in the psychology literature. Myers and Sandler (1960) is among the first to document that an increase in the variability of payoffs reduces the proportion of choices that maximize expected payoffs. Busemeyer and Townsend (1993) confirmed the robustness of this finding and coined the term "payoff variability effect" in reference to it. Subsequent studies, reviewed in Erev and Barron (2005), further demonstrated the robustness of the payoff variability effect and showed that it is different from risk or loss aversion. Bereby-Meyer and Roth (2006) make this distinction starker by noting that variance is often understood to affect the desirability of alternatives, through risk or loss aversion, but variance also has an important effect on the process of learning about alternatives. It is this latter effect of variability of payoffs that the precision effect represents.

It is instructive to understand the interaction between the precision effect and the consideration effect. As the information about payoffs becomes more precise, the c_1 consideration effect strengthens and the c_2 consideration effect weakens. This is because more precision affords easier recognition that c_1 is superior to c_2 in terms of the expected payoffs. As a consequence, in an environment with higher precision, more exposure to c_1 leads to more switches to c_1; and more exposure to c_2 leads to fewer switches to c_2.

The mechanism behind both the consideration effect and the precision effect reveals the importance for this model of the limitations on individuals' capacity to remember and analyze information. If individuals perfectly accumulate information over time, then a change in the likelihood of consideration of cultural traits does not trigger the consideration effect at the equilibrium. This is because over the course of a number of learning periods every individual would be exposed to both cultural traits, and additional exposure would not affect the set of options that they would already be considering. Similarly, in a society that is populated by fully Bayesian individuals, a change in variation or amount of information that is available in each learning period does not trigger the precision effect at the equilibrium. Such a society does not reach equilibrium until everyone has amassed sufficient knowledge and precision to have the most beneficial cultural trait and stick to it.[27] Therefore an additional increase in precision is simply irrelevant at the equilibrium.

4. Results

In this section the effects of institutions (ω), social structure (p_F, p_P), and human capital (ρ) on equilibrium culture (q^*) are discussed. First I establish that higher quality institutions facilitate the spread of the most beneficial cultural trait (Result 1). Next, I show the positive effect of human capital on equilibrium culture (Result 2). This is followed by an illustration that institutions and human capital are substitutes in shaping culture. Finally, I investigate the details of the effects of social ties on equilibrium culture (Result 4), along with the role of institutions in mediating these effects.

4.1. High-quality institutions promote the spread of beneficial cultural traits

Result 1. $\frac{\partial q^*}{\partial \omega} \geq 0$.

The proof is in Appendix B-1.

[27] Unless there are some costs associated with acquiring additional information, but even then individuals can accumulate large set of information from their own past experiences.

Consider the process that unfolds after an increase of ω at equilibrium. The precision effect of higher ω increases the rate of switches to c_1 and decreases the rate of switches to c_2. This results in a higher share of individuals with c_1 in the next learning period $\tau + 1$, $q_{\tau+1}$. This change in q modifies the composition of information to which individuals are exposed, giving rise to an indirect effect of the increase in ω. In particular, individuals are more likely to consider c_1 and less likely to consider c_2 through interactions with their peers.[28] Through the corresponding consideration effects the switches to c_1 rise and switches to c_2 drop, which contributes to a further increase of q. This may be countered by the following consequence of more exposure to c_1 at the expense of c_2. As some individuals have fewer information about c_2, their estimate of μ_2 gets noisier. As a result, more individuals incorrectly conclude that c_2 is a superior cultural trait. Put differently, given a fixed number of observations, individuals are better able to correctly identify a superior cultural trait if those observations are allocated equally across the two cultural traits.[29] Consequently, more exposure to c_1 at the expense of c_2 increases the rate of switches to c_2 for the individuals that already hold more information about c_1 than about c_2. As demonstrated in Appendix B-1, the latter type of indirect effect may outweigh the two consideration effects and make the total indirect effect negative. The direct effect is always stronger however, and the equilibrium share of individuals with c_1 follows ω.

[28] Consequently, the indirect effect is present only if $p_P \neq 0$.

[29] Specifically, consider individuals that have two pieces of information about a trait $c_k (k \in \{1,2\})$, and one piece of information about another trait $c_l, l \neq k$ ($l \in \{1,2\}$). Adding one piece of information about c_k (i.e. these individuals now have 3 observations about c_k and 1 about c_l) leads to higher probability of switch towards c_2 (inferior trait) as compared to adding one piece of information about c_l (i.e. 2 observations about c_k and 2 about c_l).

While the finding that higher quality institutions facilitate the spread of beneficial cultural traits has been obtained by Bowles (1998) and Tabellini (2008b), the current analysis suggests a very different mechanism than the one given in the existing studies. In these, culture is responsive only to material payoffs associated with various courses of action, and the corresponding expected payoffs are determined by institutions. In contrast to Bowles (1998) and Tabellini (2008b), my model suggests that institutions can influence equilibrium culture even if the expected payoffs associated with cultural traits are unaffected by institutions. This happens neither through the replicator dynamic that results in the differential spread of relatively beneficial traits as in Bowles (1998), nor through parental decisions on which traits are more beneficial to transfer to the next generation as in Tabellini (2008b). Instead, this model illustrates how institutions may shape culture through the process of learning by individuals about cultural traits. More specifically, as individuals have limited capacity to remember and analyze information, changes in the quality of institutions alter outcomes of individuals' learning through a combination of precision and consideration effects. Uncertainty of payoffs associated with cultural traits is an important and previously underexplored channel through which institutions may influence culture.

4.2. Human capital promotes the spread of beneficial cultural traits

Result 2. $\frac{\partial q^*}{\partial \rho} \geq 0$.

The proof is in Appendix B-1.

While it is intuitive that populations of individuals with higher human capital maintain greater prevalence of the superior cultural trait, it is important to understand exactly why this happens. A change in ρ has effects that are similar to those of a change in q as it too alters the composition of information that individuals acquire in the course of learning. Namely, an increase in ρ means more exposure to c_1 at the expense of less exposure to c_2. This has the corresponding consideration effects leading to more switches to c_1 (positive c_1 consideration effect) and fewer switches to c_2 (negative c_2 consideration effect). In addition, some individuals that would consider both traits regardless of the outcome of asocial learning, may now have one extra piece of information about c_1 instead of one about c_2. As discussed above, this makes switches to inferior trait (c_2) more likely for individuals that already hold more information about c_1 than about c_2. The former effect is stronger and higher human capital leads to more widespread prevalence of the beneficial cultural trait.

Though the role of human capital in shaping culture has received scant attention, the hypothesis that human capital matters for facilitating a somewhat related process of diffusion of technological innovations has been extensively studied. Nelson and Phelps (1966) appear to have been the first to formally develop this hypothesis. More recent analytical treatments include Benhabib and Spiegel (1994), Klenow and Rodriguez-Clare (2005), and Caselli and Coleman (2006). Empirical evidence is provided by Bartel and Lichtenberg (1987), Benhabib and Spiegel (1994), and more recently by Ciccone and Papaioannou (2009), and Wolff (2011). None of these papers study the mechanism through which human capital promotes adoption of technological innovations, however. In contrast, this paper explicitly models the role of human capital in the process of learning. If better education leads to quicker and more widespread adoption of beneficial technology, it may have similar effects on adoption of beneficial cultural traits.

Taken together, results 1 and 2 potentially reconcile the arguments of Acemoglu, Johnson and Robinson (2001) and Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004). While the former claims that institutional improvements cause economic growth, the latter argues that human capital accumulation leads to both economic growth and institutional improvements. Results 1 and 2 – both institutions and human capital promote the spread of beneficial cultural traits – make the two claims complementary if culture is a channel through which institutions and human capital affect economic performance.[30] In particular, Result 1 is in accordance with the findings of Acemoglu, Johnson and Robinson (2001); Result 2 agrees with the findings of Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004); and both results taken together explain how institutions may seem significant in the former study but not in the latter. If measures of human capital capture more of culture than do measures of institutions, the statistical effect of institutions might look insignificant when one controls for human capital, even though institutions are independently important.[31]

[30] Nunn (2012) also suggests reconciling the arguments of Acemoglu, Johnson and Robinson (2001) and Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004) by placing culture at the center. His arguments are based on intuition and are different from the ones made here.
[31] The same argument applies to Gennaioli, La Porta, Lopez-de-Silanes, and Shleifer (2012) which take the argument of Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004) one step further and conduct a cross-regional analysis of geographic, institutional, cultural, and human capital determinants of regional development.

4.3. Institutions and human capital as joint determinants of equilibrium culture

Institutions and human capital generally weaken each other's effect on culture (Result 3 in Appendix B-1). In terms of the underlying parameters, this means that the importance of the content of information obtained in the course of learning drops as the precision of payoffs increases. This relation goes against the intuition that more precise information should have a larger impact on the corresponding choices because of the greater discrimination between alternatives that the higher precision affords. The next two paragraphs clarify that this intuition is accurate only when the number of pieces of information is limited. As more observations become available, the content and precision of the information acquired through human capital are less important for the subsequent behavior.

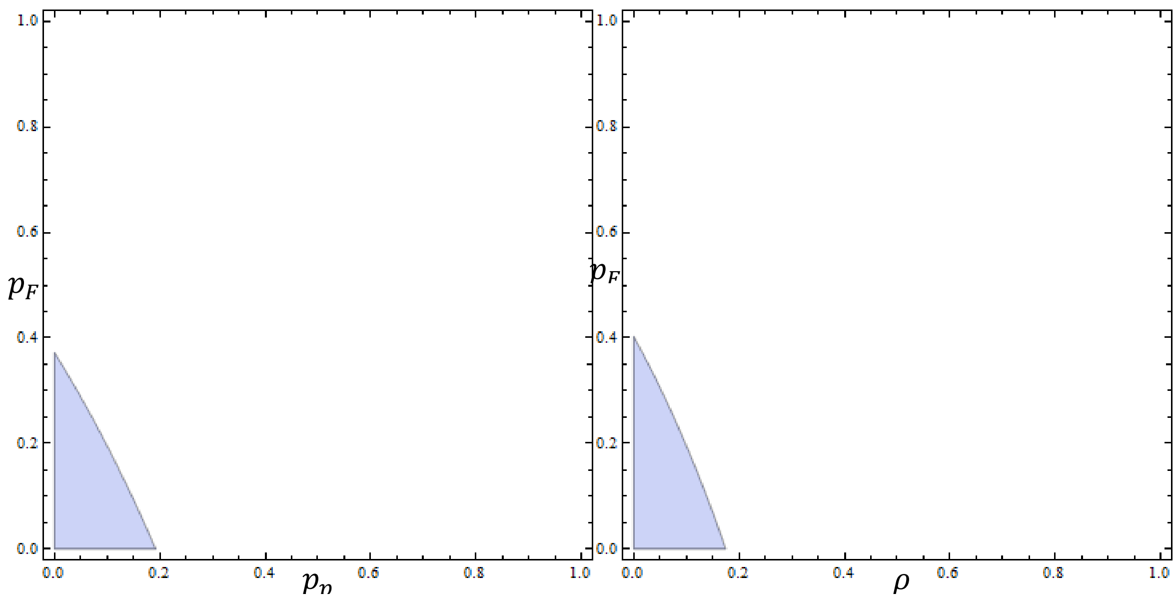
The shaded region on Figure 2-2 represents the environment where higher precision of information makes the content of that information more influential, in line with the standard intuition.[32] This is where social ties are limited (p_F and p_P are low) and hence individual deliberation is likely to be the only source of information that individuals have, apart from their actual experience. Furthermore, even if information is obtained from social ties despite low probabilities, it is likely to be about the inferior cultural trait. This is because, in the environment of low p_F and p_P, most individuals do not learn from others and have to rely on their own experience and deliberations, lowering the prevalence of c_1. Consequently, in this environment, the positive c_1 consideration effect that is triggered by an increase in ρ gets stronger with ω as higher precision contributes to correctly identifying c_1 as superior in terms

[32] Similar figures for alternative values of parameters are given in Figure B-1 in Appendix B-1.

of the expected payoffs. The negative c_2 consideration effect of an increase in ρ gets weaker however for the same reason: higher precision helps correctly identify c_2 as inferior. In the shaded region of Figure 2-2, the former counteracts the latter resulting in the complementarity of ρ and ω in shaping q^*.

In the environment with stronger social ties, individual deliberation is likely to be one among several pieces of information, and other sources are also more likely to expose individuals to c_1. This is because, in the environment of high p_F and p_P, most individuals receive information from family and peers, on top of the information that they have from their own experience and deliberations, increasing the prevalence of c_1. Consequently, the positive c_1 consideration effect of an increase in ρ gets weaker with ω. The negative c_2 consideration effect too gets weaker with ω as higher precision of information helps individuals correctly conclude that c_2 is inferior. In this environment, illustrated in the unshaded region of Figure 2-2, ρ and ω are complements in determining the level of q^*. In other words, whether c_A is about c_1 or about c_2 becomes less consequential when c_A is one among several pieces of information that (i) grows more precise, and (ii) already exposes individuals to the superior cultural trait in terms of the expected benefits. In sum, if c_A is likely to be the only source of information, then an increased precision makes the content of c_A more consequential; but if c_A is one in many sources of information, then an increased precision of information makes the content of c_A less consequential.

Figure 2-2: Effect of institutions on $\frac{\partial q^*}{\partial \rho}$



$\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial \rho}\right) > 0$ only in the shaded region

Note: $q_F = 0.5, \omega = 1$ in both figures. $\rho = 0.1$ in figure on the left, $p_P = 0.1$ in the figure on the right

4.4. Stronger social ties may hinder the spread of beneficial cultural traits

Result 4.

a. $\frac{\partial q^*}{\partial p_F} < 0$ *if and only if* $q^* \frac{\partial P_{12}}{\partial p_F} > (1 - q^*) \frac{\partial P_{21}}{\partial p_F}$.

b. $\frac{\partial q^*}{\partial p_p} < 0$ *if and only if* $q^* \frac{\partial P_{12}}{\partial p_P} > (1 - q^*) \frac{\partial P_{21}}{\partial p_P}$

c. *If* $p_F + p_P = 1$, *then* $\frac{\partial q^*}{\partial p_F} < 0$ *if and only if* $q^* \left(\frac{\partial P_{12}}{\partial p_F} - \frac{\partial P_{12}}{\partial p_P}\right) >$

$(1 - q^*) \left(\frac{\partial P_{21}}{\partial p_F} - \frac{\partial P_{21}}{\partial p_P}\right)$

where $\frac{\partial P_{12}}{\partial p_F}, \frac{\partial P_{21}}{\partial p_F}$ *represent effects of* p_F *on, respectively, probability that an individual with* c_1 *switches to* c_2, *and probability that an individual with* c_2 *switches to* c_1. $\frac{\partial P_{12}}{\partial p_P}$,

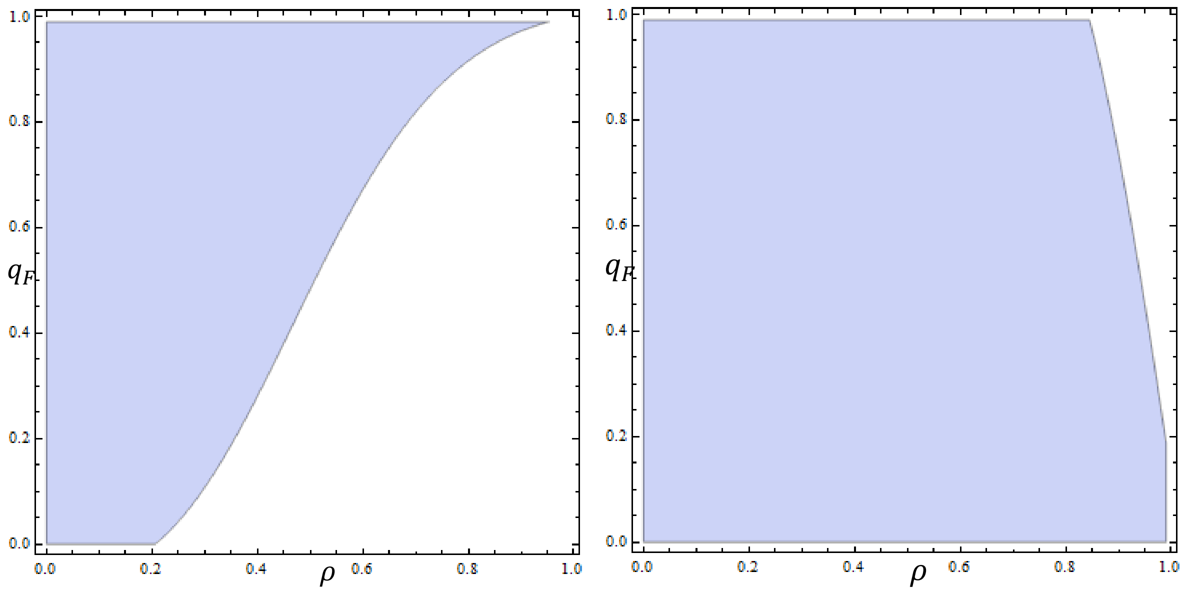
$\frac{\partial P_{21}}{\partial p_P}$ *represent effects of* p_P *on the same probabilities. Derivations of these partial derivatives are in Appendix B-1.*

Results 4a and 4b mean that additional information may be harmful in the course of learning about cultural traits. To understand the intuition behind this finding, recall that the strengthening of social ties means more exposure to the cultural traits of the corresponding generation. In the case of family ties, for instance, this triggers a positive c_1 consideration effect for individuals whose parents are c_1, and a positive c_2 consideration effect for individuals whose parents are c_2. Similarly for social ties with peers, higher p_p triggers positive c_1 consideration effect for individuals whose peers are c_1, and positive c_2 consideration effect for individuals whose peers are c_2. The two effects work in opposite directions as the former increases the rate of switches to c_1 and the latter increases the rate of switches to c_2. In addition, availability of an additional peace of information has a precision effect, increasing the rate of switches to c_1. As a result, stronger social ties lead to a lower prevalence of the superior cultural trait if the corresponding positive c_2 consideration effect outweighs the positive c_1 consideration effect and the precision effect.

Start with family ties. The positive c_2 consideration effect gets stronger as c_2 gets more prevalent among the parental generation (i.e. q_F falls). Hence family ties are less beneficial as q_F decreases because it leads to more switches to the inferior cultural trait (the left panel of Figure 2-3). Social ties with peers trigger weaker c_2 consideration effect than social ties with family because all peers are going through the same process of learning, and are likely to be exposed to a similar set of cultural traits.

Figure 2-3: Ceteris paribus effect of social ties on equilibrium culture

$\frac{\partial q^*}{\partial p_F} > 0$ only in the shaded region[33] $\frac{\partial q^*}{\partial p_P} > 0$ only in the shaded region[34]



Note: $p_F = p_P = 0.5, \omega = 1$.

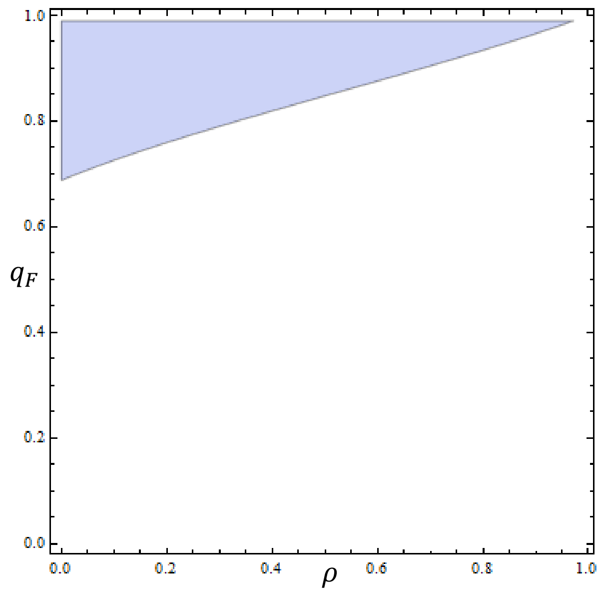
Human capital interacts with the effects of social ties as higher ρ exposes individuals to c_1 at the expense of c_2. Consequently, higher ρ weakens c_1 consideration effect of social ties (because c_1 is more likely to be considered through deliberations), and strengthens c_2 consideration effect of social ties (because social ties are more likely to be the sole sources of information about c_2). Thus, in a population with better outcomes of individual deliberation, stronger family ties, for instance, lead to a lower prevalence of c_1. Importantly, this happens even if ρ is below q_F.

[33] For alternative visualization see Figure B-2 in Appendix B-1.
[34] For alternative visualization see Figure B-4 in Appendix B-1.

Consider next the effect of an increase in the strength of family ties keeping the total strength of social ties constant, $p_F + p_P = 1$. Social interactions consume time and attention, and strengthening social ties in one direction may come at a cost of weakening social ties in other directions. Holding the total strength of social ties constant, stronger family ties means a switch of the source of information from friends to family. Intuitively, this switch decreases q^* if the superior cultural trait (c_1) is less likely to be acquired from family than from friends, i.e. when q_F is below q^*, and increases q^* otherwise. In the unshaded region on Figure 2-4, stronger family ties leads to lower prevalence of c_1 in the younger generation. This region exactly coincides with the region where $q_F < q^*$, as expected.

The finding that strong family ties might hinder the spread of cultural traits with superior expected payoffs seems similar to observations by Banfield (1958) and Putnam et al. (1993) on the spread of "amoral familism", but the mechanism at work is different. Banfield (1958) defines "amoral familism" as an exclusive trust in immediate family and expectation that everybody else does the same. Banfield (1958) and later Putnam et al. (1993) argue that strong family ties promote the spread of "amoral familism" which in its turn leads to low civic capital, low generalized trust and distrust in government. These arguments for detrimental effects of strong family ties on culture rest on the presumption that strong family ties lead individuals to (correctly) expect little from civic engagement. More precisely, because everyone exclusively trusts their immediate family, individuals are not trusted by strangers. As a result, civic engagement brings limited payoffs, and individuals choose not to engage in civic endeavors. In contrast, in this model, family ties do not influence the payoffs associated with cultural traits. Strong family ties simply lead to availability of more information about parents' cultural traits.

Figure 2-4: Effects of family ties (p_F) on equilibrium culture



$p_F + p_P = 1, \frac{\partial q^*}{\partial p_F} > 0$ only in the shaded region

Note: $p_F = p_P = 0.5, \omega = 1.$

Results 4a and 4c are in line with empirical evidence that family ties have a negative effect on civic capital, such as Alesina and Giuliano (2011). These results also complement the argument put forward by Kumar and Matsusaka (2009) on why the wealthiest economies in the 17th century (China, India, and the Islamic Middle East) industrialized more slowly than the West. In particular, Kumar and Matsusaka (2009) claim that the accumulation of skills necessary to transact with strangers is associated with externalities. As a result, societies with a large stock of "local capital" – extensive experience in transactions among family members – find it more difficult to transition to a market economy than societies with a small stock of local capital.

Kumar and Matsusaka (2009) document the pre-industrial importance of family and kinship networks in China, India, and the Islamic world compared to Europe and claim that it was these countries' local capital that hindered their quick industrialization. Results 4a and 4b suggest that slow industrialization of these societies could be a result of slow learning brought about by strong family ties combined with low q_F.

Result 4b – social ties outside of family can be beneficial – is consistent with the observations made as early as in 1820 by Hegel and in 1835 by Tocqueville. In particular, as remarked by Putnam, Leonardi and Nanetti (1993), Tocqueville noticed the propensity of Americans to form organizations that transcend family-lines and serve a large array of purposes. Tocqueville argued that participation in such organizations has "internal" effects on individual members by instilling habits of cooperation, solidarity, and public-spiritedness. Putnam, Leonardi and Nanetti (1993) add that "participation in civic organizations inculcates skills of cooperation as well as a sense of shared responsibility for collective endeavors" (p. 90). Similarly, North, Wallis and Weingast (2009) claim that a rich network of groups and organizations provides "an environment in which individual values of tolerance, participation, and civic virtue can be nurtured" (p. 7). My model helps unpack these observations and identifies several mechanisms through which non-familial social ties can be beneficial. In particular, developing relations with individuals outside of ones' family may increase benefits associated with cooperation. This is creation of "a sense of shared responsibility for collective endeavors". In terms of the model, this means an increase of μ_1, expected payoff associated with c_1. Non-familial social ties can be beneficial even when expected payoffs remain unchanged however, as suggested by Result 4b. This happens through learning about which cultural trait is superior in terms of expected payoffs, namely through "instilling habits of cooperation".

4.5. Institutions and social ties as joint determinants of equilibrium culture

Institutions often mute effect of social ties on equilibrium culture.[35] This is because a drop in uncertainty makes it easier to correctly identify c_1 as a superior trait in terms of expected benefits, thus strengthening the positive c_1 consideration effect but weakening the positive c_2 consideration effect. Consequently, in the environment where the latter overpowers the former making stronger social ties harmful, better institutions are likely to reduce the harm. This happens in unshaded regions of Figure 2-5, which illustrates interactions of institutions and family ties in shaping culture. Put differently, institutions mitigate any harm brought about by stronger social ties. At the same time, institutions may strengthen or weaken the positive effects of the social ties, as shown by region shaded, respectively, blue and purple on Figure 2-5.[36]

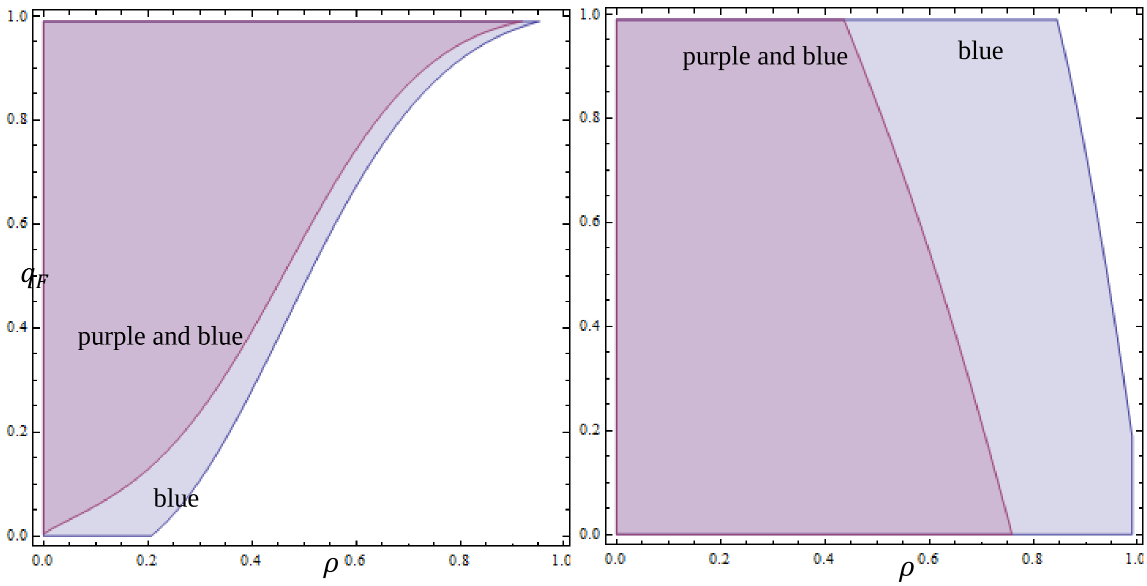
The finding that institutions and social ties are not always complements (blue on Figure 2-5) and can be substitutes (unshaded or purple and blue on Figure 2-5) indicates that the decline in the strength of social ties among Americans might not be as concerning as suggested by Putnam (2001). If a positive effect of social ties on culture weakens with the quality of institutions (meaning that institutions and social ties are substitutes in shaping culture), then a decline in the strength of social ties in a

[35] For formal relation between the effect of non-family ties and quality of institutions see Result 7 in Appendix B-1.
[36] For figures similar to Figure 2-5 over alternative parameter values see Figure B-6 in Appendix B-1.

society with high quality institutions brings about only a slim reduction of the equilibrium share of individuals with beneficial cultural traits.

Figure 2-5: Interaction of institutions and social ties …

… with family	**… with peers**
$\frac{\partial q^*}{\partial p_F} > 0$ only in the region shaded blue	$\frac{\partial q^*}{\partial p_P} > 0$ only in the region shaded blue
$\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_F}\right) < 0$ only in the region shaded purple	$\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_P}\right) < 0$ only in the region shaded purple



Note: $p_F = p_P = 0.5, \omega = 1$.

5. Conclusions

This paper uses a model of learning to study the effects on culture of institutions, social structure, and human capital. I showed that through determining uncertainty of payoffs associated with cultural traits, institutions influence the process of learning about cultural traits and the subsequent dynamics of culture even if the expected payoffs are unchanged. The model demonstrates that through determining the strength of information flows from family and peers, and subsequently influencing the content of information that individuals are getting in the course of learning about cultural traits, social structure influences the equilibrium culture even without modifying the expected payoffs of cultural traits.

The model shows that both institutions and human capital promote cultural improvement, which potentially reconciles the findings of Acemoglu, Johnson and Robinson (2001) and Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004) if culture is a channel through which both institutions and human capital affect economic performance. In addition, I found that institutions and human capital mostly substitute each other in shaping culture.

Consistent with Banfield (1958) and Putnam, Leonardi and Nanetti (1993), the model establishes that strong family ties may hinder the spread of the most beneficial cultural trait; and consistent with Putnam, Leonardi and Nanetti (1993) and North, Wallis and Weingast (2009), the model reveals that strong non-familial ties may promote the spread of most beneficial cultural trait. The model uncovers that these relations do not always hold, however. By finding conditions under which these claims cease to hold, this model has enriched our understanding of the relation between social ties and culture.

Finally, the model sheds light on complex interactions of institutions and social structure in shaping culture. While institutions and social structure are found to frequently mute each other's effect on equilibrium culture, they are also found to complement each other under specific circumstances.

Chapter 3: Understanding Trust and Institutions: A Behavioral Experiment

1. Introduction

The level of interpersonal trust has been found to determine important outcomes, such as economic development (e.g. Arrow 1972, Fukuyama 1995, Knack and Keefer 1997, La Porta et al. 1997, Zak and Knack 2001, Guiso et al. 2004, 2008c, 2009), stable democracy (Inglehart 1999), government regulations (Aghion, Algan, Cahuc, and Shleifer 2010), and social capital (Putnam 1993). Interpersonal trust varies considerably across countries (Ellingsen et al. 2012, Butler, Giuliano and Giuso 2014), cultures (Tabellini 2010), and organizations (Leana and Van Buren 1999, McAllister 1995, Rousseau et al. 1998), and its sources of variation are not well understood. This paper investigates whether or not individuals' tendency to trust is influenced by institutional environment in seemingly unrelated contexts. Through facilitating a cooperative environment in specific contexts, do institutions influence individuals' trust behavior in other contexts where these same institutions do not apply?

To answer this question, I ran a laboratory experiment with a two-part design. Part I varied institutional environment across two treatments while Part II – a trust game of Berg, McCabe, and Dickhaut (1995) – was the same. In Part I, two randomly matched individuals (called A and B) played a one-shot game in either "cooperative" or "non-cooperative" environment. In the cooperative environment, the Part I game payoffs are such that all A individuals cooperate in the sense of selecting the alternative that is preferred by B, as well as by A and B collectively. In contrast, in the non-cooperative treatment, the payoffs are such that all A individuals choose the non-cooperative action in the sense of selecting the alternative that is not preferred by B. The focus of the study is trust behavior of a third individual (called C) towards a randomly matched A, knowing the institutional environment of Part I as well as the resulting behavioral pattern of As from the session.

The existing literature implies two opposite conjectures. A cooperative environment may prompt a cooperative heuristic or behavioral "spillover" which leads individuals to cooperate in unrelated contexts (Peysakhovich and Rand 2015). Cassar, d'Adda and Grosjean (2013), Stagnaro, Arechar and Rand (2016), and Peysakhovich and Rand (2015) find evidence of this effect of institutions on trust. In contrast, a separate literature on importance of others' intentions for decisions to reciprocate (e.g. Falk, Fehr and Fischbacher 2008) suggests, albeit indirectly, that a non-cooperative heuristic may be prompted if the cooperative environment is fully determined through institutions. Put differently, a cooperative environment, if fully governed through material payoffs, may take a form of priming whereby individuals are prompted to focus on material payoffs in subsequent play. Consistent with the latter conjecture, I find a rather large, though only marginally statistically significant, negative effect of cooperative institutional environment on individuals' tendency to trust. This negative priming effect of institutions on trust rates stands in stark contrast with the positive effect that Al-Ubaydli, Houser, Nye, Paganelli, and Pan (2013) found when employing conceptually the same but indirect priming. They found that the subjects who were exposed to phrases related to markets and trade were far more trusting than others.

Both of these conjectures that help understand the effect of seemingly unrelated institutional environment on individuals' tendency to trust are based on the theory that humans are boundedly rational (Simon, 1955): they have limited computational capacity; regularly lack important pieces of relevant information; may even have imperfectly defined objectives, and frequently face complex decision tasks. To make decisions in the face of these limitations, individuals may hold systematic biases, or apply heuristics – simple tendencies or rules of behavior that provide fast, close to optimal guidance. Systematic biases triggered by a cooperative environment and applied in a context without incentives for cooperation are optimal in certain environments (Bednar and Page 2007, Bear and Rand 2016). To identify such effects of institutions on individuals' trust behavior, and distinguish them from other more mundane effects such as differential beliefs about outcomes, a careful experimental design is necessary for ruling out alternative effects of institutions, including subjects' confusion (Camerer, Loewenstein, and Rabin 2004).

These considerations differentiate the current experiment from those of Cassar, d'Adda and Grosjean (2013), Stagnaro, Arechar and Rand (2016), Peysakhovich and Rand (2015), and Bohnet and Huck (2004) that also investigate effects of institutions on individuals' tendency to trust in the contexts where these same institutions do not apply. Experimental designs of these studies differ from mine in two crucial ways. First, trustors in these studies themselves experience the institutional environments created prior to the trust interactions, inviting the differential wealth effects across treatments as well as differential motives of inequality aversion (Bolton and Ockenfels 2000), and fairness (Fehr and Schmidt

1999), among others. In contrast, the C individuals, whose trust behavior is the focus of this study do not participate in Part I of this paper's experiment.

Second, the institutional environments prior to the trust interactions are so complex in the above mentioned studies that trustors have ample room to justifiably form differential portrayals of trustees, and subsequently exhibit differential levels of trust across the various institutional environments. Such designs still reveal whether institutions influence trust in contexts where these institutions do not apply. The mechanism of such effects however remains unclear, and may include rather routine ones, such as differential learning about trustworthiness of potential partners. In contrast, I represent institutions with simplified and pruned game trees that embody a set of rewards and punishments that usually characterize these institutions. In other words, instead of presenting subjects with full game trees with branches invoking exogenous rewards or punishments, I used simplified game trees with the payoffs that reflected the corresponding institutional environment.

The rest of the paper is organized as follows. Section 2 describes the experimental design. Section 3 presents and discusses results juxtaposing them with existing studies. Section 4 provides concluding remarks. 0 contains a sample of experimental instructions and some summary statistics.

2. Experimental Design

The experiment was conducted at the Experimental Economics Laboratory at the University of Maryland (EEL-UMD) in May and June of 2014. It was programmed in z-Tree (Fischbacher 2007). 129 undergraduate students from UMD were recruited via online recruitment system of the EEL-UMD.[37] Eleven sessions were run, each lasting 30 minutes on average.[38] Treatment was randomly assigned at the session level, and subjects participated in only one of the treatments, and in only one of the three roles. The treatment with cooperative environment as described below had 69 subject (23 in role C), and the treatment with non-cooperative environment had 60 subject (20 in role C). Subjects were not permitted to communicate before or during the session. After signing the consent form, all subjects were given a copy of instructions, which were also read aloud by an experimenter (see 0 for a sample of instructions). At the end of each session, subjects completed a post-experiment questionnaire on basic demographic characteristics, after which payments were determined. Subjects received $1 in cash at the end of the session for each 10 experimental currency units (ECUs) that they earned during the session. In addition, each subject received a $5 compensation for showing up. Subjects earned on average $12.5. Each subject was paid separately and in private at the end of session.

Each treatment consisted of two parts. Part I varied institutional environment across two treatments while Part II was the same. At the start of the experiment, subjects were randomly assigned one of the three distinct roles denoted with A, B, and C. Part I consisted of a one-shot interaction between randomly matched A and B individuals. Depending on the treatment, they played either in cooperative

[37] Due to the subtlety of the experiment, it was important to recruit as many subjects without exposure to classes on game theory as possible. For this purpose, experiment-neutral flyers inviting students to join the EEL-UMD subject pool were distributed in May and June of 2014 in the buildings that house studies of biology, psychology (PLS), mathematics (MTH), physics (PHY), computer science (CSI), engineering (EGR, CHE, KEB), chemistry (CHM), and geography (LEF). The online recruitment system of the EEL-UMD was then used on a larger subject pool thus recruited.

[38] Of the 11 sessions, 3 sessions had 15 subjects each, 6 sessions had 12 subjects each, and 2 sessions had 6 subjects each.

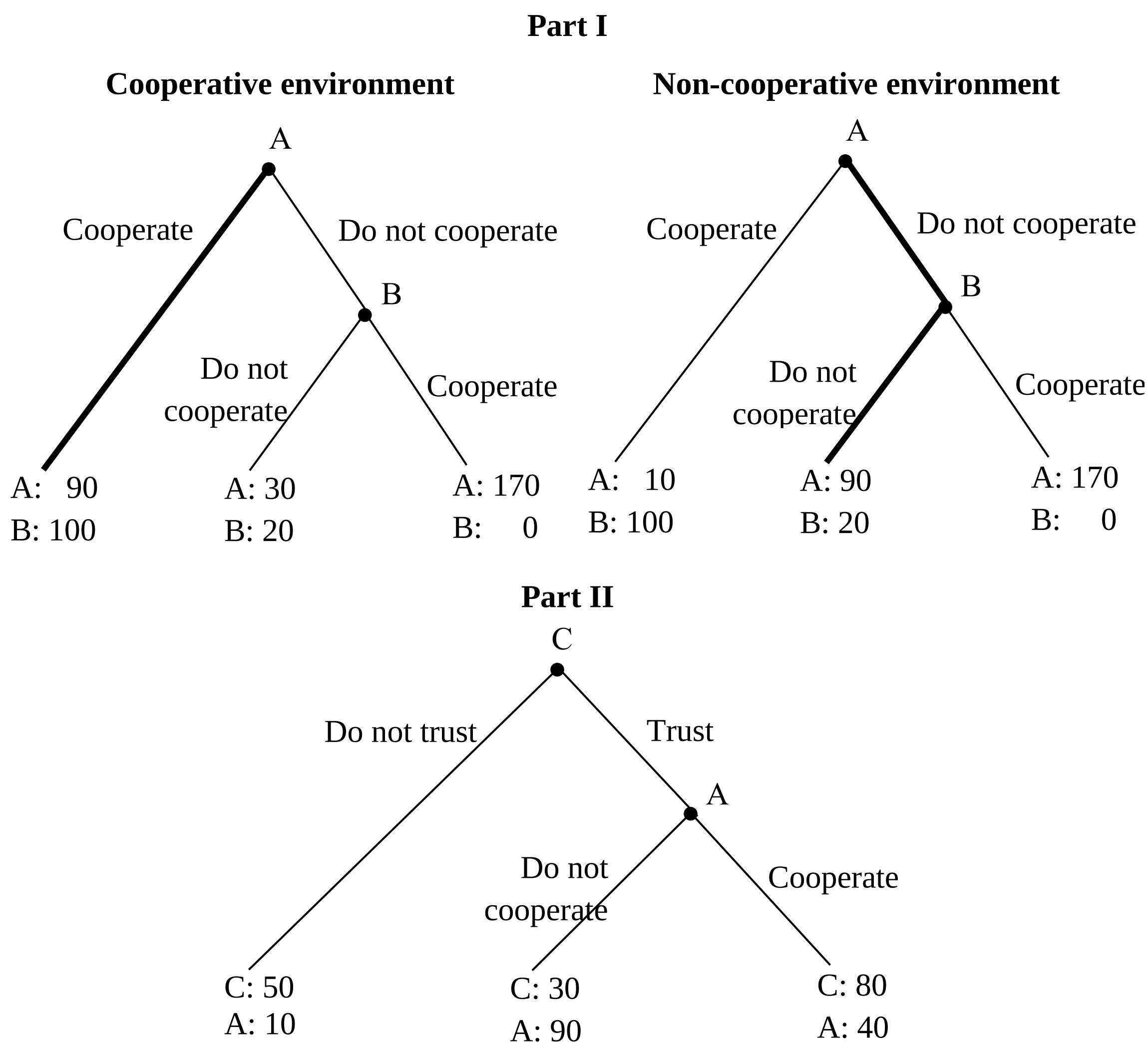
environment or non-cooperative environment embodied in the games given in the top half of Figure 3-1. After the interactions between all As and Bs were completed, the Cs were informed about the distribution of actions by As. Each C then, in Part II, was randomly matched with one A to play a one-shot trust game of Berg, McCabe, and Dickhaut (1995) with payoffs (in ECUs) as given in the bottom half of Figure 3-1. Note that the payoffs in the trust game are exactly as in Bohnet and Huck (2004) for the purposes of validating average trust rates observed in this experiment.

2.1. Discussion of the treatments

The concept of institutions is complex, multifaceted, and has been formalized in many different ways. I follow North (1990) in viewing institutions as "the rules of the game in a society" that influence individuals' behavioral regularities.[39] Institutions are represented in the experiment with simplified games to prevent Cs from mistakenly ascribing the level of cooperativeness that is created by the corresponding institutional environment to As types, and thus forming differential beliefs and preferences about As. While institutions are often understood as a set of rewards or punishments (or both) that get triggered (often probabilistically) when certain actions are taken, Part I was deliberately designed as a reduced form of such incentives. Put differently, instead of presenting subjects with full game trees with branches invoking exogenous rewards or punishments, simplified game trees were used with the payoffs that reflected the corresponding institutional environment.

[39] For a discussion on various conceptualizations of institutions see e.g. Crawford and Ostrom (1995).

Figure 3-1: Experimental Design



In particular, in the cooperative institutional environment, payoffs were set to ensure that interests of the interacting individuals are perfectly aligned even though there are no additional branches on the game tree that explicitly involve institutional interventions (such as punishment for non-cooperation, or reward for cooperation, or both). More precisely, the payoffs were set to ensure that all A individuals choose to cooperate with the corresponding B individuals in the sense of selecting the alternative that is preferred by B, as well as by A and B collectively. Similarly, in the non-cooperative institutional environment, interests of the interacting individuals are completely misaligned, as it happens when imperfect institutions are introduced to solve social dilemmas. More precisely, in the non-cooperative institutional environment, the payoffs are set to ensure that all A individuals choose the non-cooperative action in the sense of selecting the alternative that is not preferred by B.

To preclude differential learning by Cs about As types across the two institutional environments – another potential source of differential preferences and beliefs about As – Part I payoffs in both treatments were selected so that all As behaved the same way in each treatment. The key in precluding differential learning is to prevent the possibility that Cs are receiving any valuable information about As types in either treatment. For this purpose, in the cooperative environment, not only was the game designed to have a unique Nash equilibrium that involves cooperation (marked with bold line on Figure 3-1), but also to ensure that no A individual considers the non-cooperative action attractive enough (for non-monetary reasons) to try it. Similarly, in the non-cooperative environment, the payoffs and the general structure of the experiment were selected to prevent A individuals from behaving cooperatively for the strategic purpose of "earning trust" of Cs. In particular, Cs were informed only about the aggregate behavioral pattern of As and did not have information about the behavior of their partner. In addition, pretending to be cooperative was as costly as a gain that As may have hoped to reap by earning undeserved trust.[40] A unique Nash equilibrium here involves non-cooperation (marked with bold lines on Figure 3-1).

[40] By cooperating in the non-cooperative environment, As give up 80 ECUs. This is exactly as much as they can hope for by earning and not fulfilling trust in the second part of the experiment.

3. Results

I first conduct the manipulation check to verify that all A individuals behaved the same way in Part I of each session. Table 3-1 summarizes behavior of A individuals across 11 sessions and two treatments. In 2 out of 6 sessions with the cooperative environment, one A individual failed to cooperate in Part I (note that 129 experimental subjects results in 43 subjects in each of the three roles, A, B, and C.).[41] And in 1 out of 5 sessions with the non-cooperative environment, one A individual cooperated.[42] Consequently, the experimental manipulation succeeded in 4 sessions for each treatment, with each treatment comprising 15 subjects in the role of C.[43]

Table 3-1: Manipulation Check, Behavior of As in Part I

	Treatment	
	Cooperative environment	Non-cooperative environment
Sessions where all As cooperated	4 (of 6)	
Sessions where all As did not cooperate		4 (of 5)

Table 3-2 and the first two columns of Table 3-3 present respectively non-parametric and parametric estimates of the treatment effect. Note that the average trust rate of 0.33 in this experiment (0.30 with all 43 observations) approximates the baseline trust rate 0.32 in Bohnet and Huck (2004). The Mann-Whitney test reported on Table 3-2 is based on the 30 observations where experimental manipulation succeeded in inducing all As behave in the same way in a session. Probit regression

[41] Each of these two non-cooperative moves were met with non-cooperative moves by the corresponding B individuals, as expected.
[42] One B individual in the non-cooperative environment did cooperate after a non-cooperative move by the corresponding A individual, but this does not invalidate the session results since only information about the population behavior of As is conveyed to the C individuals.
[43] Total of 13 subjects in C role were affected: two of the three sessions where the experimental manipulation failed had the total of 12 subjects (with 4 observations of Cs each), and one had 15 subjects (with 5 observations of Cs).

allows controlling for the special character of the sessions where not all As behaved in the same way through dummy variables. This is done in the first column of Table 3-3 with the full sample. The second column repeats the test of Table 3-2 with observations where the Part I behavior of As where consistent with the experimental design (note that those additional dummies of the first column are irrelevant in the second as both equal 0 for all observations included in that regression). While only the parametric estimate is statistically significant at 5% level, the trust rates differ substantially across the two treatments. Cs are on average 27 percentage points less likely to trust As in the cooperative environment than in non-cooperative environment.

Table 3-2: Non-parametric Estimate of Treatment Effect

	Treatment		**Total**
	Cooperative environment	Non-cooperative environment	
Part I behavior consistent with the design			
Trust rate	0.2	0.47	0.33
N	15	15	30
Mann–Whitney test	$z = 1.523,\ \alpha < 0.128$		

Importantly, the treatment effect reported on tables 2 and 3 cannot be attributed to many known determinants of trust because those determinants are held constant across the two treatments. In particular, Cs do not have any reason to exhibit differential levels of risk aversion (Karlan 2005, Schechter 2006) across treatments.[44] This is because Cs do not participate in Part I at all and exhibit no differential wealth at the start of Part II, precluding Cs differential wealth effects not only on their risk

[44] For an argument of minimal role of risk aversion in individuals' trust behavior see Eckel and Wilson (2004), Houser, Schunk, and Winter (2008).

aversion but also on their tendency to be generous. The differential wealth effects for As, and expectations thereof, are precluded by ensuring that each A completes Part I of the experiment with exactly the same payoff, 90 ECUs, regardless of the treatment. The exact same payoffs for both As and Cs at the start of Part II of the experiment regardless of the treatment also ensures that Cs cannot exhibit differential levels of inequality aversion (Bolton and Ockenfels 2000), fairness (Fehr and Schmidt 1999), and quasi-maximin motives (Charness and Rabin 2002) across the two treatments. Furthermore, Cs exhibit equal levels of regret aversion, loss aversion (Charness and Rabin 2002), or betrayal aversion (Bohnet, Greig, Herrmann, and Zeckhauser 2008) across the treatments.[45]

In addition, there is no room for Cs to have differential levels of altruism towards As (Andreoni and Miller 2002), or beliefs about As' reciprocity (Fehr 2009) across the two treatments. This is done by ensuring that the information that Cs receive about behavioral patterns of As is equally irrelevant to As' types in both treatments. Since As behave the same way in each session, and their behavior is fully governed by the corresponding institutional environment, the aggregate statistic that Cs receive about As behavioral pattern carries no information about distribution of types in the population of As. Consequently, Cs have no basis for forming differential preferences (e.g. altruism), or beliefs (e.g. about reciprocity) about As across the two treatments, and thus the treatment effect cannot be attributed to these. Cs' confusion too cannot explain the treatment effect because Cs play exactly the same trust game

[45] See Fehr (2009) on whether the motive of betrayal aversion is conceptually different from the beliefs of reciprocity.

across the two treatments, and Part I is an equally simple four-branch extensive form game in either treatment.

In sum, the experimental design precludes alternative effects of institutions on individuals' trust behavior and allows focusing on a systematic behavioral bias that gets prompted by the corresponding institutional environment. Negative though marginally statistical significant effect of cooperative environment on trust reported on Table 3-2 and the first two columns of Table 3-3 is in contrast with the findings of Cassar, d'Adda and Grosjean (2013), Stagnaro, Arechar and Rand (2016), and Peysakhovich and Rand (2015), and is instead consistent with the conjecture that follows from the literature on importance of others' intentions for decisions to reciprocate (e.g. Falk, Fehr and Fischbacher 2008). The strong alignment of material interests of As with those of Bs in this environment – which results in a near universal cooperation – prompted at least some C individuals to view the trust game in the light of its material payoffs. These C individuals then behaved as prescribed by the Nash equilibrium of the trust game, i.e. decided against trust.

Following a rather common finding of a substantial gender disparity in trust behavior (e.g. Buchan, Croson, and Solnick 2008), the third and fourth columns of Table 3-3 investigate the variation of treatment effect across genders.[46] Consistent with the existing findings, females in this experiment exhibit considerably less trust in others than males, both in economic and statistical sense. While both genders are subject to the treatment effect of similar size, the effect is marginally statistically significant only for females. More precisely, based on the probit regression of the

[46] Note that genders were equally likely to be subject to either of the two treatments as given in Table C-1 in the Appendix C.

fourth column of Table 3-3, females are 25% less likely to trust others in the cooperative environment than in the non-cooperative environment (p<0.094), while males are 29% less likely (p<0.195).

Table 3-3: Probit Regression, Trust Behavior of Cs *(1 = trust)*

	Full Sample	Part I consistent with design	Full Sample	Part I consistent with design
Treatment	-0.76	-0.76*	-5.21	-5.02***
(1 = cooperative environment)	(-1.54)	[-2.32]	(-0.01)	[-10.38]
As cooperate partially	0.17		-0.07	
(1 = one A fails to cooperate in Part I)	(0.28)		(-0.10)	
As non-cooperate partially	-0.76		-0.69	
(1 = one A cooperates in Part I)	(-1.06)		(-0.97)	
Gender			0.72	1.24
(1 = Male)			(1.21)	[1.44]
Treatment x Gender			4.74	4.27***
			(0.01)	[4.43]
Constant	-0.08	-0.08	-0.42	-0.67
	(-0.26)	[-0.42]	(-0.96)	[-1.43]
N	43	30	43	30

Notes: z-statistics based on standard errors clustered at the session level are reported in square brackets. Clustering is not possible in the regressions with full sample because the dummy “As non-cooperate partially” equals 1 only for one session.
* p<0.05 ** p<0.01 *** p<0.001

4. Summary and Conclusions

This paper studied effects of institutions on individuals' tendency to trust in others in the contexts where these institutions do not apply. A two-part experimental design was employed. Part I varied institutional environment across two treatments while Part II, a trust game, was the same. The structure and payoffs of the games were set to ensure that the subjects whose trust behavior was studied (C individuals) had no basis for differential rationalizations of their behavior across the two treatments. For instance, C individuals had no room for developing differential levels of altruism (or other preferences) towards As, or for forming differential beliefs about As' tendencies to reciprocate. These motives underlying trust behavior were precluded in this experiment for the purposes of focusing on a systematic behavioral bias prompted by the seemingly unrelated institutional environment.

A natural question following the finding that a systematic bias is present even in a simple institutional environment such as the one depicted in this experiment, is whether or not this bias also operates through the channels of preferences and beliefs. Does complexity of institutional environment, and the corresponding ambiguity of intentions underlying others' behavior, induce individuals to systematically over- or under-attribute the observed level of cooperation to individuals' types as opposed to institutions? In other words, do institutions that facilitate but perhaps not guarantee cooperation through a complex system of rules make individuals look more or less cooperative than they really are? Does this mis-inference affect individuals' expectations about others' behavior, or their perception of how one "should" behave, or both?

The experiments by Cassar, d'Adda and Grosjean (2013), Stagnaro, Arechar and Rand (2016), and Peysakhovich and Rand (2015) provide suggestive evidence of these phenomena. Bohnet and Huck (2004) provide an intriguing hint by finding that subjects exhibit more trustworthiness (but not trust) after being exposed to an unrelated environment with more cooperation. While teasing out these systematic biases in individuals' inferences and their subsequent impact on behavior is a difficult task, their existence and magnitude may have policy implications for designing institutions or understanding the full extent of their impact. This paper has provided a small step in this direction by showing that a systematic bias is present even in a simple environment and its direction is opposite to what has previously been found.

Appendix A-1: Derivations for Chapter 1

Consider first the case where $S_H \geq L > S_L$. Limited enforcement of the third parties' decisions means the following:

$$U^{D\_seller} - \alpha(L - S_D) - \alpha\phi$$
$$< (1 - e) \cdot U^{D\_seller} + e \cdot (U^{D\_seller} - \alpha(L - S_D) - \alpha E)$$

where α is the value of each monetary unit. The left-hand side is the utility of D-type seller from complying with the third parties' decision (paying $(L - S_D)$ and ϕ), and the right-hand side is the utility from ignoring it and facing probability of e of enforcement. The above condition can be rewritten as follows:

$$e < \frac{(L - S_D) + \phi}{(L - S_D) + E} = \overline{e}$$

Thorough the paper, it is assumed that $e < \overline{e}$.

At the start of the first episode of their lives, D-type individuals face the following set of choices:

A. deliver the good of value L to the buyer, in which case the businessperson i gets:

$$U_L^{D\_seller} + EU_{with\ access}^{buyer}$$

where $U_L^{D\_seller} < U_{S_D}^{D\_seller}$

B. deliver the good of value S_D to the buyer, and comply with the third parties' decision if disputed and found liable, in which case the businessperson i gets:

$$(1 - P(dispute)\rho)U_{S_D}^{D\_seller} + P(dispute)\rho\big(U_{S_D}^{D\_seller} - \alpha(L - S_D) - \alpha\phi\big) + EU_{with\ access}^{buyer}$$

where $P(dispute)$ is the probability that the buyer has access to the third parties conditional on them entering the transaction with the seller.

This expression can be rewritten as follows:

$$U_{S_D}^{D\_seller} - P(dispute)\rho\alpha\big((L - S_D) + \phi\big) + EU_{with\ access}^{buyer}$$

C. deliver the good of value S_D to the buyer, and ignore the third parties' decision if disputed and found liable, in which case the businessperson i gets:

$$(1 - P(dispute)\rho)U_{S_D}^{D\_seller} + (1 - P(dispute)\rho)EU_{with\ access}^{buyer} + P(dispute)\rho e\big(U_{S_D}^{D\_seller} - \alpha(L - S_D) - \alpha E + EU_{with\ access}^{buyer}\big) + P(dispute)\rho(1 - e)\big(U_{S_D}^{D\_seller} + EU_{NO\ access}^{buyer}\big)$$

which can be rewritten as follows:

$$U_{S_D}^{D_{seller}} - P(dispute)\rho e\alpha\big((L - S_D) + E\big) + EU_{with\ access}^{buyer} - P(dispute)\rho(1 - e)\Delta EU^{buyer}$$

using the notation: $EU_{with\ access}^{buyer} - EU_{NO\ access}^{buyer} \equiv \Delta EU^{buyer}$.

D-type businesspeople prefer A to B if and only if:

$$U_L^{D\_seller} + EU_{with\ access}^{buyer} \geq U_{S_D}^{D\_seller} - P(dispute)\rho\alpha\big((L - S_D) + \phi\big) + EU_{with\ access}^{buyer} \Leftrightarrow$$

$$U_{S_D}^{D\_seller} - U_L^{D\_seller} \leq \alpha P(dispute)\rho\big((L - S_D) + \phi\big) \tag{1}$$

D-type businesspeople prefer B to C if and only if:

$$U_{S_D}^{D_{seller}} - P(dispute)\rho\alpha\big((L - S_D) + \phi\big) + EU_{with\ access}^{buyer}$$

$$\geq U_{S_D}^{D_{seller}} - P(dispute)\rho e\alpha\big((L - S_D) + E\big) + EU_{with\ access}^{buyer}$$

$$- P(dispute)\rho(1 - e)\Delta EU^{buyer} \Leftrightarrow$$

$$e\big(\alpha\big((L - S_D) + E\big) - \Delta EU^{buyer}\big) \geq \alpha\big((L - S_D) + \phi\big) - \Delta EU^{buyer}$$

Note that in case $EU_{NO\ access}^{buyer} \geq 0$, which happens when $\gamma_H \geq \underline{\gamma_H}$, $\Delta EU^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot \left((1 - \rho)U_{S_D}^{buyer} + \rho\left(U_{S_D}^{buyer} + \alpha(L - S_D)\right) - \alpha K\right) - \big(\gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer}\big) = (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$

Consequently: $\alpha\big((L - S_D) + E\big) > \alpha\big((L - S_D) + \phi\big) > \alpha\big((L - S_D) - K\big) > \alpha(\rho(L - S_D) - K) > (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$

In case $EU_{NO\ access}^{buyer} = 0$, which happens when $\gamma_H < \underline{\gamma_H}$, $EU_{with\ access}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot \left((1 - \rho)U_{S_D}^{buyer} + \rho\left(U_{S_D}^{buyer} + \alpha(L - S_D)\right) - \alpha K\right) = \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$. In this case too

$$\alpha\big((L - S_D) + E\big) > \alpha\big((L - S_D) + \phi\big) > \alpha\big((L - S_D) - K\big) > \alpha(\rho(L - S_D) - K)$$

$$> (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$$

$$> (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K) + \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer}$$

$$= \Delta EU^{buyer}$$

Thus $\alpha\big((L - S_D) + E\big) > \alpha\big((L - S_D) + \phi\big) > \Delta EU^{buyer}$ under all circumstances.

As a result, the condition for D-type businesspeople to prefer B over C can be rewritten as:

$$e \geq \frac{\alpha\big((L - S_D) + \phi\big) - \Delta EU^{buyer}}{\alpha\big((L - S_D) + E\big) - \Delta EU^{buyer}} \tag{2}$$

And D-type businesspeople prefer A to C if and only if:

$$\begin{aligned} U_L^{D\_seller} + EU_{with\ access}^{buyer} \\ &\geq U_{S_D}^{D_{seller}} - P(dispute)\rho e\alpha\big((L - S_D) + E\big) + EU_{with\ access}^{buyer} \\ &- P(dispute)\rho(1 - e)\Delta EU^{buyer} \Leftrightarrow \\ &U_{S_D}^{D\_seller} - U_L^{D_{seller}} \\ &\qquad \leq P(dispute)\rho e\alpha\big((L - S_D) + E\big) \\ &\qquad + P(dispute)\rho(1 - e)\Delta EU^{buyer} \end{aligned} \tag{3}$$

Note that unless D-type sellers choose to deliver the good of value L to the buyer, the buyers that do not have access to third parties earn the same utility that the buyers earn without existence of the third parties, $\gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer}$. Denote the level of γ_H at which this utility is 0 with $\underline{\gamma_H}$. This means that: $\underline{\gamma_H} = \frac{-U_{S_D}^{buyer}}{U_{S_H}^{buyer} - U_{S_D}^{buyer}}$. Recall that $U_{S_D}^{buyer} < 0 < U_{S_H}^{buyer}$, so $\underline{\gamma_H} \in (0,1)$. Consequently, if $\gamma_H < \underline{\gamma_H}$ then $EU_{NO\ access}^{buyer} < 0$, so agreements cease to be made in the absence of third parties, and in their presence the individuals without access to third parties refuse to enter transactions as buyers. Therefore, if $\gamma_H < \underline{\gamma_H}$ then $\Delta EU^{buyer} = EU_{with\ access}^{buyer}$. **Consider this case of $\boldsymbol{\gamma_H < \underline{\gamma_H}}$ first.** Note that because buyers without access to the third parties will not enter transactions with the sellers, only the buyers with access to the third parties enter transactions, hence $P(dispute) = 1$.

In compliance equilibrium, D-type sellers must prefer option B to options A and C. For this, the following are necessary and sufficient.

For option B to be (weakly) preferred over option C:

$$e \geq \frac{\alpha\big((L - S_D) + \phi\big) - \Delta EU_{CE}^{buyer}}{\alpha\big((L - S_D) + E\big) - \Delta EU_{CE}^{buyer}} \equiv \underline{e}^{comply} \tag{4}$$

where the subscript CE stands for compliance equilibrium, and $\Delta EU_{CE}^{buyer} = EU_{with\ access}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$.

Recall that $\alpha\big((L - S_D) + E\big) > \alpha\big((L - S_D) + \phi\big) > \Delta EU_{CE}^{buyer}$,

$$\frac{d\underline{e}^{comply}}{d\Delta EU_{CE}^{buyer}} \propto -\alpha(E + \phi) < 0$$

Which leads to the following:

$$\underline{e}^{comply} < \frac{(L - S_D) + \phi}{(L - S_D) + E} = \overline{e}$$

For option B to be (strongly) preferred over option A:

$$U_{S_D}^{D\_seller} - U_L^{D\_seller} > \alpha\rho\big((L - S_D) + \phi\big) \tag{5}$$

Furthermore, for compliance equilibrium, the buyers with access to the third parties must not be dissuaded to a lodge complaint if delivered good of value below L. This happens if and only if:

$$U_{S_D}^{buyer} \leq (1 - \rho)U_{S_D}^{buyer} + \rho\left(U_{S_D}^{buyer} + \alpha(L - S_D)\right) - \alpha K$$

which can be rewritten as:

$$\rho(L - S_D) \geq K \tag{6}$$

Finally, for compliance equilibrium, it must be that buyers with access to the third parties find transactions attractive, which happens if and only if the following holds:

$$\gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K) \geq 0$$

which can be rewritten as:

$$\gamma_H \geq \frac{-U_{S_D}^{buyer} - \alpha(\rho(L - S_D) - K)}{U_{S_H}^{buyer} - U_{S_D}^{buyer} - \alpha(\rho(L - S_D) - K)} = \underline{\gamma_H}^{comply} \tag{7}$$

Note that because $U_{S_H}^{buyer} > U_{S_D}^{buyer} + \alpha(\rho(L - S_D) - K)$ and $\rho(L - S_D) \geq K$:

$$\underline{\gamma_H}^{comply} < \frac{-U_{S_D}^{buyer}}{U_{S_H}^{buyer} - U_{S_D}^{buyer}} < 1$$

Now consider a case when $\boldsymbol{\gamma_H} \geq \underline{\boldsymbol{\gamma_H}}$, meaning that $\boldsymbol{EU_{NO\ access}^{buyer}} \geq \mathbf{0}$.

Consequently, in compliance equilibrium:

$$\begin{aligned}\Delta EU_{CE}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \\ \cdot \left((1 - \rho)U_{S_D}^{buyer} + \rho\left(U_{S_D}^{buyer} + \alpha(L - S_D)\right) - \alpha K\right) \\ - \left(\gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer}\right) = (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)\end{aligned}$$

$P(dispute)$ continues to equal 1 as every D individual that is found liable complies with the third parties' decisions and maintains its access to third parties.

Apart from changed ΔEU_{CE}^{buyer}, the conditions for existence of the compliance equilibrium remain the same as in the case of $\gamma_H < \underline{\gamma_H}$. In particular, compliance equilibrium exists under $e < \underline{e}$ if and only if:

$$\overline{e} > e \geq \frac{\alpha\big((L - S_D) + \phi\big) - \Delta EU_{CE}^{buyer}}{\alpha\big((L - S_D) + E\big) - \Delta EU_{CE}^{buyer}} \equiv \underline{e}^{comply} \qquad (Obs\ 1.1)$$

$$U_{S_D}^{D\_seller} - U_L^{D\_seller} > \alpha\rho\big((L - S_D) + \phi\big) \qquad (Obs\ 1.2)$$

$$\rho(L - S_D) \geq K \qquad (Obs\ 1.3)$$

$$\gamma_H \geq \underline{\gamma_H}^{comply} \text{ if } \underline{\gamma_H} > \gamma_H \qquad (Obs\ 1.4)$$

where

- $\Delta EU_{CE}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$ if $\gamma_H < \underline{\gamma_H}$, and $\Delta EU_{CE}^{buyer} = (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$ if $\gamma_H \geq \underline{\gamma_H}$
- $\underline{\gamma_H}^{comply} = \frac{-U_{S_D}^{buyer} - \alpha(\rho(L - S_D) - K)}{U_{S_H}^{buyer} - U_{S_D}^{buyer} - \alpha(\rho(L - S_D) - K)} < \underline{\gamma_H}$.

Note that:

$$\frac{d\underline{\gamma_H}^{comply}}{dL} \propto -\alpha\rho U_{S_H}^{buyer} < 0$$

$$\frac{d\underline{\gamma_H}^{comply}}{d\rho} \propto -\alpha(L - S_D) U_{S_H}^{buyer} < 0$$

$$\frac{d\underline{\gamma_H}^{comply}}{dK} \propto \alpha U_{S_H}^{buyer} > 0$$

Using implicit function theorem:

$$\frac{d\underline{\gamma_H}^{comply}}{dr} = -\frac{\frac{d\Delta EU_{CE}^{buyer}}{dr}}{\frac{d\Delta EU^{buyer}}{d\gamma_H}} \propto -\frac{d\Delta EU_{CE}^{buyer}}{dr}$$

which is negative unless a change in r moves S_D in the direction opposite to that of S_H and L. Note that

$$\frac{dEU_{CE}^{buyer}}{dr} = \left(I\left(\gamma_H < \underline{\gamma_H}\right) \cdot \left(\gamma_H \frac{dU_{S_H}^{buyer}}{dr} + (1-\gamma_H)\frac{dU_{S_D}^{buyer}}{dr}\right)\right.$$

$$\left. + \alpha(1-\gamma_H)\rho\frac{d(L-S_D)}{dr}\right)$$

$$\frac{d\underline{e}^{comply}}{d\gamma_H} \propto -\frac{d\Delta EU_{CE}^{buyer}}{d\gamma_H}\alpha(E-\phi)$$

$$\frac{d\Delta EU_{CE}^{buyer}}{d\gamma_H} = I\left(\gamma_H < \underline{\gamma_H}\right) \cdot \left(U_{S_H}^{buyer} - U_{S_D}^{buyer}\right) - \alpha(\rho(L-S_D)-K) > 0$$

Consequently,

$$\frac{d\underline{e}^{comply}}{d\gamma_H} < 0 \ \text{ if } \gamma_H < \underline{\gamma_H}, \frac{d\underline{e}^{comply}}{d\gamma_H} > 0 \ \text{ if } \gamma_H \geq \underline{\gamma_H}$$

$$\frac{d\underline{e}^{comply}}{dL} \propto \left(\alpha - \frac{d\Delta EU_{CE}^{buyer}}{dL}\right)\alpha(E-\phi) = (1-(1-\gamma_H)\cdot\rho)\alpha^2(E-\phi) > 0$$

$$\frac{d\underline{e}^{comply}}{d\rho} \propto -\frac{d\Delta EU^{buyer}}{d\rho}\alpha(E-\phi) < 0$$

$$\frac{d\underline{e}^{comply}}{d\phi} > 0$$

$$\frac{d\underline{e}^{comply}}{dK} \propto -\frac{d\Delta EU^{buyer}}{dK}\alpha(E-\phi) > 0$$

$$\frac{d\underline{e}^{comply}}{dE} < 0$$

$$\frac{d\underline{e}^{comply}}{dr} \propto \left(\alpha \frac{d(L - S_D)}{dr} - \frac{d\Delta EU^{buyer}}{dr}\right) \alpha(E - \phi)$$

$$= \left(\alpha \frac{d(L - S_D)}{dr} (1 - (1 - \gamma_H)\rho) - I\left(\gamma_H < \underline{\gamma_H}\right) \cdot \left(\gamma_H \frac{dU_{S_H}^{buyer}}{dr} + (1 - \gamma_H) \frac{dU_{S_D}^{buyer}}{dr}\right)\right) \alpha(E - \phi)$$

which is positive if: $\alpha \frac{d(L-S_D)}{dr} (1 - (1 - \gamma_H)\rho) > I\left(\gamma_H < \underline{\gamma_H}\right) \cdot \left(\gamma_H \frac{dU_{S_H}^{buyer}}{dr} + (1 - \gamma_H) \frac{dU_{S_D}^{buyer}}{dr}\right)$, i.e. when L reacts "disproportionally" to changes in r. In case L remains the same when r changes, $\underline{e}^{comply}$ decreases with r (unless S_D decreases with r).

Note that the total revenue to the third parties in compliance equilibrium is:

$$(1 - \gamma_H) \cdot (K + \varphi) \cdot N$$

H-type individuals' utility over the course of their lifetime is as follows:

$$U_{S_H}^{H_{seller}} + EU_{with\ access}^{buyer}$$

where $EU_{with\ access}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H) \cdot \alpha(\rho(L - S_D) - K)$

D-type individuals' utility over the course of their lifetime is as follows:

$$(1-\rho)U_{S_D}^{D\_seller} + \rho\left(U_{S_D}^{D\_seller} - \alpha(L-S_D) - \alpha\phi\right) + EU_{with\ access}^{buyer}$$

$$= U_{S_D}^{D\_seller} - \rho\alpha\left((L-S_D)+\phi\right) + EU_{with\ access}^{buyer}$$

And the social welfare of businesspeople in the compliance equilibrium is:

$$\Big(\gamma_H U_{S_H}^{H_{seller}} + (1-\gamma_H)\cdot\left((1-\rho)U_{S_D}^{D_{seller}} + \rho\left(U_{S_D}^{D_{seller}} - \alpha(L-S_D) - \alpha\phi\right)\right) + \gamma_H$$

$$\cdot U_{S_H}^{buyer} + (1-\gamma_H)\cdot U_{S_D}^{buyer} + (1-\gamma_H)\cdot\alpha(\rho(L-S_D)-K)$$

$$+ (1-\gamma_H)\cdot(K+\varphi)\Big)\cdot N$$

If it is assumed that the third parties value each monetary unit at α, just like the businesspeople, then the total social welfare in compliance equilibrium is:

$$\left(\gamma_H U_{S_H}^{H\_seller} + (1-\gamma_H)U_{S_D}^{D\_seller} + \gamma_H U_{S_H}^{buyer} + (1-\gamma_H)U_{S_D}^{buyer}\right)\cdot N$$

where N is the size of population.

In non-compliance equilibrium under $\boldsymbol{\gamma_H} < \underline{\boldsymbol{\gamma_H}}$,

$$\Delta EU_{NCE}^{buyer} = EU_{with\ access}^{buyer}$$

$$= \gamma_H\cdot U_{S_H}^{buyer} + (1-\gamma_H)$$

$$\cdot\left((1-\rho e)U_{S_D}^{buyer} + \rho e\left(U_{S_D}^{buyer} + \alpha(L-S_D)\right) - \alpha K\right)$$

$$= \gamma_H\cdot U_{S_H}^{buyer} + (1-\gamma_H)\cdot U_{S_D}^{buyer} + (1-\gamma_H)\cdot\alpha(\rho e(L-S_D)-K)$$

with the subscript NCE denoting non-compliance equilibrium. Note that $\Delta EU_{NCE}^{buyer} < \Delta EU_{CE}^{buyer}$. Recall that as long as $\gamma_H < \underline{\gamma_H}$, the D individuals without access to third parties will not enter transactions as buyers. Consequently, probability that the good of value below L will be disputed, conditional on buyer having entered the transaction is again 1, i.e. $P(dispute) = 1$. Similarly as the above, the conditions for non-compliance equilibrium are as follows:

For option C to be (strongly) preferred over option B:

$$e < \frac{\alpha\big((L - S_D) + \phi\big) - \Delta EU_{NCE}^{buyer}}{\alpha\big((L - S_D) + E\big) - \Delta EU_{NCE}^{buyer}} \equiv \bar{e}^{non-comply}$$

For option C to be (strongly) preferred over option A:

$$U_{S_D}^{D_{seller}} - P(dispute)\rho e\alpha\big((L - S_D) + E\big) + EU_{with\ access}^{buyer}$$
$$- P(dispute)\rho(1 - e)\Delta EU_{NCE}^{buyer} > U_L^{D\_seller} + EU_{with\ access}^{buyer} \Leftrightarrow$$

$$U_{S_D}^{D_{seller}} - U_L^{D_{seller}} > \rho e\alpha\big((L - S_D) + E\big) + \rho(1 - e)\Delta EU_{NCE}^{buyer}$$

For buyers with access to the third parties to not be dissuaded to a lodge complaint if delivered good of value below L:

$$\rho e(L - S_D) \geq K$$

Finally, for buyers with access to the third parties to find transactions attractive:

$$\gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H) \cdot \alpha(\rho e(L - S_D) - K) \geq 0$$

which can be rewritten as:

$$\gamma_H \geq \frac{-U_{S_D}^{buyer} - \alpha(\rho e(L - S_D) - K)}{U_{S_H}^{buyer} - U_{S_D}^{buyer} - \alpha(\rho e(L - S_D) - K)} \equiv \underline{\gamma_H}^{non-comply}$$

Note that $\underline{\gamma_H}^{non-comply} < \frac{-U_{S_D}^{buyer}}{U_{S_H}^{buyer} - U_{S_D}^{buyer}} = \underline{\gamma_H}$.

In non-compliance equilibrium under $\boldsymbol{\gamma_H \geq \underline{\gamma_H}}$, meaning that $EU_{NO\ access}^{buyer} \geq 0$:

$$\Delta EU_{NCE}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1-\gamma_H)$$

$$\cdot \left((1-\rho e)U_{S_D}^{buyer} + \rho e\left(U_{S_D}^{buyer} + \alpha(L-S_D)\right) - \alpha K\right)$$

$$- \left(\gamma_H \cdot U_{S_H}^{buyer} + (1-\gamma_H) \cdot U_{S_D}^{buyer}\right)$$

$$= (1-\gamma_H) \cdot \alpha(\rho e(L-S_D) - K)$$

$P(dispute) < 1$ here because even the individuals without access to third parties find it attractive to enter transactions as buyers. In particular:

$$P(dispute) = \gamma_H + (1-\gamma_H) \cdot \left(1 - P(dispute)\rho(1-e)\right)$$

where probability of dispute equals probability of being matched with H-type buyers, plus probability of being matched with the D-type buyers who have access to third parties (note that probability of transacting with or without access to third parties is 1, because $\gamma_H \geq \underline{\gamma_H}$). Consequently:

$$P(dispute) = \frac{1}{1 + (1-\gamma_H)\rho(1-e)}$$

Apart from changed ΔEU_{NCE}^{buyer} and $P(dispute) < 1$, the conditions for existence of the non-compliance equilibrium are the same as above. In particular:

$$e < \frac{\alpha\left((L-S_D) + \phi\right) - \Delta EU_{NCE}^{buyer}}{\alpha\left((L-S_D) + E\right) - \Delta EU_{NCE}^{buyer}} \equiv \bar{e}^{non-comply} < \bar{e} \tag{8}$$

$$U_{S_D}^{D_{seller}} - U_L^{D_{seller}} > P(dispute)\left[\rho e\alpha\big((L - S_D) + E\big) + \rho(1-e)\Delta EU_{NCE}^{buyer}\right] \quad (9)$$

$$\rho e(L - S_D) \geq K \quad (10)$$

$$\gamma_H \geq \underline{\gamma_H}^{non-comply} \text{ if } \underline{\gamma_H} > \gamma_H \quad (11)$$

where

- $\Delta EU_{NCE}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1-\gamma_H) \cdot U_{S_D}^{buyer} + (1-\gamma_H) \cdot \alpha(\rho e(L - S_D) - K)$ if $\gamma_H < \underline{\gamma_H}$, and $\Delta EU_{NCE}^{buyer} = (1-\gamma_H) \cdot \alpha(\rho e(L - S_D) - K)$ if $\gamma_H \geq \underline{\gamma_H}$
- $P(dispute) = 1$ if $\gamma_H < \underline{\gamma_H}$, and $P(dispute) = \frac{1}{1+(1-\gamma_H)\rho(1-e)}$ if $\gamma_H \geq \underline{\gamma_H}$
- $\underline{\gamma_H}^{non-comply} = \frac{-U_{S_D}^{buyer} - \alpha(\rho e(L-S_D)-K)}{U_{S_H}^{buyer} - U_{S_D}^{buyer} - \alpha(\rho e(L-S_D)-K)} < \underline{\gamma_H}$.

Note that to calculate the total revenue to the third parties in non-compliance equilibrium, probability of transaction is needed. In non-compliance equilibrium under $\gamma_H < \underline{\gamma_H}$, only H-type individuals and the D-type individuals that have access to third parties enter transactions as buyers. Consequently, the following must hold:

$$P(transaction) = \gamma_H + (1-\gamma_H)\big(1 - P(transaction)P(dispute)\rho(1-e)\big)$$

where the right hand side decomposes the probability of transaction into: (i) probability of being matched with H-type individuals (γ_H); and (ii) probability that the potential buyer is D-type $(1-\gamma_H)$ but has access to third parties, with D-types not having access only if they have transacted before, have their good disputed, have been found guilty, and have escaped enforcement). Note that under $\gamma_H < \underline{\gamma_H}$,

$P(dispute) = 1$ because only the buyers with access to the third parties enter transactions.

Probability of transaction therefore is:

$$P(transaction) = \frac{1}{1 + (1 - \gamma_H)\rho(1 - e)} \text{ if } \gamma_H < \underline{\gamma_H}$$

$$P(transaction) = 1 \text{ if } \gamma_H \geq \underline{\gamma_H}$$

suggesting that $P(transaction)$ is decreasing in ρ if $\gamma_H < \underline{\gamma_H}$, rather unintuitively, because D-types are less likely to have access to third parties with higher ρ, and are thus less likely to enter transactions as buyers.

Consequently, the total revenue to the third parties in non-compliance equilibrium is the following:

$$\big[\gamma_H(1 - \gamma_H) + (1 - \gamma_H) \cdot (1 - \gamma_H) \\ \cdot \big(1 - P(transaction) \cdot P(dispute) \cdot \rho \cdot (1 - e)\big)\big] \cdot K \cdot N$$

which can be rewritten as:

$$(1 - \gamma_H) \cdot \frac{1}{1 + (1 - \gamma_H)\rho(1 - e)} \cdot K \cdot N$$

which is much lower than their revenue under the compliance equilibrium (which is $(1 - \gamma_H) \cdot (K + \varphi) \cdot N$ as derived above).

H-type individuals' utility over the course of their lifetime is as follows:

$$P(transaction) \cdot U_{S_H}^{H_{seller}} + EU_{with\ access}^{buyer}$$

where $EU_{with\ access}^{buyer} = \gamma_H \cdot U_{S_H}^{buyer} + (1-\gamma_H) \cdot U_{S_D}^{buyer} + (1-\gamma_H) \cdot \alpha(\rho e(L - S_D) - K)$

D-type individuals' utility over the course of their lifetime is as follows:

$$
\begin{aligned}
& P(transaction) \\
& \qquad \cdot \Big[(1 - P(dispute)\rho) \cdot \big[U_{S_D}^{D_{seller}} + EU_{with\ access}^{buyer}\big] \\
& \qquad + P(dispute)\rho e\big[U_{S_D}^{D_{seller}} - \alpha(L - S_D) - \alpha E + EU_{with\ access}^{buyer}\big] \\
& \qquad + P(dispute)\rho(1-e)\big[U_{S_D}^{D_{seller}} + EU_{NO\ access}^{buyer}\big]\Big] \\
& \qquad + \big(1 - P(transaction)\big) \cdot EU_{with\ access}^{buyer}
\end{aligned}
$$

which can be simplified as follows:

$$
\begin{aligned}
& P(transaction) \cdot \big[U_{S_D}^{D_{seller}} - P(dispute)\rho e\alpha\big((L - S_D) + E\big)\big] + EU_{with\ access}^{buyer} \\
& \qquad - P(transaction) \cdot P(dispute)\rho(1-e)\Delta EU_{NCE}^{buyer}
\end{aligned}
$$

And the total social welfare in non-compliance equilibrium is:

$$
\begin{aligned}
& \big(P(transaction) \cdot \big[\gamma_H U_{S_H}^{H_{seller}} + (1-\gamma_H) U_{S_D}^{D_{seller}}\big] + \gamma_H U_{S_H}^{buyer} \\
& \qquad + (1-\gamma_H)\big(1 - P(transaction) \cdot P(dispute) \cdot \rho \cdot (1-e)\big) U_{S_D}^{buyer}\big) \\
& \qquad \cdot N
\end{aligned}
$$

where N is the size of population.

Combining the conditions for compliance equilibrium with those for non-compliance equilibrium shows that both equilibria are possible under the following conditions:

$$\bar{e}^{non-comply} > e \geq \underline{e}^{comply} \qquad (Obs\ 2.1)$$

$$U_{S_D}^{D\_seller} - U_L^{D_{seller}} \qquad (Obs\ 2.2)$$

$$> \max\{\alpha\rho\big((L - S_D)$$

$$+ \phi\big), P(dispute)\big[\rho e\alpha\big((L - S_D) + E\big)$$

$$+ \rho(1 - e)\Delta EU_{NCE}^{buyer}\big]\}$$

$$\rho e(L - S_D) \geq K \qquad (Obs\ 2.3)$$

$$\gamma_H > \underline{\gamma_H}^{non-comply} \geq \underline{\gamma_H}^{comply} \qquad (Obs\ 2.4)$$

where

- $\underline{e}^{comply} = \frac{\alpha\left((L-S_D)+\phi\right)-\Delta EU_{CE}^{buyer}}{\alpha\left((L-S_D)+E\right)-\Delta EU_{CE}^{buyer}}$,
- $\bar{e}^{non-comply} = \frac{\alpha\left((L-S_D)+\phi\right)-\Delta EU_{NCE}^{buyer}}{\alpha\left((L-S_D)+E\right)-\Delta EU_{NCE}^{buyer}}$, with $\overline{e} > \bar{e}^{non-comply} > \underline{e}^{comply}$
- if $\gamma_H < \underline{\gamma_H}$, then

$$\Delta EU_{CE}^{buyer}$$

$$= \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H)$$

$$\cdot \alpha(\rho(L - S_D) - K)$$

$$\Delta EU_{NCE}^{buyer}$$

$$= \gamma_H \cdot U_{S_H}^{buyer} + (1 - \gamma_H) \cdot U_{S_D}^{buyer} + (1 - \gamma_H)$$

$$\cdot \alpha(\rho e(L - S_L) - K)$$

$$P(dispute) = 1$$

- if $\gamma_H \geq \underline{\gamma_H}$, then

$$\Delta EU_{CE}^{buyer} = (1-\gamma_H)\cdot\alpha(\rho(L-S_D)-K)$$

$$\Delta EU_{NCE}^{buyer} = (1-\gamma_H)\cdot\alpha(\rho e(L-S_D)-K)$$

$$P(dispute) = \frac{1}{1+(1-\gamma_H)\rho(1-e)} < 1$$

- $\underline{\gamma_H}^{comply} = \frac{-U_{S_D}^{buyer}-\alpha(\rho(L-S_D)-K)}{U_{S_H}^{buyer}-U_{S_D}^{buyer}-\alpha(\rho(L-S_D)-K)} < \underline{\gamma_H}$, and
- $\underline{\gamma_H}^{non-comply} = \frac{-U_{S_D}^{buyer}-\alpha(\rho e(L-S_D)-K)}{U_{S_H}^{buyer}-U_{S_D}^{buyer}-\alpha(\rho e(L-S_D)-K)} < \underline{\gamma_H}$.

Note that there may exist a third type of equilibrium, the one with all D sellers delivering the good of value L to avoid disputes altogether. In this equilibrium, $\Delta EU^{buyer} = 0$. Conditions for this equilibrium are:

$$U_{S_D}^{D\_seller} - U_L^{D_{seller}} \leq \alpha\rho\big((L-S_D)+\phi\big)$$

$$U_{S_D}^{D\_seller} - U_L^{D_{seller}} \leq \rho e\alpha\big((L-S_D)+E\big)$$

$$\rho e(L-S_D) \geq K$$

$$\gamma_H \cdot U_{S_H}^{buyer} + (1-\gamma_H)\cdot U_L^{buyer} \geq 0$$

Note that this is a precarious equilibrium in that the third parties are never approached, and hence have no source of revenue, yet are expected to continue existence with ρ maintained.

Dynamics of γ_H is introduced using a simple difference equation whereby at the start of each period t (comprising two parts of every individuals' life) individuals switch type depending on how advantageous the other type is. More precisely:

$$\gamma_{H_{t+1}} = \gamma_{H_t} \cdot \left(1 + g\left(\overline{U}_t^H - \overline{U}_t^D\right)\right)$$

where

- $\overline{U}_t^H$ is average utility that H-type businesspeople earned at time t
- $\overline{U}_t^D$ is average utility that D-type businesspeople earned at time t
- $g(\cdot)$ is an increasing continuous function with $g(0) = 0$ and range $(0,1)$

In the compliance equilibrium $\overline{U}_t^H - \overline{U}_t^D$ is as follows:

$$U_{S_H}^{H_{seller}} + EU_{with\ access}^{buyer} - \left(U_{S_D}^{D_{seller}} - \rho\alpha\big((L - S_D) + \phi\big) + EU_{with\ access}^{buyer}\right)$$

$$= U_{S_H}^{H_{seller}} - U_{S_D}^{D_{seller}} + \rho\alpha\big((L - S_D) + \phi\big)$$

recall that $U_{S_H}^{H_{seller}} < U_{S_D}^{D_{seller}}$.

Consequently, in the compliance equilibrium, γ_H is increasing as long as $\rho\alpha\big((L - S_D) + \phi\big) > U_{S_D}^{D_{seller}} - U_{S_H}^{H_{seller}}$, and decreasing as long as $\rho\alpha\big((L - S_D) + \phi\big) < U_{S_D}^{D_{seller}} - U_{S_H}^{H_{seller}}$. The equilibrium γ_H is reached when the parameters are such that:

$$\rho\alpha\big((L - S_D) + \phi\big) = U_{S_D}^{D_{seller}} - U_{S_H}^{H_{seller}}$$

Note that any γ_H can be an equilibrium, and the third parties have direct influence on the direction in which γ_H is moving through their power to alter ρ and ϕ. Law-makers too have a direct influence on the direction in which γ_H is moving through their power to set L. Also note that in terms of the social welfare, none of these parameters is relevant as long as they are set to ensure that the compliance equilibrium exists.

In the non-compliance equilibrium $\overline{U}_t^H - \overline{U}_t^D$ is as follows:

$$P(transaction) \cdot U_{S_H}^{H_{seller}} + EU_{with\ access}^{buyer} - \Big[P(transaction) \cdot \big[U_{S_D}^{D_{seller}} - P(dispute)\rho e\alpha\big((L - S_D) + E\big)\big] + EU_{with\ access}^{buyer} - P(transaction) \cdot P(dispute)\rho(1-e)\Delta EU_{NCE}^{buyer}\Big]$$

which can be rewritten as follows:

$$P(transaction) \cdot \left(U_{S_H}^{H_{seller}} - U_{S_D}^{D_{seller}}\right) + P(transaction) \cdot P(dispute)\rho\Big(e\alpha\big((L - S_D) + E\big) + (1-e)\Delta EU_{NCE}^{buyer}\Big)$$

Note that γ_H increases faster under non-compliance equilibrium if the following holds:

$$\big(1 - P(transaction)\big) \cdot \left(U_{S_D}^{D_{seller}} - U_{S_H}^{H_{seller}}\right) + P(transaction) \cdot P(dispute)\rho\Big(e\alpha\big((L - S_D) + E\big) + (1-e)\Delta EU_{NCE}^{buyer}\Big) - \rho\alpha\big((L - S_D) + \phi\big) > 0$$

In the non-compliance equilibrium, γ_H is increasing over time as long as:

$$P(dispute)\rho\Big(e\alpha\big((L - S_D) + E\big) + (1-e)\Delta EU_{NCE}^{buyer}\Big) > U_{S_D}^{D_{seller}} - U_{S_H}^{H_{seller}}$$

and decreasing as long as:

$$P(dispute)\rho\Big(e\alpha\big((L - S_D) + E\big) + (1-e)\Delta EU_{NCE}^{buyer}\Big) < U_{S_D}^{D_{seller}} - U_{S_H}^{H_{seller}}$$

γ_H reaches equilibrium at:

$$P(dispute)\rho\Big(e\alpha\big((L-S_D)+E\big)+(1-e)\Delta EU_{NCE}^{buyer}\Big)=U_{S_D}^{D_{seller}}-U_{S_H}^{H_{seller}}$$

Recall that

- if $\gamma_H < \underline{\gamma_H}$, then

$$\Delta EU_{NCE}^{buyer}$$
$$=\gamma_H \cdot U_{S_H}^{buyer}+(1-\gamma_H)\cdot U_{S_D}^{buyer}+(1-\gamma_H)$$
$$\cdot\,\alpha(\rho e(L-S_D)-K)$$

$$P(dispute)=1$$

$$P(transaction)=\frac{1}{1+(1-\gamma_H)\rho(1-e)}$$

- if $\gamma_H \geq \underline{\gamma_H}$, then

$$\Delta EU_{NCE}^{buyer}=(1-\gamma_H)\cdot\alpha(\rho e(L-S_D)-K)$$

$$P(dispute)=\frac{1}{1+(1-\gamma_H)\rho(1-e)}$$

$$P(transaction)=1$$

Consequently, if $\gamma_H < \underline{\gamma_H}$, then equilibrium level of γ_H is:

$$\gamma_H$$
$$=\frac{U_{S_D}^{D_{seller}}-U_{S_H}^{H_{seller}}-(1-e)\rho U_{S_D}^{buyer}-\rho e\alpha(L-S_D)(1-(1-e)\rho)-\rho\alpha(eE+(1-e)K)}{(1-e)\rho\left(U_{S_H}^{buyer}-U_{S_D}^{buyer}-\alpha(\rho e(L-S_D)-K)\right)}$$

which is below $\underline{\gamma_H}$ if and only if:

$$\Big(U_{S_D}^{D_{seller}}-U_{S_H}^{H_{seller}}-\rho e\alpha(L-S_D)(1-(1-e)\rho)-\rho\alpha(eE+(1-e)K)\Big)\Big(U_{S_H}^{buyer}$$
$$-\,U_{S_D}^{buyer}\Big)<U_{S_D}^{buyer}(1-e)\rho\alpha(\rho e(L-S_D)-K)<0$$

If $\gamma_H \geq \underline{\gamma_H}$, then equilibrium level of γ_H satisfies:

$$\frac{1}{1+(1-\gamma_H)\rho(1-e)}\rho\left(e\alpha\big((L-S_D)+E\big)+(1-e)(1-\gamma_H)\right.$$
$$\left.\cdot\,\alpha(\rho e(L-S_D)-K)\right)=U_{S_D}^{D_{seller}}-U_{S_H}^{H_{seller}}$$

with potentially two equilibrium levels of γ_H.

Note that the level of L is immaterial for social welfare in either equilibrium as long as its level ensures than the corresponding equilibrium exists. The same holds for ρ in the compliance equilibrium. In the non-compliance equilibrium however, the level of ρ determines social welfare beyond determining the type of equilibrium. In particular, in the non-compliance equilibrium, if $\gamma_H < \underline{\gamma_H}$, then derivative of the social welfare w.r.t. ρ is:

$$\frac{-(1-\gamma_H)(1-e)}{\big(1+(1-\gamma_H)\rho(1-e)\big)^2}\left(\gamma_H U_{S_H}^{H_{seller}}+(1-\gamma_H)U_{S_D}^{D_{seller}}+U_{S_D}^{buyer}\right)\cdot N$$

which is negative if $\gamma_H U_{S_H}^{H_{seller}}+(1-\gamma_H)U_{S_D}^{D_{seller}} > -U_{S_D}^{buyer}$, and positive if $\gamma_H U_{S_H}^{H_{seller}}+(1-\gamma_H)U_{S_D}^{D_{seller}} < -U_{S_D}^{buyer}$ (recall that $U_{S_D}^{buyer} < 0$).

If $\gamma_H \geq \underline{\gamma_H}$, then derivative of the social welfare w.r.t. ρ is:

$$-\frac{(1-\gamma_H)(1-e)}{1+(1-\gamma_H)\rho(1-e)}U_{S_D}^{buyer}\cdot N$$

which is positive.

Consequently, unless $\gamma_H < \underline{\gamma_H}$ and $\gamma_H U_{S_H}^{H_{seller}}+(1-\gamma_H)U_{S_D}^{D_{seller}} > -U_{S_D}^{buyer}$, the social welfare under the non-cooperative equilibrium is increasing in ρ.

Appendix A-2: Mathematica and Stata codes for Chapter 1

Setting up the model in Mathematica:

```
Clear["Global`*"]

alpha = 1;

HH = 25;

rho = 0.6;

KK = 2;

r = 2;

II = 100;

SD = 75;

SH = 150;

phi = 15;

EE = 65;

USHbuyer=alpha*(-II+SH);

USDbuyer=alpha*(-II+SD);

USDseller = alpha*(r*II - SD);

USLseller = alpha*(r*II - L);

USHHseller = alpha*(r*II - SH + HH);

gammaHlowerbar = (-USDbuyer)/(USHbuyer - USDbuyer);

UbuyerNOTHING = gammaH*USHbuyer + (1 - gammaH)*USDbuyer;

eupperbar = ((L - SD) + phi)/((L - SD) + EE);

deltaUbuyerCE =   Boole[gammaH < gammaHlowerbar]*(gammaH*USHbuyer + (1 - gammaH)*USDbuyer) + (1 - gammaH)*alpha*(rho*(L - SD) - KK);

obs12MUSTBEPOSITIVE =  USDseller - USLseller - (alpha*rho*((L - SD) + phi));

obs13MUSTBEPOSITIVE = rho*(L - SD) - KK;
```

eCOMPLY = Max[0, (alpha*((L - SD) + phi) - deltaUbuyerCE)/(alpha*((L - SD) + EE) - deltaUbuyerCE)];

gammaCOMPLY = Max[0, (-USDbuyer - alpha*(rho*(L - SD) - KK))/(USHbuyer -

USDbuyer - alpha*(rho*(L - SD) - KK))];

obs14 = gammaH - gammaCOMPLY;

deltaUbuyerNCE = Boole[gammaH < gammaHlowerbar]*(gammaH*USHbuyer + (1 - gammaH)*USDbuyer) + (1 -

gammaH)*alpha*(rho*ee*(L - SD) - KK);

pdispute = 1/(1 + Boole[gammaH >= gammaHlowerbar]*(1 - gammaH)*rho*(1 - ee));

obs32NCEMUSTBEPOSITIVE = pdispute*(rho*ee*alpha*((L - SD) + EE) +

rho*(1 - ee)*deltaUbuyerNCE);

obs33NCEMUSTBEPOSITIVE = rho*ee*(L - SD) - KK;

eNONCOMPLY = Max[0, (alpha*((L - SD) + phi) - deltaUbuyerNCE)/(alpha*((L - SD) + EE) - deltaUbuyerNCE)];

gammaNONCOMPLY = Max[0, (-USDbuyer - alpha*(rho*ee*(L - SD) - KK))/(USHbuyer -

USDbuyer - alpha*(rho*ee*(L - SD) - KK))];

Producing Figure 1-1, Figure 1-2, and Figure 1-3

L = 115;

RegionPlot[{ee >= eCOMPLY, gammaH >= Min[gammaCOMPLY, gammaHlowerbar],

eupperbar <= ee, gammaH >= gammaHlowerbar}, {gammaH, 0, 1}, {ee, 0,

1}, PlotStyle -> White]

RegionPlot[{ee >= eCOMPLY, gammaH >= Min[gammaCOMPLY, gammaHlowerbar],

eupperbar <= ee, gammaH >= gammaHlowerbar, ee < eNONCOMPLY,

```
  obs32NCEMUSTBEPOSITIVE > 0, obs33NCEMUSTBEPOSITIVE > 0,

  gammaH >= Min[gammaNONCOMPLY, gammaHlowerbar]}, {gammaH, 0, 1},
{ee,

   0, 1}, PlotStyle -> White]

L = Max[SD + Min[(alpha*(ee*EE - phi) + (1 - ee)*(Boole[gammaH <
gammaHlowerbar]*(gammaH*USHbuyer + (1 - gammaH)*USDbuyer) - (1 -
gammaH)*alpha*KK))/(alpha*(1 - (1 - gammaH)*rho)*(1 - ee)), SH - SD], SD];

RegionPlot[{ee >= eCOMPLY && obs12MUSTBEPOSITIVE > 0 &&

   obs13MUSTBEPOSITIVE > 0 &&

   gammaH >= Min[gammaCOMPLY, gammaHlowerbar] && eupperbar > ee,

  ee < eNONCOMPLY && obs32NCEMUSTBEPOSITIVE > 0 &&

   obs33NCEMUSTBEPOSITIVE > 0 &&

   gammaH >= Min[gammaNONCOMPLY, gammaHlowerbar] &&

   eupperbar > ee}, {gammaH, 0, 1}, {ee, 0, 1}]
```

Producing Figure 1-4 using Stata

```
drop _all

set more off

global max = 301


set obs $max

gen obs = _n

gen time = obs - 1


global alpha = 1

global HH = 25
```

```
global rho = 0.6

global KK = 2

global r = 2

global II = 100

global SD = 75

global SH = 150

global phi = 15

global EE = 65

global ee = 0.6

*global ee = 0.59  // Applied for Panel C only


global speed = 0.01


global USHbuyer = $alpha*(-$II + $SH)

global USDbuyer = $alpha*(-$II + $SD)

global USDseller = $alpha*($r*$II - $SD)

global USHHseller = $alpha*($r*$II - $SH + $HH)


global gammaHlowerbar = (-$USDbuyer)/($USHbuyer - $USDbuyer)


gen gammaH = .

gen L = .

gen equilibrium = ""

gen fitnessdifferentialCE = .

gen multiplier = .
```

```
gen eCOMPLY = .

gen obs12MUSTBEPOSITIVE = .

gen obs13MUSTBEPOSITIVE = .

gen gammaCOMPLY = .

gen eNONCOMPLY = .

gen obs32NCEMUSTBEPOSITIVE = .

gen obs33NCEMUSTBEPOSITIVE = .

gen gammaNONCOMPLY = .

gen fitnessdifferentialNCE =.

gen fitnessdifferential = .


replace gammaH = 0.1 in 1


forval i = 1 / $max {

	global gammaH = gammaH[`i']

	if $gammaH < $gammaHlowerbar {

		global temp1 = ($gammaH*$USHbuyer + (1 -
$gammaH)*$USDbuyer)

		global pdispute = 1

		global ptransaction = 1/(1 + (1 - $gammaH)*$rho*(1 - $ee))

	}

	else {

		global temp1 = 0

		global pdispute = 1/(1 + (1 - $gammaH)*$rho*(1 - $ee))

		global ptransaction = 1
```

```
}

global temp2 = (1-$ee)*($temp1-(1-$gammaH)*$alpha*$KK)

global temp3 = $alpha*($ee*$EE - $phi)

global temp4 = $alpha*(1 - (1 - $gammaH)*$rho)*(1 - $ee)

global combined1 = ($temp3 + $temp2)/$temp4

global step1 = min($combined1,$SH-$SD)

global combined2 = $SD + $step1

global step2 = max($combined2,$SD)

global L = $step2

*	global L = 150 // Applied for Panel B only

replace L = $L in `i'


global USLseller = $alpha*($r*$II - $L)

global eupperbar = (($L - $SD) + $phi)/(($L - $SD) + $EE)

global deltaUbuyerCE  = $temp1 + (1 - $gammaH)*$alpha*($rho*($L - $SD) - $KK)

global deltaUbuyerNCE = $temp1 + (1 - $gammaH)*$alpha*($rho*$ee*($L - $SD) - $KK)

global obs12MUSTBEPOSITIVE = $USDseller - $USLseller - ($alpha*$rho*(($L - $SD) + $phi))

global obs13MUSTBEPOSITIVE = $rho*($L - $SD) - $KK

global obs32NCEMUSTBEPOSITIVE = $pdispute*($rho*$ee*$alpha*(($L - $SD) + $EE) + $rho*(1 - $ee)*$deltaUbuyerNCE)

global obs33NCEMUSTBEPOSITIVE = $rho*$ee*($L - $SD) - $KK

global eCOMPLY = ($alpha*(($L - $SD) + $phi) - $deltaUbuyerCE)/($alpha*(($L - $SD) + $EE) - $deltaUbuyerCE)
```

```
global eNONCOMPLY = ($alpha*(($L - $SD) + $phi) - $deltaUbuyerNCE)/($alpha*(($L - $SD) + $EE) - $deltaUbuyerNCE)

global gammaCOMPLY = (-$USDbuyer - $alpha*($rho*($L - $SD) - $KK))/($USHbuyer - $USDbuyer - $alpha*($rho*($L - $SD) - $KK))

global gammaNONCOMPLY = (-$USDbuyer - $alpha*($rho*$ee*($L - $SD) - $KK))/($USHbuyer - $USDbuyer - $alpha*($rho*$ee*($L - $SD) - $KK))

local equilibrium = ""


if ($ee - $eCOMPLY+0.00001) > 0 & $obs12MUSTBEPOSITIVE > 0 & $obs13MUSTBEPOSITIVE > 0 & $gammaH >= min($gammaCOMPLY,$gammaHlowerbar) {

	local equilibrium = "CE"

}

if ($ee - $eNONCOMPLY-0.00001) < 0 & $obs32NCEMUSTBEPOSITIVE > 0 & $obs33NCEMUSTBEPOSITIVE > 0 & $gammaH >= min($gammaNONCOMPLY,$gammaHlowerbar) {

	qui count if equilibrium == "CE"

	if `r(N)' == 0 {

		local equilibrium = "NCE"

	}

	else if "`equilibrium'" != "CE" {

		local equilibrium = "NCE"

	}

}

replace equilibrium = "`equilibrium'" in `i'


global fitnessdifferentialCE = $rho*$alpha*($L - $SD + $phi) + ($USHHseller - $USDseller)
```

```
	replace fitnessdifferentialCE = (1-$gammaH)*$fitnessdifferentialCE if obs == `i'

	global fitnessdifferentialNCE = $ptransaction*($USHHseller - $USDseller) + $ptransaction*$pdispute*$rho*($ee*$alpha*($L - $SD + $EE) + (1 - $ee)*$deltaUbuyerNCE)

	replace fitnessdifferentialNCE = (1-$gammaH)*$fitnessdifferentialNCE if obs == `i'

	local appropriatefit = "fitnessdifferential`equilibrium'"

	replace fitnessdifferential = $`appropriatefit' if obs == `i'

	global temp = 1 + $speed*(1-exp(-$`appropriatefit'))/(1+exp(-$`appropriatefit'))

	replace multiplier = $temp if obs == `i'

	global nextgammaH =  min(max($gammaH * $temp,0),1)

	if `i' <= ($max - 1) {

		replace gammaH = $nextgammaH if obs == `i'+1

	}

	replace eCOMPLY = $eCOMPLY if obs == `i'

	replace obs12MUSTBEPOSITIVE = $obs12MUSTBEPOSITIVE if obs == `i'

	replace obs13MUSTBEPOSITIVE = $obs13MUSTBEPOSITIVE if obs == `i'

	replace gammaCOMPLY = $gammaCOMPLY if obs == `i'


	replace eNONCOMPLY = $eNONCOMPLY if obs == `i'

	replace obs32NCEMUSTBEPOSITIVE = $obs32NCEMUSTBEPOSITIVE if obs == `i'

	replace obs33NCEMUSTBEPOSITIVE = $obs33NCEMUSTBEPOSITIVE if obs == `i'

	replace gammaNONCOMPLY = $gammaNONCOMPLY if obs == `i'

}
```

Appendix B-1: Derivations for Chapter 2

The probability that an individual of c_2 switches to c_1, denoted by P_{21}, is derived in detail. The derivation of the probability an individual c_1 switches to c_2 is analogous. Denote the outcome of asocial learning by A, it equals 1 if c_1 is learnt asocially, and equals 0 if c_2 is learnt instead. Probability of each realization of A is:

$$\Pr(A) = \rho^A (1-\rho)^{(1-A)}$$

where ρ is the level of human capital.

Similarly, the variable F equals 1 if the parent has c_1, and equals 0 if the parent has c_2. The variable FT equals 1 if the parental cultural trait is considered, and equals 0 otherwise. Probabilities of all four combinations of realizations of F and FT is given by:

$$\Pr(F, FT) = q_F^F (1-q_F)^{(1-F)} \cdot p_F^{FT} (1-p_F)^{(1-FT)}$$

where p_F is the strength of family ties. For example, probability that the parent is c_1 ($F = 1$) and it is considered in the subsequent decision making process ($FT = 1$) is $q_F p_F$.

Denote the number of peers with the trait c_k by n_{c_k} ($n_1 + n_2 = n_P$). The probability of having exactly n_1 peers of c_1 among the total of n_P randomly selected peers is: $\binom{n_P}{n_1} q^{n_1} (1-q)^{n_2}$. The probability of learning c_1 from n_{P_1} peers and c_2 from n_{P_2} peers from the peer-group that is composed of n_1 individuals of $c_1$and n_2 individuals of c_2 is: $\binom{n_1}{n_{p_1}} p_P^{n_{P_1}} (1-p_P)^{n_1 - n_{P_1}} \cdot \binom{n_2}{n_{P_2}} p_P^{n_{P_2}} (1-p_P)^{n_2 - n_{P_2}}$, or after combining terms $\binom{n_1}{n_{p_1}}\binom{n_2}{n_{P_2}}p_P^{n_{P_1}+n_{P_2}}(1-p_P)^{n_P-(n_{P_1}+n_{P_2})}$. The product of these two probabilities is the probability that after interacting with n_P randomly selected peers an individual learns c_1 from n_{P_1} peers and c_2 from n_{P_2} peers. This equals the following:

$$\Pr\left(n_1,n_2,n_{P_1},n_{P_2}\right) = \binom{n_P}{n_1}q^{n_1}(1-q)^{n_2}\cdot\binom{n_1}{n_{p_1}}\binom{n_2}{n_{P_2}}p_P^{n_{P_1}+n_{P_2}}(1-p_P)^{n_P-(n_{P_1}+n_{P_2})}$$

Consequently, the total probability of switching from c_2 to $c_1$is:

$$P_{21} = \sum_{A=0}^{1}\sum_{F=0}^{1}\sum_{FT=0}^{1}\sum_{n_1=0}^{n_P}\sum_{n_{P_1}=0}^{n_1}\sum_{n_{P_2}=0}^{n_2} I_{\{A+F\cdot FT+\,n_{P_1}>0\}}\ \Pr(A)\Pr(F,FT)\Pr\left(n_1,n_2,n_{P_1},n_{P_2}\right)\Phi(\alpha_{21}\omega\Delta\mu)$$

where,

- $I_{\{A+F\cdot FT+\,n_{P_1}>0\}}$ is the indicator function equal to 1 when $A+F\cdot FT+\ n_{P_1}>0$, equal to 0 otherwise.
- $\Phi(x)$ is the CDF of the standard normal distribution at the point x
- $\alpha_{21}=\left(\frac{1}{A+F\cdot FT+\,n_{P_1}}+\frac{1}{1+(1-A)+(1-F)\cdot FT+\,n_{P_2}}\right)^{-1/2}$
- ω is the quality of institutions
- $\Delta\mu=\mu_1-\mu_2$, assumed to equal 1

The indicator function in the expression for P_{21} makes sure that individuals are not switching to c_1 in case it was not considered as a possible option; more specifically, when $A=0, F\cdot FT=0$ and $n_{P_1}=0$, the individual has not been exposed to c_1 at all.

The probability of switching to c_2 from c_1 is similarly derived and is equal to:

$$P_{12} = \sum_{A=0}^{1}\sum_{F=0}^{1}\sum_{FT=0}^{1}\sum_{n_1=0}^{n_P}\sum_{n_{P_1}=0}^{n_1}\sum_{n_{P_2}=0}^{n_2} I_{\{(1-A)+(1-F)\cdot FT+\, n_{P_2}>0\}} \Pr(A)\Pr(F,FT)\Pr\left(n_1,n_2,n_{P_1},n_{P_2}\right)\Phi(-\alpha_{12}\omega$$

where $\alpha_{12} = \left(\frac{1}{1+A+F\cdot FT+n_{P_1}} + \frac{1}{(1-A)+(1-F)\cdot FT+n_{P_2}}\right)^{-\frac{1}{2}}$.

Proof of the claim that equation (2) cannot be rewritten in terms of a stationary Markov Chain

In matrix form, equation (2) can be rewritten as follows:

$$\begin{bmatrix} q_{\tau+1} \\ 1-q_{\tau+1} \end{bmatrix} = \begin{bmatrix} \left(1-P_{12}(q_\tau)\right) & P_{21}(q_\tau) \\ P_{12}(q_\tau) & \left(1-P_{21}(q_\tau)\right) \end{bmatrix} \begin{bmatrix} q_\tau \\ 1-q_\tau \end{bmatrix}$$

The transition matrix cannot be represented as a product of two matrices one of which is time-invariant. This claim is proven for 2x2 matrices but the argument is the same for any other dimensions.

Suppose the transition matrix can be represented as a product of two matrices:

$$\begin{bmatrix} \left(1-P_{12}(q_\tau)\right) & P_{21}(q_\tau) \\ P_{12}(q_\tau) & \left(1-P_{21}(q_\tau)\right) \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix} \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}$$

If this is to hold for any q_τ, the following must hold:

$$x_{11}y_{11} + x_{12}y_{21} + x_{21}y_{11} + x_{22}y_{21} = 1$$

The above must hold because the first two term must equal $\left(1-P_{12}(q_\tau)\right)$ and the last two term must equal $P_{12}(q_\tau)$. Similarly, the following must hold:

$$x_{11}y_{12} + x_{12}y_{22} + x_{21}y_{12} + x_{22}y_{22} = 1$$

These two equations can be rewritten as:

$$\begin{cases}(x_{11} + x_{21})y_{11} + (x_{12} + x_{22})y_{21} = 1 \\ (x_{11} + x_{21})y_{12} + (x_{12} + x_{22})y_{22} = 1\end{cases}$$

Without loss of generality, suppose $\begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix}$ is time-invariant, while $\begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}$ is a function of q_τ. If so, the above system has a solution only if $y_{11} - y_{12} = C_1$ and $y_{21} - y_{22} = C_2$, where C_1 and C_2 are some constants.

$$\begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix} \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} x_{11}y_{11} + x_{12}y_{21} & x_{11}y_{12} + x_{12}y_{22} \\ x_{21}y_{11} + x_{22}y_{21} & x_{21}y_{12} + x_{22}y_{22} \end{bmatrix}$$

$$= \begin{bmatrix} x_{11}y_{11} + x_{12}y_{21} & x_{11}(y_{11} - C_1) + x_{12}(y_{21} - C_2) \\ x_{21}y_{11} + x_{22}y_{21} & x_{21}(y_{11} - C_1) + x_{22}(y_{21} - C_2) \end{bmatrix}$$

$$= \begin{bmatrix} x_{11}y_{11} + x_{12}y_{21} & x_{11}y_{11} + x_{12}y_{21} - x_{11}C_1 - x_{12}C_2 \\ x_{21}y_{11} + x_{22}y_{21} & x_{21}y_{11} + x_{22}y_{21} - x_{21}C_1 - x_{22}C_2 \end{bmatrix}$$

For this to equal to $\begin{bmatrix} \left(1 - P_{12}(q_\tau)\right) & P_{21}(q_\tau) \\ P_{12}(q_\tau) & \left(1 - P_{21}(q_\tau)\right) \end{bmatrix}$, it is necessary (though not sufficient) that $\left(1 - P_{12}(q_\tau)\right) - P_{21}(q_\tau) = x_{11}C_1 + x_{12}C_2$ for any q_τ. The right hand-side of this condition is a function of q_τ while the left-hand side is constant. Therefore, this condition cannot hold for any q_τ. Consequently, at least one of the terms x_{11}, C_1, x_{12}, C_2 has to be a function of q_τ which contradicts to the original conjecture.

Similar holds for matrices of any dimension the product of which result in a 2x2 matrix. The transition matrix is thus not reducible to a product of two matrices one of which is time-invariant.

Proof of the Proposition

Proof of existence and uniqueness of steady state $q^* \in [0,1]$ *for the entire permissible domain of the parameter space, which is* $q_F, p_F, p_P, \rho \in [0,1]$ *and* $\omega\left(=\frac{1}{\sigma}\right) > 0.$

Using the simplifying assumption that $n_P = 1$, the switching probabilities can be rewritten in the following way:

$$P_{12} = q\mathcal{A} + (1-q)\mathcal{B}$$

$$P_{21} = q\mathcal{C} + (1-q)\mathcal{D}$$

where

$$\mathcal{A} = \sum_{A=0}^{1}\sum_{F=0}^{1}\sum_{FT=0}^{1}\sum_{n_{P_1}=0}^{1} I_{\{(1-A)+(1-F)\cdot FT>0\}} \Pr(A)\Pr(F,FT)\, p_P^{n_{P_1}}(1 - p_P)^{1-n_{P_1}}\Phi(-\alpha_{12}\omega)$$

$$\mathcal{B} = \sum_{A=0}^{1}\sum_{F=0}^{1}\sum_{FT=0}^{1}\sum_{n_{P_2}=0}^{1} I_{\{(1-A)+(1-F)\cdot FT+\, n_{P_2}>0\}} \Pr(A)\Pr(F,FT)\, p_P^{n_{P_2}}(1 - p_P)^{1-n_{P_2}}\Phi(-\alpha_{12}\omega)$$

$$\mathcal{C} = \sum_{A=0}^{1}\sum_{F=0}^{1}\sum_{FT=0}^{1}\sum_{n_{P_1}=0}^{1} I_{\{A+F\cdot FT+\, n_{P_1}>0\}} \Pr(A)\Pr(F,FT)\, p_P^{n_{P_1}}(1 - p_P)^{1-n_{P_1}}\Phi(\alpha_{21}\omega)$$

$$\mathcal{D} = \sum_{A=0}^{1}\sum_{F=0}^{1}\sum_{FT=0}^{1}\sum_{n_{P_2}=0}^{1} I_{\{A+F\cdot FT>0\}} \Pr(A)\Pr(F,FT)\, p_P^{n_{P_2}}(1 - p_P)^{1-n_{P_2}}\Phi(\alpha_{21}\omega)$$

Notice that $\mathcal{A}, \mathcal{B}, \mathcal{C}$ and $\mathcal{D} \in [0,1]$ for the entire permissible domain of the parameter space.

The equilibrium dynamics (2) can be rewritten as:

$$q_{\tau+1} = q_\tau(1 - q_\tau\mathcal{A} - (1 - q_\tau)\mathcal{B}) + (1 - q_\tau)(q_\tau\mathcal{C} + (1 - q_\tau)\mathcal{D})$$

Denote the right-hand side of the above equation with $\mathcal{K}(q_\tau)$. This function can be rewritten as:

$$\mathcal{K}(q_\tau) = q_\tau^2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) + q_\tau(\mathcal{C} - \mathcal{B} - 2\mathcal{D} + 1) + \mathcal{D}$$

which is continuously differentiable in q_τ.

At $q_\tau = 0$, $\mathcal{K}(q_\tau = 0) = \mathcal{D} \in [0,1]$, so in $q_\tau \in [0,1]$ domain, $\mathcal{K}(q_\tau)$ always starts at or above the 45^o line. $\mathcal{D} = 0$ if and only if $\rho = q_F = 0$ or $\rho = p_F = 0$, so unless these conditions are met, $\mathcal{K}(q_\tau)$ always starts strictly above the 45^o line. At $q_\tau = 1$, $\mathcal{K}(q_\tau = 1) = 1 - \mathcal{A} \in [0,1]$, so in $q_\tau \in [0,1]$ domain, $\mathcal{K}(q_\tau)$ always ends at or below the 45^o line. $\mathcal{A} = 0$ if and only if $\rho = q_F = 1$ or $\rho = 1, p_F = 0$, so unless these conditions are met, $\mathcal{K}(q_\tau)$ always ends strictly below the 45^o line. Notice that $\mathcal{A} = 0$ and $\mathcal{D} = 0$ cannot hold at the same time.

It is shown next that of the two roots of the equation $q^* = \mathcal{K}(q^*)$, there is always one and only one satisfying $q_\tau \in [0,1]$.

The equation $q^* = \mathcal{K}(q^*)$, can be rewritten as:

$${q^*}^2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) + q^*(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + \mathcal{D} = 0$$

The two roots of this equation are:

$$q_1^* = \frac{-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$$

$$q_2^* = \frac{-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$$

$$\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} = \sqrt{\mathcal{C}^2 - 2\mathcal{C}\mathcal{B} + \mathcal{B}^2 + 4\mathcal{A}\mathcal{D}}$$

$$= \sqrt{(\mathcal{C} - \mathcal{B})^2 + 4\mathcal{A}\mathcal{D}}$$

Since, $(\mathcal{C} - \mathcal{B})^2 \geq 0$ and $\mathcal{A}\mathcal{D} \geq 0$, $\sqrt{(\mathcal{C} - \mathcal{B})^2 + 4\mathcal{A}\mathcal{D}}$ is always real.

It is shown next that for the entire permissible domain of the parameter space, $q_1^* \notin [0,1]$ and $q_2^* \in [0,1]$.

Consider first the case when $(\mathcal{B} + D - \mathcal{A} - \mathcal{C}) > 0$

$$\mathcal{A}(\mathcal{A} + \mathcal{C} - \mathcal{B} - \mathcal{D}) < 0 \Leftrightarrow \mathcal{A}^2 + \mathcal{A}\mathcal{C} - \mathcal{A}\mathcal{B} - \mathcal{A}\mathcal{D} < 0 \Leftrightarrow$$

$$\mathcal{B}^2 - 4\mathcal{A}\mathcal{B} - 2\mathcal{B}\mathcal{C} + 4\mathcal{A}^2 + 4\mathcal{A}\mathcal{C} + \mathcal{C}^2 < \mathcal{C}^2 + \mathcal{B}^2 - 2\mathcal{B}\mathcal{C} + 4\mathcal{A}\mathcal{D} \Leftrightarrow$$

$$(\mathcal{B} - 2\mathcal{A} - \mathcal{C})^2 < (\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})$$

This means that either

$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$ and $(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) > -\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$

Or

$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) > \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$ and $(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < -\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$

Consider the first case:

$$(\mathcal{B}-2\mathcal{A}-\mathcal{C}) < \sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} \Leftrightarrow$$

$$-(\mathcal{C}-\mathcal{B}-2\mathcal{D})+(\mathcal{B}-2\mathcal{A}-\mathcal{C})$$

$$< -(\mathcal{C}-\mathcal{B}-2\mathcal{D})+\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} \Leftrightarrow$$

$$2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) < -(\mathcal{C}-\mathcal{B}-2\mathcal{D})+\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}$$

$$\Leftrightarrow$$

$$1 < \frac{-(\mathcal{C}-\mathcal{B}-2\mathcal{D})+\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}}{2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} = q_1^*$$

$$(\mathcal{B}-2\mathcal{A}-\mathcal{C}) > -\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} \Leftrightarrow$$

$$-(\mathcal{C}-\mathcal{B}-2\mathcal{D})+(\mathcal{B}-2\mathcal{A}-\mathcal{C})$$

$$> -(\mathcal{C}-\mathcal{B}-2\mathcal{D})-\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} \Leftrightarrow$$

$$2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) > -(\mathcal{C}-\mathcal{B}-2\mathcal{D})-\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}$$

$$\Leftrightarrow$$

$$1 > \frac{-(\mathcal{C}-\mathcal{B}-2\mathcal{D})-\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}}{2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} = q_2^*$$

In the second case:

$$(\mathcal{B}-2\mathcal{A}-\mathcal{C}) > \sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} \Leftrightarrow$$

$$-(\mathcal{C}-\mathcal{B}-2\mathcal{D})+(\mathcal{B}-2\mathcal{A}-\mathcal{C})$$

$$> -(\mathcal{C}-\mathcal{B}-2\mathcal{D})+\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} \Leftrightarrow$$

$$2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) > -(\mathcal{C}-\mathcal{B}-2\mathcal{D})+\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}$$

$$\Leftrightarrow$$

$$1 > \frac{-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} = q_1^*$$

And

$$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < -\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Leftrightarrow$$

$$-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + (\mathcal{B} - 2\mathcal{A} - \mathcal{C})$$

$$< -(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Leftrightarrow$$

$$2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) < -(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$$

$$\Leftrightarrow$$

$$1 < \frac{-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} = q_2^* \Leftrightarrow$$

This however suggests that $q_1^* < 1 < q_2^*$ which holds if and only if:

$$\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$$

$$< -\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$$

This however contradicts the convention taken above that $\sqrt{}$ denotes a positive root.

Therefore,

$$(\mathcal{B} - 2\mathcal{A} - \mathcal{C})^2 < (\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})$$

means that

$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$ and $(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) > -\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$

which in their turn mean that $q_2^* < 1 < q_1^*$.

Finally,

$$-\mathcal{A} < \mathcal{D} \Leftrightarrow$$

$$0 < \mathcal{B} + \mathcal{D} - \mathcal{C} - \mathcal{A} < \mathcal{B} + \mathcal{D} - \mathcal{C} + D = -\mathcal{C} + \mathcal{B} + 2\mathcal{D} = -(\mathcal{C} - \mathcal{B} - 2\mathcal{D})$$

As $-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) > 0$, and

$-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) > \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Rightarrow q_2^* > 0.$

To summarize, whenever $(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) > 0$, $0 < q_2^* < 1$ and $q_1^* > 1$.

Now consider the case when $(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) < 0$

$$\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} - (\mathcal{C} - \mathcal{B} - 2\mathcal{D}) > 0 \Leftrightarrow$$

$$\frac{\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} - (\mathcal{C} - \mathcal{B} - 2\mathcal{D})}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} < 0 \Leftrightarrow q_1^* < 0$$

Also, $-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) < \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$, therefore

$$-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} < 0 \Leftrightarrow$$

$$\frac{-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} > 0 \Leftrightarrow q_2^* > 0$$

At the same time,

$$\mathcal{A}(\mathcal{A} + \mathcal{C} - \mathcal{B} - \mathcal{D}) > 0 \Leftrightarrow \mathcal{A}^2 + \mathcal{A}\mathcal{C} - \mathcal{A}\mathcal{B} - \mathcal{A}\mathcal{D} > 0 \Leftrightarrow$$

$$\mathcal{B}^2 - 4\mathcal{A}\mathcal{B} - 2\mathcal{B}\mathcal{C} + 4\mathcal{A}^2 + 4\mathcal{A}\mathcal{C} + \mathcal{C}^2 > \mathcal{C}^2 + \mathcal{B}^2 - 2\mathcal{B}\mathcal{C} + 4\mathcal{A}\mathcal{D} \Leftrightarrow$$

$$(\mathcal{B} - 2\mathcal{A} - \mathcal{C})^2 > (\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})$$

This means that either

$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) > \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$ and $(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) > -\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$

Or

$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$ and $(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < -\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$

Consider the first case:

$$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) > \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Leftrightarrow$$

$$-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + (\mathcal{B} - 2\mathcal{A} - \mathcal{C}) > -(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Leftrightarrow$$

$$2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) > -(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Leftrightarrow$$

$$1 < \frac{-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} = q_1^*$$

This however contradicts $q_1^* < 0$.

Consider the second case:

$$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Leftrightarrow 1 > q_1^*$$

$$(\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < -\sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Leftrightarrow$$

$$-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + (\mathcal{B} - 2\mathcal{A} - \mathcal{C}) < -(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} \Leftrightarrow$$

$$2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) < -(\mathcal{C}-\mathcal{B}-2\mathcal{D}) - \sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}$$

$$\Leftrightarrow$$

$$1 > \frac{-(\mathcal{C}-\mathcal{B}-2\mathcal{D}) - \sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}}{2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} = q_2^*$$

To summarize, whenever $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) < 0$, $0 < q_2^* < 1$ and $q_1^* < 0$.

Finally, consider the case when $(\mathcal{B}+D-\mathcal{A}-\mathcal{C}) = 0$. Here the equilibrium condition can be rewritten as:

$$q^*(\mathcal{C}-\mathcal{B}-2\mathcal{D}) + \mathcal{D} = 0 \Rightarrow q^* = -\frac{D}{(\mathcal{C}-\mathcal{B}-2\mathcal{D})}$$

Using, $(\mathcal{B}+D-\mathcal{A}-\mathcal{C}) = 0 \Rightarrow \mathcal{C} = \mathcal{B}+D-\mathcal{A}$, therefore the above becomes:

$$q^* = -\frac{D}{\mathcal{B}+D-\mathcal{A}-\mathcal{B}-2\mathcal{D}} = \frac{D}{\mathcal{A}+\mathcal{D}}$$

Notice that $\mathcal{D}$ and $\mathcal{A}$ cannot both be 0, therefore $\frac{D}{\mathcal{A}+\mathcal{D}} \in [0,1]$.

Everything taken together, whatever is the sign of $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})$, $q_1^* \notin [0,1]$ and $q_2^* \in [0,1]$, in addition q_2^* is always real. If $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) = 0$, than $q^* = \frac{D}{\mathcal{A}+\mathcal{D}} \in [0,1]$.

Henceforth, q_2^* will be denoted as q^*.

Whenever $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) \neq 0$

$$q^* = \frac{-(\mathcal{C}-\mathcal{B}-2\mathcal{D}) - \sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}}{2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}$$

Whenever $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) = 0$

$$q^* = \frac{D}{\mathcal{A} + \mathcal{D}}$$

Proof of independence of the equilibrium q^* from initial condition q^0.

As $\mathcal{A}, \mathcal{B}, \mathcal{C}$ and $\mathcal{D}$ are independent from q^0 and q^* is function of only these, q^* is independent of q^0.

Proof of stability of the equilibrium q^*

Recall that the dynamics is described as:

$$q_{\tau+1} = \mathcal{K}(q_\tau)$$

where $\mathcal{K}(q_\tau) = q_\tau^2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) + q_\tau(\mathcal{C} - \mathcal{B} - 2\mathcal{D} + 1) + \mathcal{D}$.

For stability at q^*, it needs to be shown that $\mathcal{K}'(q^*) < 1$

$$\mathcal{K}'(q_\tau) = 2q_\tau(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) + (\mathcal{C} - \mathcal{B} - 2\mathcal{D} + 1)$$

Consider the case when $(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) \neq 0$.

Evaluating $\mathcal{K}'(q_\tau)$ at q^*:

$$\mathcal{K}'(q^*) = 2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})$$

$$\cdot \frac{-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$$

$$+ (\mathcal{C} - \mathcal{B} - 2\mathcal{D} + 1)$$

$$= -(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$$

$$+ (\mathcal{C} - \mathcal{B} - 2\mathcal{D} + 1) =$$

$$= 1 - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}$$

As $\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})} \geq 0$, $\mathcal{K}'(q^*) \leq 1$. The equilibrium q^* is thus always stable.

Consider the case when $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) = 0$.

$$\mathcal{K}'(q_\tau) = (\mathcal{C}-\mathcal{B}-2\mathcal{D}+1)$$

Using $(\mathcal{B}+D-\mathcal{A}-\mathcal{C}) = 0 \Rightarrow \mathcal{C} = \mathcal{B}+D-\mathcal{A}$, therefore the above becomes:

$$\mathcal{K}'(q_\tau) = (\mathcal{B}+D-\mathcal{A}-\mathcal{B}-2\mathcal{D}+1) = 1-(\mathcal{A}+\mathcal{D}) \leq 1$$

Proof that the steady state is non-degenerate apart from specific corner values of parameters

To find the conditions under which $q^* = 0$, consider first the case when $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) = 0$. In this case $q^* = \frac{D}{\mathcal{A}+\mathcal{D}}$. Therefore, for q^* to be 0, the following should hold: $\mathcal{D} = 0, \mathcal{A} \neq 0$ and $\mathcal{B}-\mathcal{A}-\mathcal{C} = 0$.

$\mathcal{D} = 0$ if and only if $\rho = q_F = 0$ or $\rho = p_F = 0$. Whenever $\rho = 0$, $\mathcal{A} \neq 0$.

For $\mathcal{B}-\mathcal{A}-\mathcal{C} = 0$ to hold, $p_p = 0$ is necessary and sufficient.

In sum, $q^* = 0$ if and only if $\rho = q_F = p_P = 0$ or $\rho = p_F = p_P = 0$. These values of parameters imply that individuals do not learn from social interactions and the only trait they are learning from asocial learning is c_2. These conditions lead to full prevalence of c_2.

Now consider the case when $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C}) \neq 0$. In this case $q^* = \frac{-(\mathcal{C}-\mathcal{B}-2\mathcal{D})-\sqrt{(\mathcal{C}-\mathcal{B})^2+4\mathcal{A}\mathcal{D}}}{2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}$. Therefore, for q^* to be 0, the following is necessary and sufficient: $\mathcal{D} = 0$ and $\mathcal{B} > \mathcal{C}$. The latter conditional on the former holds if and only if

$p_P \leq \overline{p_P}$ where $\overline{p_P} \in [0,0.5)$ and is found only implicitly (that $\overline{p_P} < 0.5$ is established numerically).

Combining these two cases, $q^* = 0$ if and only if $\rho = q_F = 0$ or $\rho = p_F = 0$ and $p_P \leq \overline{p_P}$. These values of parameters imply that individuals do not learn from parents, learning from peers is limited and the only trait they are learning from asocial learning is c_2. These conditions lead to full prevalence of c_2.

To find the conditions under which $q^* = 1$, consider first the case when $(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) = 0$. In this case $q^* = \frac{D}{\mathcal{A}+\mathcal{D}}$. Therefore, for q^* to be 0, the following should hold: $\mathcal{D} \neq 0, \mathcal{A} = 0$ and $\mathcal{B} + \mathcal{D} - \mathcal{C} = 0$.

$\mathcal{A} = 0$ holds if and only if $\rho = q_F = 1$ or $\rho = 1, p_F = 0$. Whenever $\rho \neq 0$, $\mathcal{D} \neq 0$ holds. For additional condition $\mathcal{B} + \mathcal{D} - \mathcal{C} = 0$ to also hold, the following is necessary and sufficient: $p_P = 0$.

In sum, $q^* = 1$ if and only if $\rho = q_F = 1, p_P = 0$ or $\rho = 1, p_F = p_P = 0$. The first set of values of parameters implies that individuals do not learn from peers, every parent has c_1 and they may learn from them and the only trait they are learning from asocial learning is c_1. The second set of values of parameters implies the same about asocial learning but individuals are not learning from social interactions at all. It is intuitive than under such conditions c_1 completely prevails.

Now consider first the case when $(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) \neq 0$. In this case $q^* = \frac{-(\mathcal{C}-\mathcal{B}-2\mathcal{D}) - \sqrt{(\mathcal{C}-\mathcal{B})^2 + 4\mathcal{A}\mathcal{D}}}{2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}$. Therefore, for q^* to be 1, the following is necessary and sufficient: $\mathcal{A} = 0$ and $\mathcal{B} < \mathcal{C}$. The latter always holds conditional on the former.

Combining these two cases, $q^* = 1$ if and only if $\rho = q_F = 1$ or or $\rho = 1, p_F = 0$. These values of parameters imply that the only trait they are learning from asocial learning is c_1 and individuals either do not learn from parents, or they learn only $c_1$from them.

To summarize the conditions under which q^* is degenerate, $q^* = 0$ if and only if $\rho = q_F = 0$ or $\rho = p_F = 0$ and $p_P \leq \overline{p_P}$, and $q^* = 1$ if and only if $\rho = q_F = 1$ or or $\rho = 1, p_F = 0$. In all other cases $q^* \in (0,1)$.

Proof of Result 1: Applying the implicit function theorem to the equilibrium condition: $q^* - q^*(1 - P_{12}) - (1 - q^*)P_{21} = 0$, which simplifies to $P_{12}q^* - (1 - q^*)P_{21} = 0$:

$$\frac{\partial q^*}{\partial \omega} = -\frac{q^* \frac{\partial P_{12}}{\partial \omega} - (1 - q^*) \frac{\partial P_{21}}{\partial \omega}}{P_{12} + P_{21} + q^* \frac{\partial P_{12}}{\partial q^*} - (1 - q^*) \frac{\partial P_{21}}{\partial q^*}}$$

Consider the denominator first.

$$P_{12} + P_{21} + q^* \frac{\partial P_{12}}{\partial q^*} - (1 - q^*) \frac{\partial P_{21}}{\partial q^*}$$

$$= q^*\mathcal{A} + (1 - q^*)\mathcal{B} + q^*\mathcal{C} + (1 - q^*)\mathcal{D} + q^*(\mathcal{A} - \mathcal{B})$$

$$- (1 - q^*)(\mathcal{C} - \mathcal{D})$$

$$= q^*\mathcal{A} + \mathcal{B} - q^*\mathcal{B} + q^*\mathcal{C} + \mathcal{D} - q^*\mathcal{D} + q^*A - q^*\mathcal{B} - \mathcal{C} + \mathcal{D} + q^*\mathcal{C}$$

$$- q^*\mathcal{D} = 2q^*\mathcal{A} - 2q^*\mathcal{B} + 2q^*\mathcal{C} - 2q^*\mathcal{D} + 2D + \mathcal{B} - C$$

$$= 2q^*(\mathcal{A} + \mathcal{C} - \mathcal{B} - \mathcal{D}) + 2\mathcal{D} + \mathcal{B} - \mathcal{C}$$

Consider first the case when $(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) \neq 0$, plugging q^* in the above:

$$2(\mathcal{A}+\mathcal{C}-\mathcal{B}-\mathcal{D})\cdot\frac{-(\mathcal{C}-\mathcal{B}-2\mathcal{D})-\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}}{2(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}$$

$$+2\mathcal{D}+\mathcal{B}-\mathcal{C}$$

$$=-\left(-(\mathcal{C}-\mathcal{B}-2\mathcal{D})-\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}\right)$$

$$+2D+B-C$$

$$=\mathcal{C}-\mathcal{B}-2\mathcal{D}+\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}+2D$$

$$+B-C=\sqrt{(\mathcal{C}-\mathcal{B}-2\mathcal{D})^2-4\mathcal{D}(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})}\geq 0$$

with strict inequality unless $\mathcal{C}=\mathcal{B}$, and $\mathcal{A}=0$ or $\mathcal{D}=0$ under which conditions $q^*=0$ or $q^*=1$.

Consider the case when $(\mathcal{B}+\mathcal{D}-\mathcal{A}-\mathcal{C})=0$, the above then becomes

$$P_{12}+P_{21}+q^*\frac{\partial P_{12}}{\partial q^*}-(1-q^*)\frac{\partial P_{21}}{\partial q^*}=\ 2\mathcal{D}+\mathcal{B}-\mathcal{C}$$

Using $(\mathcal{B}+D-\mathcal{A}-\mathcal{C})=0\Rightarrow\mathcal{C}=\mathcal{B}+D-\mathcal{A}$, the above can be rewritten as:

$$2\mathcal{D}+\mathcal{B}-\mathcal{C}=2\mathcal{D}+\mathcal{B}-\mathcal{B}-D+\mathcal{A}=\mathcal{D}+\mathcal{A}>0$$

The denominator is thus always positive. From the expressions of P_{12} and P_{21}it directly follows that $\frac{\partial P_{12}}{\partial\omega}<0$ and $\frac{\partial P_{21}}{\partial\omega}>0$. The numerator is thus always negative. Therefore $\frac{\partial q^*}{\partial\omega}>0$ for the entire range of parameter values.

Indirect effects

The term $q^*\frac{\partial P_{12}}{\partial q^*}-(1-q^*)\frac{\partial P_{21}}{\partial q^*}$ represents the indirect effect on equilibrium culture. Using the same notation it can be rewritten as:

$$q^* \frac{\partial P_{12}}{\partial q^*} - (1-q^*) \frac{\partial P_{21}}{\partial q^*} = q^*(\mathcal{A} - \mathcal{B}) - (1-q^*)(\mathcal{C} - \mathcal{D})$$

$$= q^*(\mathcal{A} + \mathcal{C} - \mathcal{B} - \mathcal{D}) + \mathcal{D} - \mathcal{C}$$

Consider first the case when $(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C}) \neq 0$, plugging q^* in the above:

$$q^* \frac{\partial P_{12}}{\partial q^*} - (1-q^*) \frac{\partial P_{21}}{\partial q^*}$$

$$= (\mathcal{A} + \mathcal{C} - \mathcal{B} - \mathcal{D})$$

$$\cdot \frac{-(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) - \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})} + \mathcal{D}$$

$$- \mathcal{C}$$

$$= \frac{(\mathcal{C} - \mathcal{B} - 2\mathcal{D}) + \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2} + \mathcal{D}$$

$$- \mathcal{C} = \frac{-(\mathcal{C} + \mathcal{B}) + \sqrt{(\mathcal{C} - \mathcal{B} - 2\mathcal{D})^2 - 4\mathcal{D}(\mathcal{B} + \mathcal{D} - \mathcal{A} - \mathcal{C})}}{2}$$

which can be positive or negative.

Three direct effects of an increase in $\boldsymbol{\rho}$

P_{21} and P_{12} can be rewritten in the following way.

$$P_{21}$$

$$= \rho \sum_{F=0}^{1} \sum_{FT=0}^{1-F} \sum_{n_1=0}^{1} \sum_{n_{P_2}=0}^{1-n_1} \Pr(F, FT) \Pr\left(n_1, n_{P_2}\right) \Phi\left(\alpha_{21|A=1, n_{P_1}=0}\omega\right)$$

$$+ \rho p_F p_P [(1-q_F)q + q_F(1-q) - q_F q] \left\{\Phi(\omega) - \Phi\left(\frac{\sqrt{3}}{2}\omega\right)\right\}$$

$$+ \sum_{F=0}^{1} \sum_{FT=0}^{1} \sum_{n_1=0}^{1} \sum_{n_{P_1}=0}^{n_1} \sum_{n_{P_2}=0}^{1-n_1} I_{\{F \cdot FT + n_{P_1} > 0\}} \Pr(F, FT) \Pr\left(n_1, n_{P_1}, n_{P_2}\right) \Phi\left(\alpha_{21|A=0}\omega\right)$$

where $\Pr\left(n_{c_1}, n_{P_2}\right) = \Pr\left(n_1, n_2 = 1 - n_1, n_{P_1} = 0, n_{P_2}\right)$ and $\Pr\left(n_1, n_{P_1}, n_{P_2}\right) = \Pr\left(n_1, n_2 = 1 - n_1, n_{P_1}, n_{P_2}\right)$.

The first term in this expression represents c_1 consideration effect; the rest represent the effect on individuals with c_2 who would consider both cultural traits regardless of the level of ρ.

Similarly,

$$P_{12}$$

$$= (1-\rho)\sum_{FT=0}^{1}\sum_{F=0}^{1-FT}\sum_{n_1=0}^{1}\sum_{n_{P_1}=0}^{n_1} \Pr(F, FT)\Pr\left(n_1, n_{P_1}\right)\Phi\left(-\alpha_{12|A=0,n_{P_2}=0}\omega\right)$$

$$+ \rho p_F p_P[(1-q_F)q + q_F(1-q) - (1-q_F)(1-q)]\left\{\Phi\left(-\frac{\sqrt{3}}{2}\omega\right) - \Phi(-\omega)\right\}$$

$$+ \sum_{F=0}^{1}\sum_{FT=0}^{1}\sum_{n_1=0}^{1}\sum_{n_{P_1}=0}^{n_1}\sum_{n_{P_2}=0}^{1-n_1} I_{\{(1-F)\cdot FT + n_{P_2} > 0\}}\Pr(F, FT)\Pr\left(n_1, n_{P_1}, n_{P_2}\right)\Phi\left(-\alpha_{12|A=0}\omega\right)$$

where $\Pr\left(n_1, n_{P_1}\right) = \Pr\left(n_1, n_2 = 1 - n_1, n_{P_1}, n_{P_2} = 0\right)$ and $\Pr\left(n_1, n_{P_1}, n_{P_2}\right) = \Pr\left(n_1, n_2 = 1 - n_1, n_{P_1}, n_{P_2}\right)$.

The first term in this expression represents c_2 consideration effect; the rest represent the effect on individuals with c_1 who would consider both cultural traits regardless of the level of ρ.

Proof of Result 2: Applying the implicit function theorem to the equilibrium condition:

$$\frac{\partial q^*}{\partial \rho} = -\frac{q^* \frac{\partial P_{12}}{\partial \rho} - (1 - q^*) \frac{\partial P_{21}}{\partial \rho}}{P_{12} + P_{21} + q^* \frac{\partial P_{12}}{\partial q^*} - (1 - q^*) \frac{\partial P_{21}}{\partial q^*}}$$

As already shown above, the denominator is always positive. Therefore,

$$\frac{\partial q^*}{\partial \rho} \propto -\left(q^* \frac{\partial P_{12}}{\partial \rho} - (1 - q^*) \frac{\partial P_{21}}{\partial \rho}\right)$$

Using the decomposition of effects of ρ on P_{12} and P_{21} into the three effects discussed in the paper, the above expression can be rewritten as follows:

$$-\left(q^* \frac{\partial P_{12}}{\partial \rho} - (1 - q^*) \frac{\partial P_{21}}{\partial \rho}\right)$$

$$= q^* \left[\sum_{FT=0}^{1} \sum_{F=0}^{1-FT} \sum_{n_1=0}^{1} \sum_{n_{P_1}=0}^{n_1} \Pr(F, FT) \Pr\left(n_1, n_{P_1}\right) \Phi\left(-\alpha_{12|A=0, n_{P_2}=0} \omega\right)\right]$$

$$+ (1 - q^*) \left[\sum_{F=0}^{1} \sum_{FT=0}^{1-F} \sum_{n_1=0}^{1} \sum_{n_{P_2}=0}^{1-n_1} \Pr(F, FT) \Pr\left(n_1, n_{P_2}\right) \Phi\left(\alpha_{21|A=1, n_{P_1}=0} \omega\right)\right]$$

$$- q^* \left[p_F p_P [(1 - q_F) q^* + q_F (1 - q^*) - (1 - q_F)(1 - q^*)] \left\{\Phi\left(-\frac{\sqrt{3}}{2} \omega\right)\right.\right.$$

$$\left.\left.- \Phi(-\omega)\right\}\right]$$

$$+ (1 - q^*) \left[p_F p_P [(1 - q_F) q^* + q_F (1 - q^*) - q_F q^*] \left\{\Phi(\omega) - \Phi\left(\frac{\sqrt{3}}{2} \omega\right)\right\}\right]$$

which can further be simplified as:

$$-\left(q^*\frac{\partial P_{12}}{\partial \rho}-(1-q^*)\frac{\partial P_{21}}{\partial \rho}\right)$$

$$=q^*\left[\sum_{FT=0}^{1}\sum_{F=0}^{1-FT}\sum_{n_1=0}^{1}\sum_{n_{P_1}=0}^{n_1}\Pr(F,FT)\Pr\ \left(n_1,n_{P_1}\right)\Phi\left(-\alpha_{12|A=0,n_{P_2}=0}\omega\right)\right]$$

$$+(1-q^*)\left[\sum_{F=0}^{1}\sum_{FT=0}^{1-F}\sum_{n_1=0}^{1}\sum_{n_{P_2}=0}^{1-n_1}\Pr(F,FT)\Pr\ \left(n_1,n_{P_2}\right)\Phi\left(\alpha_{21|A=1,n_{P_1}=0}\omega\right)\right]$$

$$-\left\{\Phi(\omega)-\Phi\left(\frac{\sqrt{3}}{2}\omega\right)\right\}p_Fp_P\left[3{q^*}^2(1-2q_F)-q_F-2q^*(1-3q_F)\right]$$

The first two terms are positive (these are c_2 consideration effect and c_1 consideration effect, respectively). The last term represent the effect on individuals who would consider both cultural traits regardless of the level of ρ; it can be positive or negative as discussed in the paper.

It is shown numerically that for the entire range of permissible values of parameters, $-\left(q^*\frac{\partial P_{12}}{\partial \rho}-(1-q^*)\frac{\partial P_{21}}{\partial \rho}\right)\geq 0$. This is done by showing that the global minimum of this function is at or above zero. Global minimum of this function is found using two methods, genetic algorithm and pattern search. The optimization problems are solved in Matlab. The corresponding codes are available upon request.

Three direct effects of an increase in p_F

P_{21} and P_{12} can be rewritten in the following way.

$$P_{21} = p_F(1-\rho)q_F \sum_{n_{c_1}=0}^{1} \sum_{n_{P_2}=0}^{1-n_{c_1}} \Pr\left(n_{c_1}, n_{P_2}\right) \Phi\left(\alpha_{21|A=0,F\cdot FT=1,n_{P_1}=0}\ \omega\right)$$

$$+ p_F \sum_{A=0}^{1} \sum_{F=0}^{1} \sum_{n_{c_1}=0}^{1} \sum_{n_{P_1}=0}^{n_{c_1}} \sum_{n_{P_2}=0}^{1-n_{c_1}} I_{\{A+n_{P_1}>0\}} \Pr(A)\, q_F^F (1$$

$$- q_F)^{(1-F)} \Pr\left(n_{c_1}, n_{P_1}, n_{P_2}\right) \left\{\Phi\left(\alpha_{21|FT=1}\omega\right) - \Phi\left(\alpha_{21|FT=0}\omega\right)\right\}$$

$$+ \sum_{A=0}^{1} \sum_{F=0}^{1} \sum_{n_{c_1}=0}^{1} \sum_{n_{P_1}=0}^{n_{c_1}} \sum_{n_{P_2}=0}^{1-n_{c_1}} I_{\{A+n_{P_1}>0\}} \Pr(A)\, q_F^F (1$$

$$- q_F)^{(1-F)} \Pr\left(n_{c_1}, n_{P_1}, n_{P_2}\right) \Phi\left(\alpha_{21|FT=0}\omega\right)$$

The first term in this expression represents the c_1 consideration effect and the second term represents the precision effect (which is positive as $\Phi\left(\alpha_{21|FT=1}\omega\right) \geq \Phi\left(\alpha_{21|FT=0}\omega\right)$ with strict inequality for some of the cases in the summation).

Similarly,

$$P_{12} = p_F\rho(1-q_F) \sum_{n_{c_1}=0}^{1} \sum_{n_{P_1}=0}^{n_{c_1}} \Pr\left(n_{c_1}, n_{P_1}\right) \Phi\left(-\alpha_{12|A=1,(1-F)\cdot FT=1,n_{P_2}=0}\omega\right)$$

$$+ p_F \sum_{A=0}^{1} \sum_{F=0}^{1} \sum_{n_{c_1}=0}^{1} \sum_{n_{P_1}=0}^{n_{c_1}} \sum_{n_{P_2}=0}^{1-n_{c_1}} I_{\{(1-A)+n_{P_2}>0\}} \Pr(A)\, q_F^F (1$$

$$- q_F)^{(1-F)} \Pr\left(n_{c_1}, n_{P_1}, n_{P_2}\right) \left\{\Phi\left(-\alpha_{12|FT=1}\omega\right) - \Phi\left(-\alpha_{12|FT=0}\omega\right)\right\}$$

$$+ \sum_{A=0}^{1} \sum_{F=0}^{1} \sum_{n_{c_1}=0}^{1} \sum_{n_{P_1}=0}^{n_{c_1}} \sum_{n_{P_2}=0}^{1-n_{c_1}} I_{\{(1-A)+n_{P_2}>0\}} \Pr(A)\, q_F^F (1$$

$$- q_F)^{(1-F)} \Pr\left(n_{c_1}, n_{P_1}, n_{P_2}\right) \Phi\left(-\alpha_{12|FT=0}\omega\right)$$

The first term in this expression represents the c_2 consideration effect and the second term represents the precision effect (which is negative as $\Phi\left(-\alpha_{12|FT=1}\omega\right) \leq \Phi\left(-\alpha_{12|FT=0}\omega\right)$ with strict inequality for some of the cases in the summation).

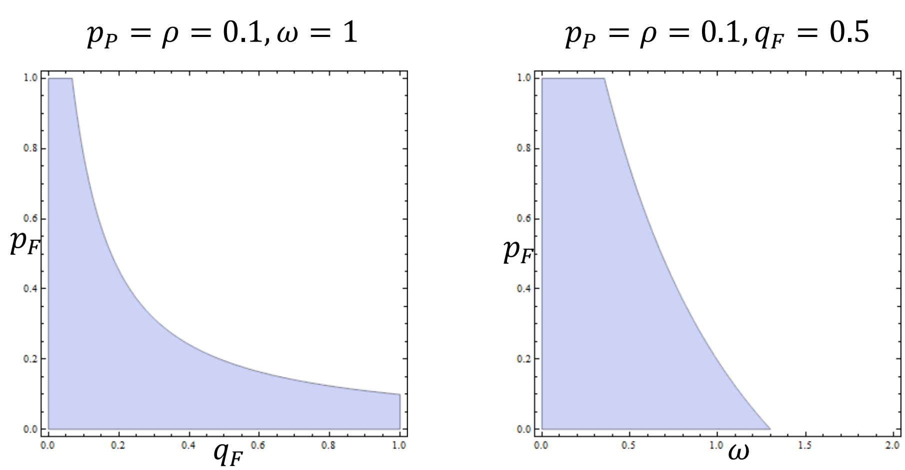
Result 3:

$$\frac{\partial}{\partial\omega}\left(\frac{\partial q^*}{\partial\rho}\right) \propto -\left(\frac{\partial\Xi(q_F,\rho,p_F,p_P,\omega)}{\partial\omega}\cdot\Upsilon(q_F,\rho,p_F,p_P,\omega) - \Xi(q_F,\rho,p_F,p_P,\omega) \cdot\frac{\partial\Upsilon(q_F,\rho,p_F,p_P,\omega)}{\partial\omega}\right)$$

where $\Xi(q_F,\rho,p_F,p_P,\omega) = q^*\frac{\partial P_{12}}{\partial\rho} - (1-q^*)\frac{\partial P_{21}}{\partial\rho}$ and $\Upsilon(q_F,\rho,p_F,p_P,\omega) = P_{12} + P_{21} + q^*\frac{\partial P_{12}}{\partial q^*} - (1-q^*)\frac{\partial P_{21}}{\partial q^*}$.

Result 3 directly follows from the expression for $\frac{\partial q^*}{\partial\rho}$ derived in Result 2.

Figure B-1: Effect of institutions on $\frac{\partial q^*}{\partial\rho}$



$$\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_F}\right) > 0 \text{ only in the shaded region}$$

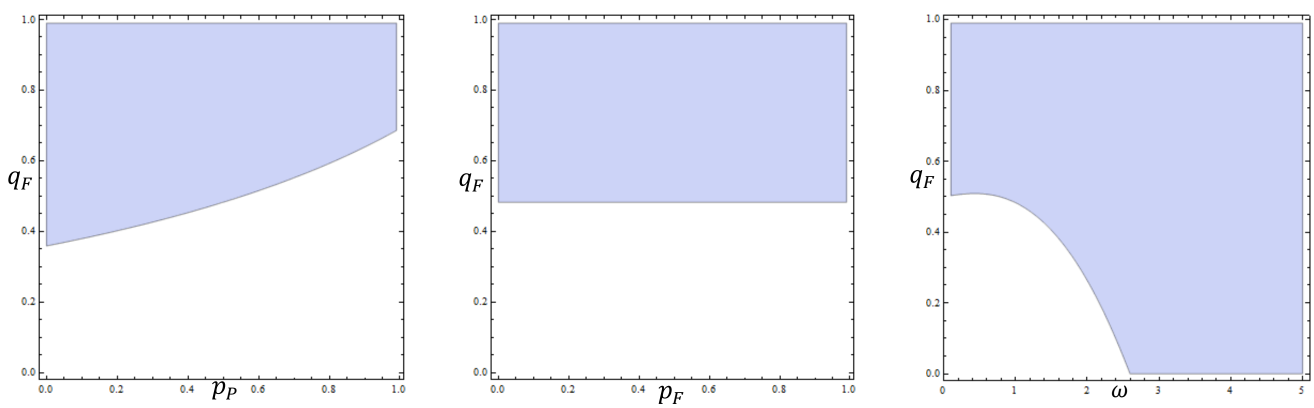
Proof of Result 4a: Applying the implicit function theorem to the equilibrium condition:

$$\frac{\partial q^*}{\partial p_F} = -\frac{q^* \frac{\partial P_{12}}{\partial p_F} - (1-q^*)\frac{\partial P_{21}}{\partial p_F}}{P_{12} + P_{21} + q^* \frac{\partial P_{12}}{\partial q^*} - (1-q^*)\frac{\partial P_{21}}{\partial q^*}}$$

As the denominator is always positive, $\frac{\partial q^*}{\partial p_F} < 0$ if and only if $q^* \frac{\partial P_{12}}{\partial p_F} - (1 - q^*)\frac{\partial P_{21}}{\partial p_F} > 0$.

Figure B-2: Ceteris paribus effect of family ties ($\boldsymbol{p_F}$) on equilibrium culture

$p_F = \rho = 0.5, \omega = 1$ $\qquad$ $p_P = \rho = 0.5, \omega = 1$ $\qquad$ $p_F = p_P = \rho = 0.5$



$$\frac{\partial q^*}{\partial p_F} > 0 \text{ only in the shaded region}$$

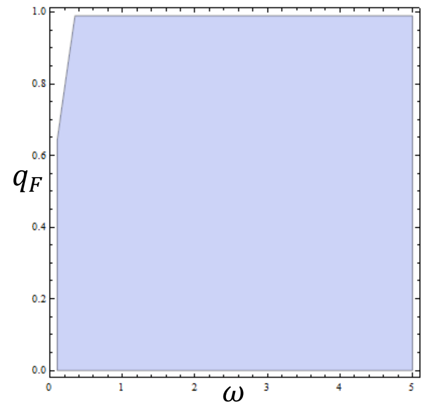
Proof of Result 4b: Applying the implicit function theorem to the equilibrium condition:

$$\frac{\partial q^*}{\partial p_P} = -\frac{q^* \frac{\partial P_{12}}{\partial p_P} - (1-q^*)\frac{\partial P_{21}}{\partial p_P}}{P_{12} + P_{21} + q^* \frac{\partial P_{12}}{\partial q^*} - (1-q^*)\frac{\partial P_{21}}{\partial q^*}}$$

As the denominator is always positive, $\frac{\partial q^*}{\partial p_P} < 0$ if and only if $q^* \frac{\partial P_{12}}{\partial p_P} - (1 - q^*) \frac{\partial P_{21}}{\partial p_P} > 0$.

Figure B-3: Ceteris paribus effect of non-family ties (p_P) on equilibrium culture

$p_F = p_P = \rho = 0.5$



$\frac{\partial q^*}{\partial p_P} > 0$ only in the shaded region

Note: similar figures are all shaded in (p_F, q_{F0}) and (p_P, q_F) space if respectively $p_P = \rho = 0.5, \omega = 1$ and $p_F = \rho = 0.5, \omega = 1$

Proof of Result 4c: Applying the implicit function theorem to the equilibrium condition:

$$\left.\frac{\partial q^*}{\partial p_F}\right|_{p_P=1-p_F} = -\frac{q^* \left.\frac{\partial P_{12}}{\partial p_F}\right|_{p_P=1-p_F} - (1 - q^*) \left.\frac{\partial P_{21}}{\partial p_F}\right|_{p_P=1-p_F}}{P_{12} + P_{21} + q^* \frac{\partial P_{12}}{\partial q^*} - (1 - q^*) \frac{\partial P_{21}}{\partial q^*}}$$

As the denominator is always positive, $\left.\frac{\partial q^*}{\partial p_F}\right|_{p_P=1-p_F} < 0$ if and only if $q^* \left.\frac{\partial P_{12}}{\partial p_F}\right|_{p_P=1-p_F} - (1 - q^*) \left.\frac{\partial P_{21}}{\partial p_F}\right|_{p_P=1-p_F} > 0$.

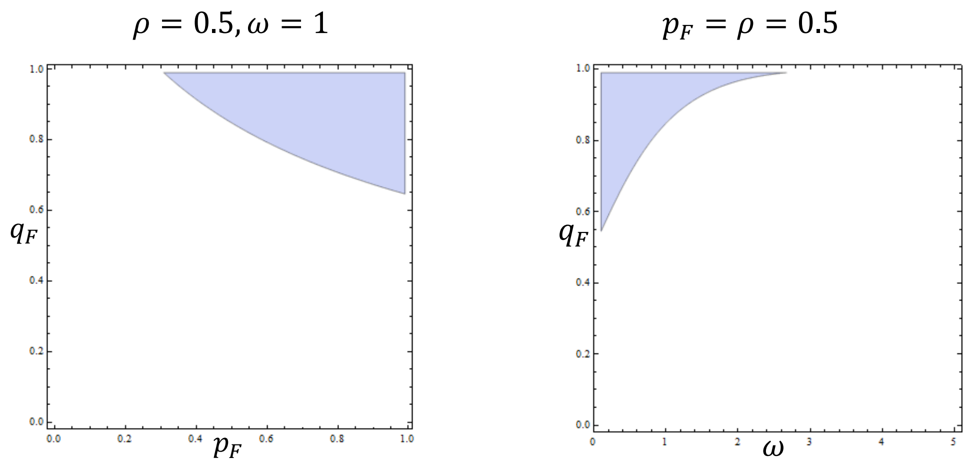
Noticing that

$$\left.\frac{\partial P_{12}}{\partial p_F}\right|_{p_P=1-p_F} = \frac{\partial P_{12}}{\partial p_F} - \frac{\partial P_{12}}{\partial p_P}$$

$$\left.\frac{\partial P_{21}}{\partial p_F}\right|_{p_P=1-p_F} = \frac{\partial P_{21}}{\partial p_F} - \frac{\partial P_{21}}{\partial p_P}$$

gives the statement of Result 4c.

Figure B-4: Effects of family ties (p_F) on equilibrium culture



$p_F + p_P = 1$ and $\frac{\partial q^*}{\partial p_F} > 0$ only in the shaded region

Result 5: $\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_F}\right) < 0$ if and only if

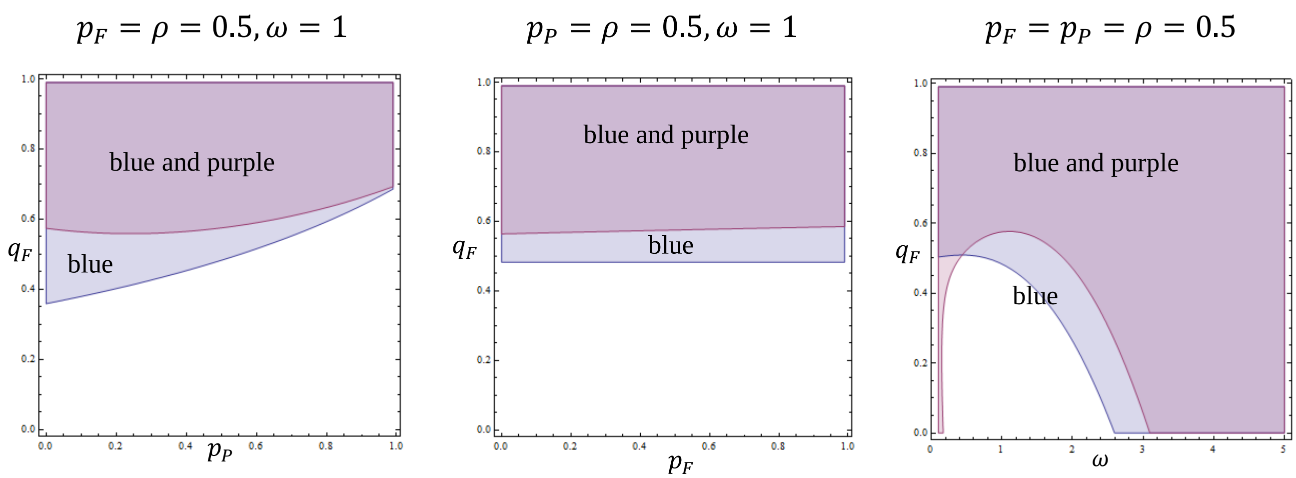
$$\frac{\partial \Upsilon(q_F, \rho, p_F, p_P, \omega)}{\partial \omega} \cdot \Theta(q_F, \rho, p_F, p_P, \omega) < \Upsilon(q_F, \rho, p_F, p_P, \omega) \cdot \frac{\partial \Theta(q_F, \rho, p_F, p_P, \omega)}{\partial \omega}$$

where $\Upsilon(q_F, \rho, p_F, p_P, \omega) = (P_{12} + P_{21}) + \; q^* \frac{\partial P_{12}}{\partial q^*} - (1 - q^*) \frac{\partial P_{21}}{\partial q^*}$ *and*

$\Theta(q_F, \rho, p_F, p_P, \omega) = q^* \frac{\partial P_{12}}{\partial p_F} - (1 - q^*) \frac{\partial P_{21}}{\partial p_F}$.

Result 5 directly follows from the expression for $\frac{\partial q^*}{\partial p_F}$ ***derived in Result 4a.***

Figure B-5: $\frac{\partial q^*}{\partial p_F}$ and its relation with institutions



$\frac{\partial q^*}{\partial p_F} > 0$ only in the region shaded blue

$\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_F}\right) < 0$ only in the region shaded purple

Result 6: $\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_P}\right) < 0$ if and only if

$$\frac{\partial \Upsilon(q_F, \rho, p_F, p_P, \omega)}{\partial \omega} \cdot \Gamma(q_F, \rho, p_F, p_P, \omega) < \Upsilon(q_F, \rho, p_F, p_P, \omega) \cdot \frac{\partial \Gamma(q_F, \rho, p_F, p_P, \omega)}{\partial \omega}$$

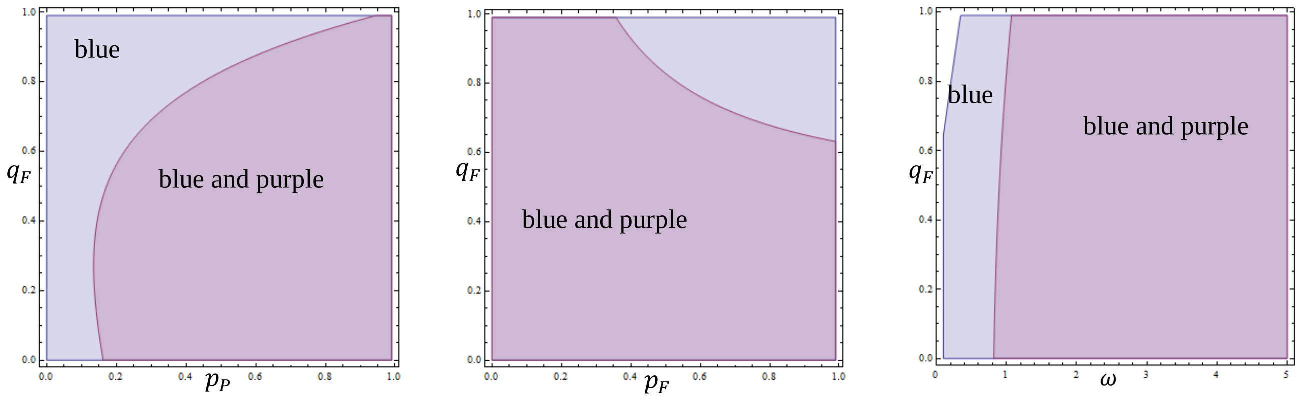
where $\Upsilon(q_0, \rho, p_F, p_P, \omega) = (P_{12} + P_{21}) + \; q^* \frac{\partial P_{12}}{\partial q^*} - (1 - q^*) \frac{\partial P_{21}}{\partial q^*}$ *and*

$\Gamma(q_0, \rho, p_F, p_P, \omega) = q^* \frac{\partial P_{12}}{\partial p_P} - (1 - q^*) \frac{\partial P_{21}}{\partial p_P}$.

Result 6 directly follows from the expression for $\frac{\partial q^*}{\partial p_P}$ ***derived in Result 4b.***

Figure B-6: $\frac{\partial q^*}{\partial p_P}$ and its relation with institutions

$p_F = \rho = 0.5, \omega = 1$ $\quad$ $p_P = \rho = 0.5, \omega = 1$ $\quad$ $p_F = p_P = \rho = 0.5$



$$\frac{\partial q^*}{\partial p_P} > 0 \text{ only in the region shaded blue}$$

$$\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_P}\right) < 0 \text{ only in the region shaded purple}$$

For completeness, Result 7 investigates how effects of a shift in the social structure instead of a ceteris paribus change of social interactions interact with quality of institutions. Figure B-7 provides its visualization.

Result 7: *If* $p_F + p_P = 1$, *than* $\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_F}\right) < 0$ if and only if

$$\frac{\partial \Upsilon(q_F, \rho, p_F, p_P, \omega)}{\partial \omega} \cdot \Lambda(q_F, \rho, p_F, p_P, \omega) < \Upsilon(q_F, \rho, p_F, p_P, \omega) \cdot \frac{\partial \Lambda(q_F, \rho, p_F, p_P, \omega)}{\partial \omega}$$

where $\Upsilon(q_F, \rho, p_F, p_P, \omega) = (P_{12} + P_{21}) + \ q^* \frac{\partial P_{12}}{\partial q^*} - (1 - q^*) \frac{\partial P_{21}}{\partial q^*}$ *and*

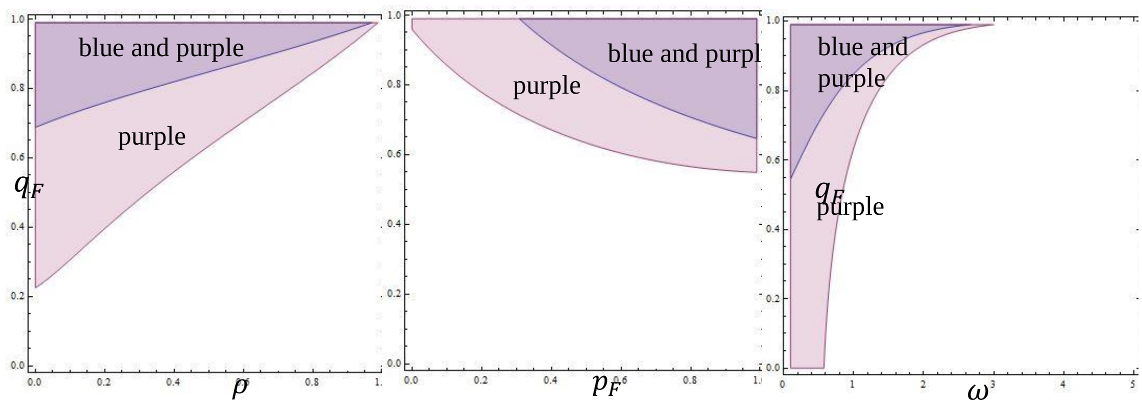
$\Lambda(q_F, \rho, p_F, p_P, \omega) = q^* \left(\frac{\partial P_{12}}{\partial p_F} - \frac{\partial P_{12}}{\partial p_P}\right) - (1 - q^*) \left(\frac{\partial P_{21}}{\partial p_F} - \frac{\partial P_{21}}{\partial p_P}\right).$

Result 7 directly follows from the expression derived in Result 4b.

Figure B-7 combines results 7 and 4c, representing more clearly the relation between the effects of shift in the social structure and institutions. On Figure B-7, in the region shaded blue and purple, institutions and a shift in social structure towards family are substitutes in promoting the spread of the most beneficial cultural trait. In this region, the shift in social structure towards stronger family ties has a positive impact on the equilibrium culture, as do institutions (by results 4b and 1). The social shift and institutions weaken each other's effect, however (Result 7).

Figure B-7: Effects of institutions on $\frac{\partial q^*}{\partial p_F}$ keeping the total strength of social ties constant

$p_F = p_P = 0.5, \omega = 1.$ $\qquad$ $\rho = 0.5, \omega = 1$ $\qquad$ $p_F = \rho = 0.5$



$p_F + p_P = 1$ and $\frac{\partial q^*}{\partial p_F} > 0$ only in the region shaded blue

$p_F + p_P = 1$ and $\frac{\partial}{\partial \omega}\left(\frac{\partial q^*}{\partial p_F}\right) < 0$ only in the region shaded purple

In the unshaded region, the shift in social structure towards family hinders the spread of the most beneficial cultural trait (by Result 4b) and institutions weaken this negative effect of the social shift. Put differently, institutions become more important in shaping equilibrium culture as the social structure shifts towards more ties within family. Looked at from an alternative perspective, the unshaded region purple is where both institutions and social shifts towards stronger ties with peers promote the spread of the most beneficial cultural trait, with a positive interaction. Thus in this region a social shift towards peers complements institutions in improving the equilibrium culture.

In the region shaded in purple, the social shift toward more interaction within family has a negative impact on the equilibrium culture and this negative impact is exacerbated with quality institutions. In other words, high quality institutions promote the spread of the most beneficial cultural trait, but they also amplify the negative effect that the social shift towards stronger family ties has on the equilibrium culture. Alternatively, in this region, institutions and a social shift towards more interactions with peers are substitutes in promoting the spread of the most beneficial cultural trait. In particular, both the social shift towards peers and institutions have a positive effect on the equilibrium culture.

Appendix B-2: Mathematica codes for Chapter 2

Setting up the model in Mathematica:

```
Clear["Global`*"]

nh = 1;

mu1 = 1;

mu2 = 0;

deltamu = mu1 - mu2;

P21sum = 0;

P12sum = 0;

CT1effect = 0;

CT2effect = 0;

restrho21 = 0;

restnorho21 = 0;

restrho12 = 0;

restnorho12 = 0;


For[

 ind = 0,

 ind <= 1,

 ind ++,

 For[

  vert = 0,

  vert <= 1,

  vert ++,
```

```
For[
 VT = 0,
 VT <= 1,
 VT ++,
 For[
  n1 = 0,
  n1 <= nh,
  n1 ++,
  For[
   nh1 = 0,
   nh1 <= n1,
   nh1 ++,
   For[
    nh2 = 0,
    nh2 <= (nh - n1),
    nh2++,

    n2 = nh - n1;
    TE = rho^ind*(1 - rho)^(1 - ind);
    V =
     q0^vert*(1 - q0)^(1 - vert)*
      pv^(vert*VT)*(1 - pv)^(vert*(1 - VT))*
      pv^((1 - vert)*VT)*(1 - pv)^((1 - vert)*(1 - VT));
    H1 = Binomial[nh, n1]*qstar^n1*(1 - qstar)^n2;
    H2 = Binomial[n1, nh1]*ph^nh1*(1 - ph)^(n1 - nh1);
```

```
H3 = Binomial[n2, nh2]*ph^nh2*(1 - ph)^(n2 - nh2);
H = H1*H2*H3;
 If [
 (vert*VT + ind + nh1) > 0,
 sigma21 =
  Sqrt[sigma^2/(vert*VT + ind + nh1) +
    sigma^2/(1 + (1 - vert)*VT + (1 - ind) + nh2)];
 phi21 = CDF[NormalDistribution[-deltamu, sigma21], 0];
 If [sigma21 == 0, phi21 = 1];
 P21sum = P21sum + (TE*V*H*phi21);
 If[ind == 1 && vert*VT == 0 && nh1 == 0,
  CT1effect = CT1effect + V*H*phi21];
 If[ind == 1 && (vert*VT + nh1 > 0),
  restrho21 = restrho21 + V*H*phi21];
 If[ind == 0 && (vert*VT + nh1 > 0),
  restnorho21 = restnorho21 + V*H*phi21];
 ];
 If [
 ((1 - vert)*VT + (1 - ind) + nh2) > 0,
 sigma12 =
  Sqrt[sigma^2/(1 + vert*VT + ind + nh1) +
    sigma^2/((1 - vert)*VT + (1 - ind) + nh2)];
 phi12 = CDF[NormalDistribution[deltamu, sigma12], 0];
 If [sigma12 == 0, phi12 = 0];
 P12sum = P12sum + (TE*V*H*phi12);
```

```
        If[ind == 0 && (1 - vert)*VT == 0 && nh2 == 0,
         CT2effect = CT2effect + V*H*phi12];
        If[ind == 0 && ((1 - vert)*VT + nh2 > 0),
         restrho12 = restrho12 + V*H*phi12];
        If[ind == 1 && ((1 - vert)*VT + nh2 > 0),
         restnorho12 = restnorho12 + V*H*phi12];
        ];
       ]
      ]
     ]
    ]
   ]
  ]
f = qstar*(P21sum + P12sum) - P21sum;
solution = Solve[f == 0, qstar];
sigma = 1/omega;
qstar = Evaluate[qstar /. solution[[2]]];
dqstardrho = D[qstar, rho];
dqstardrhodomega = D[dqstardrho, omega];
```

Producing Figure 2-2

```
omega = 1;
rho = 0.1;
q0 = 0.5;
RegionPlot[{dqstardrhodomega > 0}, {ph, 0.0001, 0.99}, {pv, 0.0001,
```

```
  0.99}]
Clear[pv, q0, rho, ph, omega]
ph = 0.1;
omega = 1;
q0 = 0.5;
RegionPlot[{dqstardrhodomega > 0}, {rho, 0.0001, 1}, {pv, 0.0001, 1}]
Clear[pv, q0, rho, ph, omega]
```

Producing Figure 2-3 and Figure 2-4

```
dqdpv = D[qstar, pv];
dqdph = D[qstar, ph];
pv = 0.5;
ph = 0.5;
omega = 1;
RegionPlot[dqdpv > 0, {rho, 0.0001, 0.99}, {q0, 0.0001, 0.99}]
RegionPlot[dqdph > 0, {rho, 0.0001, 0.99}, {q0, 0.0001, 0.99}]
Clear[pv, q0, rho, ph]
ph = 1 - pv;
dqdpv = D[qstar, pv];
pv = 0.5;
RegionPlot[dqdpv > 0, {rho, 0.0001, 0.99}, {q0, 0.0001, 0.99}]
Clear[pv, q0, rho, ph, omega]
```

Producing Figure 2-5

```
dqdpv = D[qstar, pv];
```

```
dqdph = D[qstar, ph];

dqdpvds = D[dqdpv, omega];

dqdphds = D[dqdph, omega];

pv = 0.5;

ph = 0.5;

omega = 1;

RegionPlot[{dqdpv > 0, dqdpvds < 0}, {rho, 0.0001, 0.99}, {q0, 0.0001,
  0.99}]

RegionPlot[{dqdph > 0, dqdphds < 0}, {rho, 0.0001, 0.99}, {q0, 0.0001,
  0.99}]

Clear[pv, q0, rho, ph, omega]
```

Producing Figure B-1

```
ph = 0.1;

omega = 1;

rho = 0.1;

RegionPlot[{dqstardrhodomega > 0}, {q0, 0.0001, 1}, {pv, 0.0001, 1}]

q0 = 0.5;

RegionPlot[{dqstardrhodomega > 0}, {omega, 0.0001, 2}, {pv, 0.0001, 1}]

Clear[pv, q0, rho, ph, omega]
```

Producing Figure B-2

```
pv = 0.5;

rho = 0.5;

omega = 1;
```

```
RegionPlot[dqdpv > 0, {ph, 0.0001, 0.99}, {q0, 0.0001, 0.99}]

ph = 0.5;

RegionPlot[dqdpv > 0, {pv, 0.0001, 0.99}, {q0, 0.0001, 0.99}]

RegionPlot[dqdpv > 0, {omega, 0.1, 5}, {q0, 0.0001, 0.99}]

Clear[pv, q0, rho, ph, omega]
```

Producing Figure B-3

```
pv = 0.5;

rho = 0.5;

ph = 0.5;

RegionPlot[dqdph > 0, {omega, 0.1, 5}, {q0, 0.0001, 0.99}]

Clear[pv, q0, rho, ph, sigma, omega]
```

Producing Figure B-4

```
ph = 1 - pv;

dqdpv = D[qstar, pv];

rho = 0.5;

omega = 1;

RegionPlot[dqdpv > 0, {pv, 0.0001, 0.99}, {q0, 0.0001, 0.99}]

Clear[pv, q0]

pv = 0.5;

RegionPlot[dqdpv > 0, {omega, 0.1, 5}, {q0, 0.0001, 0.99}]

Clear[pv, q0, rho, ph, omega]

dqdpv = D[qstar, pv];
```

Producing Figure B-5

```
pv = 0.5;

omega = 1;

rho = 0.5;

RegionPlot[{dqdpv > 0, dqdpvds < 0}, {ph, 0.0001, 0.99}, {q0, 0.0001,
  0.99}]

Clear[pv]

ph = 0.5;

RegionPlot[{dqdpv > 0, dqdpvds < 0}, {pv, 0.0001, 0.99}, {q0, 0.0001,
  0.99}]

Clear[omega]

pv = 0.5;

RegionPlot[{dqdpv > 0, dqdpvds < 0}, {omega, 0.1, 5}, {q0, 0.0001,
  0.99}]

Clear[pv, q0, rho, ph, omega]
```

Producing Figure B-6

```
pv = 0.5;

omega = 1;

rho = 0.5;

RegionPlot[{dqdph > 0, dqdphds < 0}, {ph, 0.0001, 0.99}, {q0, 0.0001,
  0.99}]

Clear[pv]

ph = 0.5;

RegionPlot[{dqdph > 0, dqdphds < 0}, {pv, 0.0001, 0.99}, {q0, 0.0001,
  0.99}]
```

```
Clear[omega]

pv = 0.5;

RegionPlot[{dqdph > 0, dqdphds < 0}, {omega, 0.1, 5}, {q0, 0.0001,
  0.99}]

Clear[pv, q0, rho, ph, omega]
```

Producing Figure B-7

```
ph = 1 - pv;

dqdpv = D[qstar, pv];

dqdpvds = D[dqdpv, omega];

pv = 0.5;

omega = 1;

RegionPlot[{dqdpv > 0, dqdpvds < 0}, {rho, 0.0001, 0.99}, {q0, 0.0001,
   0.99}]

Clear[pv]

rho = 0.5;

RegionPlot[{dqdpv > 0, dqdpvds < 0}, {pv, 0.0001, 0.99}, {q0, 0.0001,
  0.99}]

Clear[omega]

pv = 0.5;

RegionPlot[{dqdpv > 0, dqdpvds < 0}, {omega, 0.1, 5}, {q0, 0.0001,
  0.99}]

Clear[pv, q0, rho, ph, omega]

dqdpv = D[qstar, pv];

dqdpvds = D[dqdpv, omega];
```

Appendix C: Experimental Instructions for Chapter 3

Below are the instructions that were given to all subjects in one of the two treatments. The instructions for the other treatment were exactly the same except for the payoff structure on Figure C-1, as described in the main text. The instructions were also read aloud by an experimenter at the start of each session.

INSTRUCTIONS

Thank you for participating in this experiment on economic decision-making. Various research foundations have provided funds for this research. The instructions are simple. Please follow them carefully. Your earnings in this experiment will depend on your decisions and the decisions of other participants, as explained in detail below. You will be paid in cash in private once you complete the experiment. The experiment will last about 30 minutes.

Please do not talk, or in any way try to communicate, with other participants during the experiment. If you have a question, please quietly raise your hand, an assistant will come over to you and answer your question in private.

The experiment consists of two interactions. In each interaction, you will be randomly matched with one other participant. That participant is another volunteer, just like you, participating in this experiment. You will not know which of the other participants you are matched with. Likewise, the other participants will not know with whom they are matched. <u>The matching is different for the two interactions.</u> So you interact with a different participant each time.

Roles and Interactions

At the beginning of the experiment, you will be randomly assigned one of the three roles: A, B, or C, which you will keep throughout the experiment. Those with roles A and B interact first. This is Interaction AB. Afterwards, those with roles A and C interact. This is Interaction AC.

After the two interactions are completed, you will be asked to complete a brief questionnaire regarding your age and other general information. The questionnaire does not ask you to reveal your identity. After you complete the questionnaire, you will be given your earnings in a sealed envelope which is identified by the ID number that is assigned to your computer. Your name will not be recorded in this experiment. After receiving your envelope with your earnings you may leave.

Earnings

In each interaction, you will collect points based on your decisions and the decisions of other participants. Your earnings in US dollars will be

$$\frac{\text{Your points}}{10}$$

If your role is A, then you will have the opportunity to collect points in Interaction AB and Interaction AC.

If your role is B, then you will have the opportunity to collect points only in Interaction AB.

If your role is C, then you will have the opportunity to collect points only in Interaction AC.

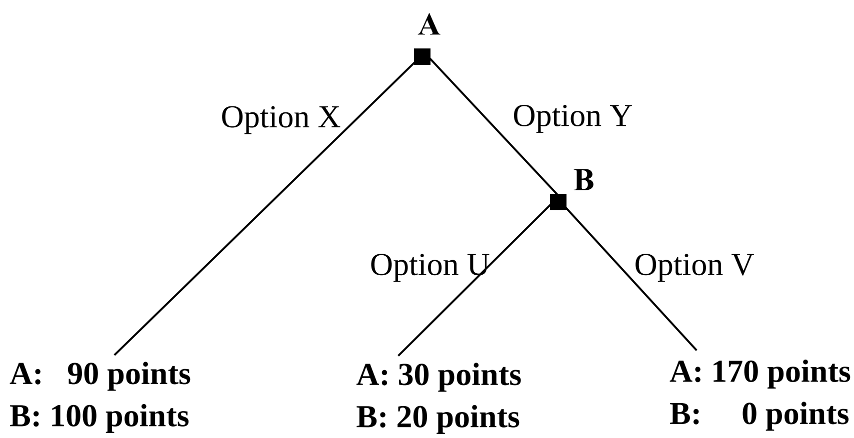
In addition, you will receive $5 compensation for coming to the experiment. You will be paid the sum of all your earnings privately in cash once you complete the experiment.

Information on collecting points is given in detail below.

Interaction AB

Each A is randomly and anonymously matched with one B. Each A chooses either Option X or Option Y (see Figure C-1 for illustration).

Figure C-1: Interaction AB



If A chooses Option X, B does not make any choice, and A collects 90 points, and B collects 100 points.

If A chooses Option Y, then B chooses either Option U or Option V. The choices made by the matched A and B determine their points in this interaction. More precisely, if, after A's choice of Option Y, B chooses Option U, then A collects 30 points, and B collects 20 points; And if, after A's choice of Option Y, B chooses Option V, then A collects 170 points and B collects 0 points.

Interaction AB takes place only once. It is complete once A and B make their decisions.

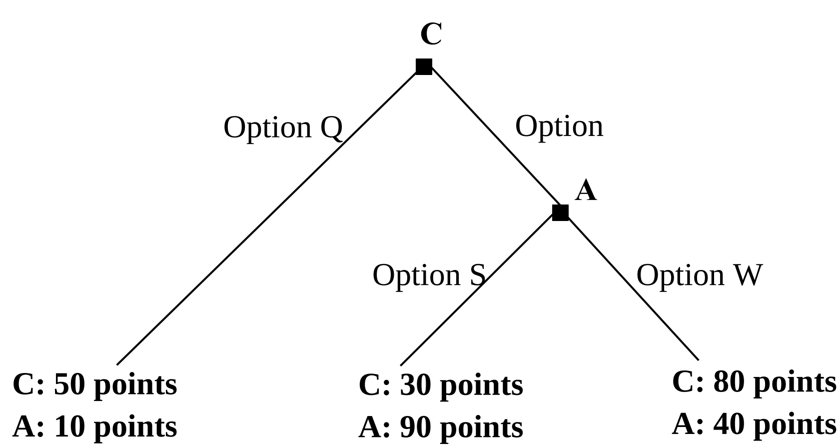
Interaction AC

Interaction AC starts only after Interaction AB is completed. In this interaction, each A is randomly and anonymously matched with one C.

Before making any choice, C's are informed about the overall share of A's who had chosen Option X or Option Y in Interaction AB. Notice that C's are <u>not</u> informed about the particular choice made by the A that they are matched with. For example, if 4 out of 10 A's had chosen Option X, then C's are informed that 40% of A's chose Option X and 60% of A's chose Option Y.

Each C then chooses either Option Q or Option R (see Figure C-2 for illustration).

Figure C-2: Interaction AC



Notice that this interaction is different from Interaction AB.

If C chooses Option Q, A does not make any choice, and C collects 50 points, and A collects 10 points.

If C chooses Option R, then A chooses either Option S or Option W. The choices made by the matched A and C determine their points in this interaction. More precisely, if, after C's choice of Option R, A chooses Option S, then C collects 30 points, and A collects 90 points; And if, after C's choice of Option R, A chooses Option W, then C collects 80 points, and A collects 40 points.

Interaction AC takes place only once. It is complete once A and C make their decisions.

Are there any questions?

Table C-1: Gender Distribution Across Treatments

	Cooperative environment	Non-cooperative environment
Male	7	7
Female	8	8

Bibliography

Acemoglu, D. and Jackson, M.O., 2016. Social Norms and the Enforcement of Laws.

Acemoglu, D. and Wolitzky, A., 2015. Sustaining Cooperation: Community Enforcement vs. Specialized Enforcement. *NBER Working Paper Series*, p.21457.

Acemoglu, D., Johnson, S., Robinson, J.A. and Yared, P., 2009. Reevaluating the modernization hypothesis. *Journal of Monetary Economics*, *56*(8), pp.1043-1058.

Acemoglu, Daron, Asuman Ozdaglar, and Ali ParandehGheibi. "Spread of (mis) information in social networks." *Games and Economic Behavior* 70, no. 2 (2010): 194-227.

Acemoglu, Daron, Kostas Bimpikis, and Asuman Ozdaglar. 2010. Dynamics of information exchange in endogenous social networks. *Theoretical Economics*, Econometric Society.

Acemoglu, Daron, Munther A. Dahleh, Ilan Lobel, Asuman Ozdaglar. 2011. Bayesian Learning in Social Networks. *Review of Economic Studies*, Oxford University Press, vol. 78(4), pages 1201-1236.

Acemoglu, Daron, Simon Johnson, and James A. Robinson. 2001. The colonial origins of comparative development: an empirical investigation. *American Economic Review* 91:1369-1401.

Aghion, Philippe, Yann Algan, Pierre Cahuc, and Andrei Shleifer. 2010. Regulation and Distrust. *Quarterly Journal of Economics* 125 (3): 1015-1049.

Agranov, M. and Ortoleva, P., 2017. Stochastic choice and preferences for randomization. *Journal of Political Economy*, *125*(1), pp. 40-68.

Alesina, Alberto and Alexander F. Wagner. 2006. Choosing (and Reneging on) Exchange Rate Regimes. *Journal of the European Economic Association*, MIT Press, vol. 4(4), pages 770-799, 06.

Alesina, Alberto and Paola Giuliano. 2011. Family Ties and Political Participation. *Journal of the European Economic Association*, Volume 9, Issue 5, pages 817–839.

Alesina, Alberto, and Nicola Fuchs-Schündeln. 2007. Goodbye Lenin (or Not?): The Effect of Communism on People. *American Economic Review*, 97(4): 1507-1528.

Ali, S.N. and Miller, D.A., Enforcing Cooperation in Networked Societies.

Almond, Gabriel A., and Sidney Verba. *The Civic Culture: Political Attitudes and Democracy in Five Nations*. Princeton University Press, 1963.

Al-Ubaydli, Omar, Daniel Houser, John Nye, Maria Pia Paganelli, and Xiaofei Sophia Pan. "The Causal Effect of Market Priming on Trust: An Experimental Investigation Using Randomized Control." PloS one 8, no. 3 (2013).

Andreoni, James, and John Miller. "Giving according to GARP: An experimental test of the consistency of preferences for altruism." *Econometrica* 70, no. 2 (2002): 737-753.

Arrow, Kenneth J. "Gifts and exchanges." *Philosophy & Public Affairs* 1, no. 4 (1972): 343-362.

Axelrod, R.M., 2006. *The evolution of cooperation*. Basic books.

Axelrod, Robert. 1997. The Dissemination of Culture: A Model with Local Convergence and Global Polarization. *Journal of Conflict Resolution*, Vol. 41, No. 2, pp. 203-226.

Bandura, Albert. 1986. *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, N.J.: Prentice-Hall.

Banerjee, Abhijit, and Drew Fudenberg. 2004. Word-of-mouth learning. *Games and Economic Behavior*, Elsevier, vol. 46(1), pages 1-22, January.

Banfield, Edward C. 1958. *The Moral Basis of a Backward Society*. New York: The Free Press.

Barro, R.J., 1999. Determinants of democracy. *Journal of Political economy*, *107*(S6), pp.S158-S183.

Bartel, Ann P., and Frank R.Lichtenberg. 1987. The comparative advantage of educated workers in implementing new technology. *Review of Economics and Statistics* 69 (1), 1–11.

Bear, A. and Rand, D.G., 2016. Intuition, deliberation, and the evolution of cooperation. *Proceedings of the National Academy of Sciences*, 113(4), pp.936-941.

Becker, G.S., 1968. Crime and punishment: An economic approach. In *The Economic Dimensions of Crime* (pp. 13-68). Palgrave Macmillan UK.

Bednar, Jenna, Page, Scott E., 2007. Can game(s) theory explain culture?: The emergence of cultural behavior in multiple games. *Rationality and Society* 19(1), 65–97.

Bednar, Jenna, Aaron Bramson, Andrea Jones-Rooy, and Scott Page. 2010. Emergent cultural signatures and persistent diversity: A model of conformity and consistency. *Rationality and Society,* November 22: 407-444

Benabou, R. and Tirole, J., 2012. *Laws and Norms* (No. 6290). Institute for the Study of Labor (IZA).

Benhabib, Jess, and Mark M. Spiegel. 1994. The role of human capital in economic development: Evidence from aggregate cross-country data. *Journal of Monetary Economics* 34, 143–173.

Benhabib, Jess, and Mark M. Spiegel. 2005. Human Capital and Technology Diffusion. In *Handbook of Economic Growth*, vol. 1, edited by Philippe Aghion and Steven Durlauf, 935–66. Amsterdam: Elsevier.

Benson, B.L., 1989. The spontaneous evolution of commercial law. *Southern Economic Journal*, pp.644-661.

Bereby-Meyer, Yoella, and Alvin E. Roth. 2006. The Speed of Learning in Noisy Games: Partial Reinforcement and the Sustainability of Cooperation. *American Economic Review*, Volume 96, Number 4, pp. 1029-1042(14).

Berg, Joyce, John Dickhaut, and Kevin McCabe. "Trust, reciprocity, and social history." *Games and economic behavior* 10, no. 1 (1995): 122-142.

Bernstein, L., 1992. Opting out of the legal system: Extralegal contractual relations in the diamond industry. *The Journal of Legal Studies*, *21*(1), pp.115-157.

Bikhchandani, Sushil, David Hirshleifer and Ivo Welch. 1992. A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades. *Journal of Political Economy*, Vol. 100, No. 5, pp. 992-1026.

Bisin, Alberto, and Thierry Verdier. 1998. On the Cultural Transmission of Preferences for Social Status. *Journal of Public Economics*, 70, 75–97.

Bisin, Alberto, and Thierry Verdier. 2000. Beyond the Melting Pot: Cultural Transmission, Marriage and the Evolution of Ethnic and Religious Traits. *Quarterly Journal of Economics*, 115, 955–988.

Bisin, Alberto, and Thierry Verdier. 2001a. The Economics of Cultural Transmission and the Dynamics of Preferences. *Journal of Economic Theory* 97, 298–319.

Bisin, Alberto, and Thierry Verdier. 2001b. Agents with imperfect empathy may survive natural selection. *Economics Letters*, Volume 71, Issue 2, Pages 277-285.

Bisin, Alberto, and Thierry Verdier. 2011. The economics of cultural transmission and socialization. In J. Benhabib, A. Bisin and M.O. Jackson (Eds.), *Handbook of Social Economics*, Amsterdam: Elsevier Science, 2011.

Bohnet, I., Greig, F., Herrmann, B. and Zeckhauser, R., 2008. Betrayal aversion: Evidence from brazil, china, oman, switzerland, turkey, and the united states. *The American Economic Review*, *98*(1), pp.294-310.

Bohnet, Iris, and Steffen Huck. "Repetition and reputation: Implications for trust and trustworthiness when institutions change." *The American Economic Review*94, no. 2 (2004): 362-366.

Bolton, Gary E., and Axel Ockenfels. "ERC: A theory of equity, reciprocity, and competition." *American economic review* (2000): 166-193.

Bowles, Samuel and Herbert Gintis. 1998. The Moral Economy of Communities: Structured Populations and the Evolution of Pro-Social Norms. *Evolution and Human Behavior*, Volume 19, Issue 1, Pages 3-25.

Bowles, Samuel. 1998. Endogenous Preferences: The Cultural Consequences of Markets and Other Economic Institutions. *Journal of Economic Literature*, Vol. 36, No. 1, pp. 75-111.

Boyd, Robert and Peter Richerson. 1985. *Culture and the Evolutionary Process*. University of Chicago Press, Chicago, IL.

Buchan, N.R., Croson, R.T. and Solnick, S., 2008. Trust and gender: An examination of behavior and beliefs in the Investment Game. *Journal of Economic Behavior & Organization*, *68*(3), pp.466-476.

Busemeyer, Jerome R., and James T. Townsend. 1993. Decision Field Theory: A Dynamic-Cognitive Approach to Decision Making in an Uncertain Environment. *Psychological Review*, 100, 432-459.

Butler, Jeffrey, Paola Giuliano, Luigi Guiso. 2014. The Right Amount of Trust.

Callander, Steven. 2011. Searching and learning by trial and error. *American Economic Review* 101.6: 2277-2308.

Calvó-Armengol, A. and Zenou, Y., 2004. Social networks and crime decisions: The role of social structure in facilitating delinquent behavior. *International Economic Review*, *45*(3), pp.939-958.

Camerer, C.F., Loewenstein, G. and Rabin, M. eds., 2011. Advances in behavioral economics. Princeton University Press.

Casella, A. and Rauch, J.E., 2002. Anonymous market and group ties in international trade. *Journal of International Economics*, *58*(1), pp.19-47.

Caselli, Francesco, and John Wilbur Coleman II. 2006. The World Technology Frontier. *American Economic Review,* 96, no. 3 (2006), 499–522.

Cassar, Alessandra, Giovanna d'Adda, and Pauline Grosjean. *Institutional Quality, Culture, and Norms of Cooperation: Evidence from a Behavioral Field Experiment*. No. 2013-10. 2013.

Cavalli Sforza, Luigi L., and Marcus Feldman. 1981. *Cultural Transmission and Evolution: A Quantitative Approach*. Princeton University Press, Princeton, NJ.

Çelen, Boğaçhan and Shachar Kariv. 2005. An Experimental Test of Observational Learning under Imperfect Information. *Economic Theory*, Vol. 26, No. 3, pp. 677-699.

Charness, Gary, and Matthew Rabin. "Understanding social preferences with simple tests." *The Quarterly Journal of Economics* 117, no. 3 (2002): 817-869.

Ciccone, Antonio, and Elias Papaioannou. 2009. Human Capital, the Structure of Production, and Growth. *Review of Economics and Statistics,* 91, no. 1, 66–82.

Crawford Sue E. S., and Elinor Ostrom. 1995. A Grammar of Institutions. *American Political Science Review,* Vol. 89, No. 3, pp. 582-600.

Cubeddu, R. 2002. Uncertainty, institutions and order in Hayek. In Birner, Garrouste and Aimar (Eds), *F.A. Hayek as a Political Economist: Economic Analysis and Values*. Routledge, 2002.

DeMarzo, Peter M., Dimitri Vayanos, and Jeffrey Zwiebel. 2003. Persuasion Bias, Social Influence, and Unidimensional Opinions. *Quarterly Journal of Economics* 118(3): 909-968.

Dessi, Roberta. 2008. Collective Memory, Cultural Transmission and Investments. *American Economic Review* 98 (1), 534–560.

Di Tella, Rafael, Sebastian Galiani and Ernesto Schargrodsky. 2007. The Formation of Beliefs: Evidence from the Allocation of Land Titles to Squatters. *Quarterly Journal of Economics*, MIT Press, vol. 122(1), pages 209-241, 02.

Dixit, A.K., 2007. *Lawlessness and economics: alternative modes of governance*. Princeton University Press.

Dixit, Avinash. 2009. Socializing Education and Pro-Social Preferences. Mimeo, Princeton University.

Easterly, William, and Ross Levine. 2003. Tropics, germs, and crops: how endowments influence economic development. *Journal of Monetary Economics*, Elsevier, vol. 50(1), pages 3-39.

Easterly, William, Jozef Ritzen, and Michael Woolcock. 2006. Social Cohesion, Institutions, and Growth. *Economics and Politics*, Volume 18, Issue 2, pages 103–120.

Eckel, C.C. and Wilson, R.K., 2004. Is trust a risky decision?. *Journal of Economic Behavior & Organization*, *55*(4), pp.447-465.

Ellickson, R., 2005. Order without Law: How Neighbors Settle Disputes.

Ellingsen T, Herrmann B, Nowak MA, Rand DG, Tarnita CE (2012) Civic capital in two cultures: The nature of cooperation in Romania and USA. Working paper, Stockholm School of Economics, Stockholm. http://ssrn.com/abstract=2179575

Ellison, Glenn, and Drew Fudenberg. 1993. Rules of Thumb for Social Learning. *Journal of Political Economy*, University of Chicago Press, vol. 101(4), pages 612-43.

Ellison, Glenn, and Drew Fudenberg. 1995. Word-of-Mouth Communication and Social Learning. *Quarterly Journal of Economics*, MIT Press, vol. 110(1), pages 93-125.

Erev, Ido and Ernan Haruvy. 2012. Learning and the Economics of Small Decisions. In the second volume of *The Handbook of Experimental Economics* edited by John H. Kagel and Alvin E. Roth.

Erev, Ido, and Greg Barron. 2005. On Adaptation, Maximization, and Reinforcement Learning Among Cognitive Strategies. *Psychological Review*, 112 (2005): 912-931.

Erev, Ido, Eyal Ert, Alvin E. Roth, Ernan Haruvy, Stefan M. Herzog, Robin Hau, Ralph Hertwig, Terrence Stewart, Robert West, and Christian Lebiere. 2010a. A choice prediction competition, for choices from experience and from description. *Journal of Behavioral Decision Making*, 23, 15-47.

Erev, Ido, Eyal Ert., and Alvin E. Roth. 2010b. A Choice Prediction Competition for Market Entry Games: An Introduction. *Games*, 1(2), 117-136.

Falk, A., Fehr, E. and Fischbacher, U., 2008. Testing theories of fairness—Intentions matter. *Games and Economic Behavior*, 62(1), pp.287-303.

Fehr, Ernst, and Klaus M. Schmidt. "A theory of fairness, competition, and cooperation." *The quarterly journal of economics* 114, no. 3 (1999): 817-868.

Fehr, Ernst. "On the economics and biology of trust." *Journal of the European Economic Association* 7, no. 2-3 (2009): 235-266.

Ferrer, R., 2010. Breaking the law when others do: A model of law enforcement with neighborhood externalities. *European Economic Review*, *54*(2), pp.163-180.

Filiz-Ozbay, E., 2012. Incorporating unawareness into contract theory. *Games and Economic Behavior*, *76*(1), pp.181-194.

Fischbacher, U., 2007. z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental economics*, *10*(2), pp.171-178.

Fudenberg, Drew, and David K. Levine. "Whither Game Theory?." (2016).

Fukuyama, F. (1995). Trust. New York: Free Press.

Fuller, L.L., 1964. The Morality of Law.

Fuller, L.L., 1969. Human Interaction and the Law. *The American Journal of Jurisprudence*, *14*(1), pp.1-36.

Gale, Douglas, and Shachar Kariv. "Bayesian learning in social networks." *Games and Economic Behavior* 45, no. 2 (2003): 329-346.

Gelderblom, O., 2005. The Resolution of Commercial Conflicts in Bruges, Antwerp, and Amsterdam, 1250-1650.". *Law and Long-Term Economic Change, Debin Ma, and Jan Luiten van Zanden, eds.(Stanford University Press, 2011)*, pp.244-276.

Gennaioli, Nicola, Rafael La Porta, Florencio Lopez-de-Silanes, and Andrei Shleifer. 2010. Human Capital and Regional Development. *Quarterly Journal of Economics* first published online November 18.

Gintis, H., 2000. *Game theory evolving: A problem-centered introduction to modeling strategic behavior*. Princeton university press.

Giuliano P, Nunn N. 2017. Understanding Cultural Persistence and Change. Working Paper.

Glaeser, E.L. and Shleifer, A., 2002. Legal origins. *Quarterly Journal of Economics*, pp.1193-1229.

Glaeser, Edward L., Rafael La Porta, Florencio Lopez-De-Silanes, and Andrei Shleifer. 2004. Do institutions cause growth? *Journal of Economic Growth* 9: 271-303.

Glaeser, E.L., Sacerdote, B. and Scheinkman, J.A., 1996. Crime and Social Interactions. *The Quarterly journal of economics*, *111*(2), pp.507-548.

Goeree, M.S., 2008. Limited information and advertising in the US personal computer industry. *Econometrica*, *76*(5), pp.1017-1074.

Golub, Benjamin, and Matthew O. Jackson. 2010. Naïve Learning in Social Networks and the Wisdom of Crowds. *American Economic Journal: Microeconomics*, American Economic Association, vol. 2(1), pages 112-49.

Grajzl, P. and Murrell, P., 2006. Lawyers and politicians: the impact of organized legal professions on institutional reforms. *Constitutional Political Economy*, *17*(4), pp.251-276.

Greif, Avner. 1993. Contract enforceability and economic institutions in early trade: The Maghribi traders' coalition. The American economic review, pp.525-548.

Greif, Avner. 1994. Cultural Beliefs and the Organization of Society: A Historical and Theoretical Reflection on Collectivist and Individualist Societies. *Journal of Political Economy*, Vol. 102, No. 5, pp. 912-950.

Greif, Avner. 2002. Institutions and impersonal exchange: from communal to individual responsibility. Journal of Institutional and Theoretical Economics JITE, 158(1), pp.168-204.

Greif, Avner. 2004. Impersonal Exchange without Impartial Law: The Community Responsibility System. Chicago Journal of International Law, 5(1), p.109.

Greif, Avner. 2006. History lessons: the birth of impersonal exchange: the community responsibility system and impartial justice. The Journal of Economic Perspectives, 20(2), pp.221-236.

Greif, Avner. 2006. *Institutions and the path to the modern economy: lessons from medieval trade*. Cambridge University Press.

Greif, A., Milgrom, P. and Weingast, B.R., 1994. Coordination, commitment, and enforcement: The case of the merchant guild. *Journal of political economy*, *102*(4), pp.745-776.

Grosjean, Pauline. 2011. The Weight of History on European Cultural Integration: A Gravity Approach. *American Economic Review*, Volume 101, Number 3, pp. 504-508(5).

Guiso, Luigi, Paola Sapienza, and Luigi Zingales. "Cultural biases in economic exchange?." *The Quarterly Journal of Economics* 124, no. 3 (2009): 1095-1131.

Guiso, Luigi, Paola Sapienza, and Luigi Zingales. "The role of social capital in financial development." *American Economic Review* 94, no. 3 (2004): 526-556.

Guiso, Luigi, Paola Sapienza, and Luigi Zingales. "Trusting the stock market." *the Journal of Finance* 63, no. 6 (2008c): 2557-2600.

Guiso, Luigi, Paola Sapienza, and Luigi Zingales. 2008a. Alfred marshall lecture social capital as good culture. *Journal of the European Economic Association*, *6*(2-3), pp.295-320.

Guiso, Luigi, Paola Sapienza, and Luigi Zingales. 2008b. Long Term Persistence.*NBER Working Paper*, (w14278).

Hadfield, G.K. and Weingast, B.R., 2012. What is law? A coordination model of the characteristics of legal order. *Journal of Legal Analysis*, *4*(2), pp.471-514.

Hadfield, G.K., 2005. The many legal institutions that support contractual commitments. In *Handbook of New Institutional Economics* (pp. 175-203). Springer US.

Hart, H.L., 1994. The concept of law (1961). *Oxford: Clarendon Press, 19842*, pp.94-5.

Hendley, K., 2001. Beyond the tip of the iceberg: business disputes in Russia. *Assessing the Value of Law in Transition Economies*, *20*.

Henrich, Joseph, and Robert Boyd, and Peter. J. Richerson. 2008. Five Misunderstandings about Cultural Evolution. *Human Nature,* 19: 119–137.

Henrich, Joseph, and Robert Boyd. 1998. The Evolution of Conformist Transmission and the Emergence of Between-Group Differences. *Evolution and Human Behavior,*19: 215–242.

Henrich, Joseph, Robert Boyd, Samuel Bowles, Colin Camerer, Erns Fehr, Herbert Gintis, Richard McElreath, Michael Alvard, Abigail Barr, Jean Ensminger, Kim Hill, Francisco Gil-White, Michael Gurven, Frank W. Marlowe, John Q. Patton, Natalie Smith, and David Tracer. 2005. "Economic Man" in Cross-cultural Perspective: Behavioral Experiments in 15 Small-scale Societies. *Behavioral and Brain Sciences*, 28: 795–855.

Houser, D., Schunk, D. and Winter, J., 2008. Risk Preference and Trust in the Investment Game.

Inglehart, R. 1999. 'Trust, Well-being and Democracy.' In *Democracy and Trust*, ed. M. E. Warren, pp. 88–120. Cambridge: Cambridge University Press.

Karlan, Dean S. "Using experimental economics to measure social capital and predict financial decisions." *American Economic Review* (2005): 1688-1699.

Kaufmann, Daniel, Aart Kraay, and Pablo Zoido-Lobaton. 1999. Governance matters. Policy Research Working Paper Series 2196, The World Bank.

Kendal, Jeremy, Luc-Alain Giraldeau, and Kevin Laland. 2009. The evolution of social learning rules: Payoff-biased and frequency-dependent biased transmission. *Journal of Theoretical Biology*, Volume 260, Issue 2, Pages 210-219.

Klenow, Peter, and Andres Rodriguez-Clare. 2005. Externalities and Growth in *Handbook of Economic Growth*, vol. 1A, Philippe Aghion and Steven Durlauf, eds. (Amsterdam: Elsevier, 2005).

Knack, Stephen, and Philip Keefer. "Does social capital have an economic payoff? A cross-country investigation." *The Quarterly journal of economics* 112, no. 4 (1997): 1251-1288.

Kramer, M., Grant, C., Colburn, B. and Hatzistavrou, A. eds., 2008. *The Legacy of HLA Hart: Legal, Political and Moral Philosophy*. OUP Oxford.

Kumar,Krishna B., and John G. Matsusaka. 2009. From families to formal contracts: An approach to development. *Journal of Development Economics*, Volume 90, Issue 1, Pages 106-119.

La Porta, R., Lopez-de-Silanes, F. and Shleifer, A., 2008. The economic consequences of legal origins. *Journal of economic literature*, *46*(2), pp.285-332.

La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert W. Vishny. "Trust in Large Organizations." *The American Economic Review* (1997): 333-338.

Landes, W.M. and Posner, R.A., 1979. Adjudication as a Private Good. *The Journal of Legal Studies*, *8*(2), pp.235-284.

Leana CR III, Van Buren HJ (1999) Organizational social capital and employment practices. Acad. Management Rev. 24(3):538–555.

Levine, D.K. and Modica, S., 2016. Peer discipline and incentives within groups. *Journal of Economic Behavior & Organization*, *123*, pp.19-30.

Li, J., 2009. Information structures with unawareness. *Journal of Economic Theory*, *144*(3), pp.977-993.

Lipset, S.M., 1960. Political man: The social basis of modern politics.

Manzini, P. and Mariotti, M., 2014. Stochastic choice and consideration sets. *Econometrica*, *82*(3), pp.1153-1176.

Masatlioglu, Y., Nakajima, D. and Ozbay, E.Y., 2012. *American Economic Review*, 102(5): 2183–2205

Masten, S.E. and Prüfer, J., 2014. On the evolution of collective enforcement institutions: communities and courts. *The Journal of Legal Studies*, *43*(2), pp.359-400.

McAllister DJ (1995) Affect- and cognition-based trust as foundations for interpersonal cooperation in organizations. Acad. Management J. 38(1):24–59

McElreath, Richard and Pontus Strimling. 2008. When Natural Selection Favors Imitation of Parents. *Current Anthropology* , Vol. 49, No. 2, pp. 307-316.

Milgrom Paul R., Douglass C. North, and Barry R. Weingast. 1990. The Role of Institutions in the Revival of Trade: the Law Merchant, Private Judges, and the Champagne Fairs. *Economics and Politics*, Volume 2, Issue 1, pages 1-23.

Milgrom, P.R., North, D.C. and Weingast, B.R., 1990. The Role Of Institutions In The Revival Of Trade: The Law Merchant, Private Judges, And The Champagne Fairs. *Economics and Politics*, *2*(1), pp.1-23.

Miller, Edward, M. M. Postan, and E. E. Rich. 1965. *The Cambridge economic history of Europe*. Cambridge: Cambridge University Press.

Modica, S. and Rustichini, A., 1994. Awareness and partitional information structures. *Theory and decision*, *37*(1), pp.107-124.

Murrell, P., 2001. *Assessing the value of law in transition economies*. University of Michigan Press.

Myers, Jerome L., and Ernest Sadler. 1960. Effects of range of payoffs as a variable in risk taking. *Journal of Experimental Psychology*, 60, 306-309.

Nelson, Richard R., and Edmund S. Phelps. 1966. Investment in Humans, Technological Diffusion, and Economic Growth. *American Economic Review* 56 (1/2): 69–75.

North, Douglas C. 1990. *Institutions, Institutional Change, and Economic Performance*, Cambridge: Cambridge University Press.

North, Douglas C., John Joseph Wallis and Barry R. Weingast. 2009. *Violence and Social Orders: A Conceptual Framework for Interpreting Recorded Human History*. Cambridge University Press.

Nunn, Nathan. 2007. Relationship-Specificity, Incomplete Contracts and the Pattern of Trade. *Quarterly Journal of Economics*, 122(2):569-600.

Nunn, Nathan. 2012. Culture and the Historical Process. *Economic History of Developing Regions*, Vol. 27, S108-S126.

Ogilvie, S., 2011. *Institutions and European trade: Merchant guilds, 1000–1800*. Cambridge University Press.

Peysakhovich, A. and Rand, D.G., 2015. Habits of virtue: creating norms of cooperation and defection in the laboratory. *Management Science*, *62*(3), pp.631-647.

Pollock, F. and Maitland, F.W., 1895. *The history of English law before the time of Edward I.*

Putnam, R. (1993). Making democracy work: Civic traditions in modern Italy. Princeton, NJ: Princeton University Press.

Putnam, Robert D. 2001. *Bowling Alone: The Collapse and Revival of American Community.* Touchstone Books by Simon, Schuster.

Putnam, Robert D., Robert Leonardi, and Raffaella Nanetti. 1993. *Making Democracy Work. Civic Traditions in Modern Italy*, Princeton-NJ: Princeton University Press.

Ratcliff, R. and McKoon, G., 2008. The diffusion decision model: theory and data for two-choice decision tasks. *Neural computation*, *20*(4), pp.873-922.

Rendell, Luke, Robert Boyd, D. Cownden, Marquist Enquist, Kimmo Eriksson, Marcus W. Feldman, L. Fogarty, Stefano Ghirlanda, T. Lillicrap, and Kevin N. Laland. 2010. Why copy others? Insights from the social learning strategies tournament. *Science* 328, no. 5975: 208-213.

Reyerson, K., 1985. *Business, banking, and finance in medieval Montpellier*(Vol. 75). PIMS.

Richerson Peter J., and Robert Boyd. 2005. *Not by Genes Alone: How Culture Transformed Human Evolution*. Chicago: University of Chicago Press.

Richman, B.D., 2004. Firms, Courts, and Reputation Mechanisms: Towards a Positive Theory of Private Ordering. *Columbia Law Review*, pp.2328-2368.

Rodrik, Dani, Arvind Subramanian, and Francesco Trebbi. 2004. Institutions Rule: The Primacy of Institutions over Geography and Integration in Economic Development. *Journal of Economic Growth*, Vol. 9, No. 2 (Jun., 2004), pp. 131-165.

Rogers, Alan R. 1988. Does biology constrain culture? *American Anthropologist* 90:819–831.

Rogers, Everett M. 1995. Diffusion of innovations. New York: Free Press.

Rousseau DM, Sitkin SB, Burt RS, Camerer C (1998) Not so different after all: A cross-discipline view of trust. Acad. Management Rev. 23(3):393–404

Sachs, S.E., 2006. From St. Ives to Cyberspace: The Modern Distortion of the Medieval'Law Merchant'. *American University International Law Review*, *21*(5), pp.685-812.

Sala-i-Martin, Xavier, and Arvind Subramanian. 2003. Addressing the Natural Resource Curse: An Illustration from Nigeria. NBER Working Papers 9804.

Schechter, L., 2006. Trust, trustworthiness, and risk in rural Paraguay.*Experimental Economics*, *9*(2), pp.173-173.

Simon, H.A., 1955. "A behavioral model of rational choice", *The Quarterly Journal of Economics*, pp: 99-118

Simon, H. A., 1957. Models of Man, Social and Rational: Mathematical Essays on Rational Human Behavior in a Social Setting. New York: John Wiley and Sons.

Smith, Lones, and Peter Norman Sørensen. 2008. Informational Herding and Optimal Experimentation.

Stagnaro, M.N., Arechar, A.A. and Rand, D.G., 2016. From good institutions to good norms: Top-down incentives to cooperate foster prosociality but not norm enforcement. *Available at SSRN*.

Stout, Dietrich. 2005. The social and cultural context of stone-knapping skill acquisition. In *Stone knapping: the necessary conditions for a uniquely hominin behaviour* (eds Roux V., Bril B.), pp. 331–340. Cambridge, MA:McDonald Institute for Archaeological Research.

Stout, Dietrich. 2011. Stone toolmaking and the evolution of human culture and cognition. *Philosophical Transactions of Royal Society B* 366 1567 1050-1059.

Stutzer, Alois, Lorenz Goette, and Michael Zehnder. 2011. Active Decisions and Prosocial Behaviour: a Field Experiment on Blood Donation. *The Economic Journal*, Volume 121, Issue 556, pages F476–F493.

Tabellini, Guido. 2008a. Presidential address institutions and culture. *Journal of the European Economic Association*, *6*(2-3), pp.255-294.

Tabellini, Guido. 2008b. The Scope of Cooperation: Values and Incentives. *Quarterly Journal of Economics*, 123(3): 905–50.

Tabellini, Guido. 2010. Culture and institutions: economic development in the regions of Europe. *Journal of the European Economic Association*, *8*(4), pp.677-716.

Takahashi, S., 2010. Community enforcement when players observe partners' past play. *Journal of Economic Theory*, *145*(1), pp.42-62.

Tirole, J., 2009. Cognition and incomplete contracts. *The American Economic Review*, *99*(1), pp.265-294.

Weber, Max. 1968. *Economy and society: An outline of interpretive sociology*. New York: Bedminster Press.

Williamson, O.E., 1987. Transaction cost economics: The comparative contracting perspective. *Journal of economic behavior & organization*, *8*(4), pp.617-625.

Williamson, Oliver E. 1979. Transaction-Cost Economics: The Governance of Contractural Relations. *Journal of Law and Economics*, University of Chicago Press, vol. 22(2), pages 233-61.

Williamson, Oliver E. 1985. *The Economic Institutions of Capitalism*. Free Press, New York.

Williamson, Oliver E. 1998. The Institutions of Governance. *American Economic Review*, American Economic Association, vol. 88(2), pages 75-79.

Wolff, Edward. 2011. Spillovers, Linkages, and Productivity Growth in the US Economy, 1958–2007. NBER Working Paper No. 16864.

Wolitzky, A., 2013. Cooperation with network monitoring. *The Review of Economic Studies*, *80*(1), pp.395-427.

Wright, Peter, and Fredrick Barbour. 1977. “Phased Decision Strategies: Sequels to an Initial Screening.” In: Studies in Management Sciences, Multiple Criteria Decision Making, ed. Martin K. Starr, and Milan Zeleny, 91-109, Amsterdam: North-Holland.

Zak, Paul J., and Stephen Knack. "Trust and growth." *The economic journal*111, no. 470 (2001): 295-321.