The Cultural Evolution of Economic Development

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I certify that all material in this thesis which is not my own work has been identified and that any material that has previously been submitted and approved for the award of a degree by this or any other University has been acknowledged.

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Abstract

Economic development has several stages, from the exchange of tools and weapons in prehistory, to the adoption of money systems, to globalised economies driven by digitally-represented currencies. These stages present different challenges to societies, but also common ones. Perhaps the most important of these is cooperation. Exchange puts parties in positions vulnerable to exploitation, as they have to give payment in anticipation of goods, or goods in anticipation of payment. At its origin, money use creates a similar situation in which a party gives up valuable objects for a promise of future repayment. Explaining the diversity in economic performance and money systems therefore requires consideration of ecological and cultural factors that shape the levels of cooperation in societies. History can also have an influence on this diversity. Events in a society's history can have persistent effects on its culture and institutions, and more general patterns of shared history can determine how culturally similar societies are. A cultural evolutionary framework can be used to synthesise these different factors as part of the same explanation. Historical experiences, the ecology and cultural traits all shape variation in each other and create conditions that determine the adaptiveness of cooperation, and therefore the potential for money use and large-scale economic activity to emerge and spread. Using a multiple method and multiple hypothesis approach, in this thesis I seek to examine existing theories for variation in economic development and money use, and generate and test new hypotheses using a cultural evolutionary framework.

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Chapter 1: Introduction

In their lives, virtually all people will participate in behaviours that contribute to an economy. Purchasing objects using money or credit is an obvious example of a common behaviour that supports economic growth. Such economic behaviours involve numerous parties, and are therefore a fundamentally social interaction (Graeber, 2012). Fulfilling the needs of yourself and others involves calculation of costs and benefits, trading-off cultural expectations of fairness and duty against payoffs that can contribute to your own fitness. This all takes place in the context of legal frameworks and systems of storing value such as money. These shape what choices are most beneficial for oneself and the broader economy, and are themselves shaped by history, ecological factors and culture. I use a cultural evolutionary perspective to generate and test hypotheses explaining the emergence of monetary systems and global disparities in economic performance. In this first section I introduce the reader to key concepts including economies, money and cooperation. I describe cultural evolution and present how a cultural evolutionary approach can be used to synthesise economic, historical and behavioural literatures and ask new questions of existing theories and ideas around the development of economies.

What is an economy?

An economy is the system of industry, trade and investment by which societies produce and use goods, services and money. The scope and content of economies have changed through time, reflecting the attainment of key historical milestones which changed the nature of economic activity. At its

origin, economic activity involved small groups foraging for food, creating material culture and trading ideas, tools, food and mates in response to needs. For example, starting in the upper Palaeolithic, flint weapons and other tools were traded between groups to aid their hunting success (Gamble, 1980). Evidence for economic specialisation, in which individuals or groups become dedicated suppliers of particular skills or items, has been found as early as the late Pleistocene (Rots & Van Peer, 2006), and appears more clearly in the Neolithic. Some societies may develop the technology to produce salt, while others may be skilled weavers. Trade allows both societies to have access to salt and cloth without spending the time learning how to produce both (Dorward, 1976). This specialisation often reflected differences in environmental conditions and resources. Specialisation drove a greater scale of exchange, as it encouraged individuals to seek out and trade with different groups to access their specialities. This expansion of economic activity is associated with the emergence of commodity and token moneys. Around 3200BC, we see the first evidence of economic systems based on credit and debt relationships that involve token money objects such as clay tablets (Graeber, 2011). Tokens of debt first took the form of bills in Europe around 650 years ago (Hart, 1986). These systems that enable debt to be used in economic transactions further increased the scale of exchange possible and laid the foundations for modern, globalised economies which are largely based on the circulation of credit and loans as opposed to physical currency.

In each of these historical milestones, the purpose, scale and media of exchange are different. However, common to each of the milestones is that to develop an economy, a society must have the ability to supply goods or services that others desire and/or have a means of acquiring goods and

services produced by others. Individuals or societies must be able to offer assets or skills such as tools, resources and food; and they must have the ability to pay others for their assets and skills, using systems like money, exchange or debt. A society's economy is also functionally related to other aspects of societal development. A successful economy provides the resources needed to govern effectively and maintain infrastructure. A society's economic success also encourages meaningful relationships with other societies seeking to invest in growing economic opportunities. Economic performance is therefore considered a critically important goal for modern societies, and has become the yardstick that is used to measure the success of different political regimes, polices and other initiatives. For example, the policy-making procedure for all OECD countries incorporates an assessment of economic impact (Malyshev, 2006).

What is money?

Exchange exists in all human societies that have been observed ethnographically and documented archaeologically (Earle, 2002). As there is geographical variation in resources and specialised skills, some individuals and societies can produce goods and services that others cannot. This makes these goods and services accessible only by exchange. Common examples of such goods and services are commodities such as tools, food, medicine, weapons, decorative items such as feathers and pigments, or labour in the form of slaves (Earle, 2002; Einzig, 1966; Quiggin, 1979). For example, the Tiv are a large ethno-linguistic group in West Africa historically well-known for their skill in manufacturing cloths. These cloths were coveted by neighbouring societies for their durability, and were used in exchanges for cattle (among other items) that

the neighbouring societies had a greater specialism in producing (Dorward, 1976). Commodities, decorative items and labour all contribute towards societal or individual needs such as combat, ceremony or subsistence, which makes people motivated to secure access to them. Since this motivation is mutual, individuals can offer things that are easy to for them to secure in exchange for those that are not (Beckwith, 1991).

A central dilemma with exchange is that the goods that parties want and those that they can offer fluctuate over time. This means that more often than not, one party wants what the other does not have, which precludes any exchange between them. When two parties want what each other has, this is called the ‘double coincidence of wants’ (Jevons, 1897). Ethnographic evidence suggests that achieving such a double coincidence is rare, as there is no evidence for the existence of economies based on direct exchange at all outside of modern, artificially-controlled environments such as prisons (Humphrey, 1985). According to classical economic theory, the emergence of money was a result of the motivation of parties to maximise the frequency with which the double coincidence of wants is met. Money achieves this by fundamentally being objects that are desired by everyone (Jevons, 1897; Kitoyaki & Wright, 1989). Money, therefore, is considered an early step in the development of large-scale economic activity.

Money has featured in human societies for millennia. The definition of money is long-standing and states that money is comprised of three properties (Kiyotaki & Wright, 1989). First, money is a medium of exchange. It is offered to others as compensation for the goods and services that they provide. Second, money is a unit of account. It provides a common measure to represent the relative prices of particular goods and services. Third, money is a store of value.

It is reliably useful, and so can be saved and used over time. These three components make money an effective solution to the problem of achieving a double coincidence of wants.

Alongside this broad traditional definition, money can be divided into two types: commodities and tokens. Commodity moneys are objects with intrinsic value. This value makes them desired by many parties, which means that they are widely accepted in exchanges. In instances where one party lacks what the other desires, a commodity can be offered instead as it can be used in subsequent exchanges with parties who do possess desired objects. For example, subsistence-related objects such as cattle were commonly used as money because they were highly-coveted resources able to be used in exchanges for other items (Hutchinson, 1992). Cattle, however, are difficult to transport and because they can be destroyed by ecological changes or disease, they do not infinitely hold value. In general, a given commodity is more or less likely to be used as money depending on its portability, divisibility and durability as a store of value, as these variables contribute to how readily they can be used in exchanges (Clower, 1984). These early commodity moneys laid the foundation for coinage, the earliest known mints of which date to 650-600 B.C Asia Minor. Although the intrinsic value of precious metals may be disputed due to the fact that they lack an intrinsic use (in the sense that coins are difficult to work into something that provides direct benefits outside of being used as payment), it is largely accepted that coins get their perceived value from their intrinsic precious metal content (Bell, 2001).

Token moneys are objects used as money despite having no intrinsic value. These tokens work as money by being markers of outstanding debts (Graeber, 2011), whose value is backed by social systems such as third-party

institutions that track debts and impose costs on those who default on their debts. In contrast to commodity moneys whose value is derived entirely from the object itself, tokens theoretically can be any object. This is because the object only exists to signal an outstanding debt. As a consequence, token moneys have historically taken many forms. Among the most well-known are tally sticks and clay tablets, used in Medieval Britain (Maurer, 2015) and Mesopotamia (Ezzamel & Hoskin, 2002; Keister, 1963) respectively. These are intrinsically valueless objects distinguishable only because they contain information about creditors, debtors, amounts owed and dates. They circulate on the basis that the holder of the token is due repayment from the debtor. After this repayment takes place, the object is destroyed. However, consistent with the idea that the objects themselves are immaterial, circulation of these tokens does not require them to physically change hands. Rai stones used by the Micronesian Yap society as token money are disc-shaped stones that are large enough to be immovable. Between which parties these stones circulate—and therefore who is indebted to whom— is knowledge tracked and disseminated by community elders (Frisby, 2014; Morse, 2018). This illustrates that token money objects are not restricted in terms of their divisibility or portability, and can in theory be any object provided that members of the society recognise that they signal outstanding debts.

Variation in economies

The value of goods and services a society produces in a given time period is changeable. Variation in available resources, the development of particular industries and institutions and the extent of global demand for specific products or services all shape the ability of a society to take a position within a

global marketplace (de Ferranti et al, 2002; Stijns, 2005). For example, Venezuela enjoyed economic growth in the latter half of the 20th century largely due to global demand for its considerable oil reserves. But its economy has since suffered a downturn and now experiences massive inflation due to decreases in global oil prices and political corruption causing the misallocation of funds (Davis et al, 2003; Hammond, 2011; Leite & Weidmann, 2002). In contrast, India continues to be one of the fastest growing economies in the world as a result of a shift to a more diverse and service-based economy which allows it to satisfy the demands of a large range of trading partners (Eichengreen & Gupta, 2011; Kohli, 2006).

Despite this variability, economic development around the world does show some broad patterns that are fairly consistent over time. Western European, North American and East Asian societies are currently the wealthiest in the world, while Central Asian, Sub-Saharan African and South American societies are among the last wealthy (World Bank, 2018a). This distribution of wealth seems to reach back into history. The majority of the world's wealth has been accounted for by eight countries, mostly comprised of Western European and East Asian populations (France, Germany, the UK, Italy, USA, India, China and Japan), for the last two thousand years (Maddison, 2007). This suggests that although fluctuations in economic performance do occur, there is a broader overarching pattern in which some societies are persistently wealthy, and others are persistently poor.

One way in which the economies of modern nation states do not vary is money systems. The relative wealth of modern nation states can be easily compared because they all share a common concept of what money is. In these societies, token moneys such as physical coins or notes (or a digital

representation of these objects) are used. These acquire their value from a shared belief that they can be given in exchange for goods and services, which makes the tokens themselves relatively immaterial. For example, the precious metal content of coinage has varied throughout time, but has never impacted on its purchasing power as whatever is accepted by states as taxation and by vendors as payment is considered money (Graeber, 2011). This shared definition provides a common measure of the value of goods and services societies buy and sell, which enables economic development to be defined almost exclusively in terms of money and its relative flows. The most common measure, GDP, is a combination of measures of spending, investment and production that derives the net monetary value of goods and services created by a society, and allows us to determine, for example, that South Korea's economic output per person is more than five times that of India (World Bank, 2018a, b).

However, the unanimous adoption of token money in modern nation states understates the huge amount of variation in money systems in traditional societies and in the histories of modern nations. Many existing traditional societies that are not tightly linked to centralized state governmental systems do not use money, having never been exposed to the system or after finding it unhelpful as a mechanism used to organise their economic activity (Sahlins, 1974). Some societies use commodity money. For example, several societies in Siberia, Mongolia and China use bricks of tea as money, the value of this money object being determined by the quality of the tea that comprises it (Einzig, 1966). Other societies use tokens that signify outstanding debts like the notes used in modern nation states, such as giant immovable Rai stones in the Micronesian Yap society. The diversity of this aspect of economies has not

been the subject of much research relative to investigations into wealth, despite the dependence of modern economic development on the emergence and maintenance of a money system.

Cultural evolution and economic behaviours

The diversity in economic development in terms of wealth and money systems can depend on competition and intentional actions by some societies on others. The network of development loans from developed nations to underdeveloped nations is a modern example of how societies can maintain their relative wealth by exploiting others (Perkins, 2006). Colonialism is a better-known example. Societies have long transplanted institutions into other societies, having long-lasting detrimental effects in the case of extractive regimes and stimulating long-term growth in the case of systems such as money and formalised law (Acemoglu & Robinson, 2012; Acemoglu et al, 2001, 2002).

But economic development is also led by the behaviours and psychologies of individuals within societies, and so can emerge endogenously as opposed to being the result of actions by other societies. Classical economic theory argues that a central component of economic behaviours that drive growth is the human ability to weigh the absolute value of different opportunities, and our stable preference to maximise payoffs in any situation (McKenzie, 2010). As these are calculations, they are independent of context and will always result in the same outcome. These economic principles are convenient for statistical modelling of how individuals behave in economies, and allow economists to make predictions about what behaviours emerge in different conditions.

However, these are not the only principles driving economic behaviour. Cultural evolutionary theory proposes that there are different drivers that explain the substantial variation we observe in behaviour. Cultural evolution involves applying the mechanisms that shape biological evolution to understand how cultural traits such as behaviours, norms and beliefs change over time (Mesoudi, 2011; Richerson & Boyd, 2005). The differences in the features of biological organisms that we observe are due to selection acting upon heritable variation (Darwin, 1859/1975). Over generations, heritable traits that provide fitness benefits are passed on to offspring, and traits that are deleterious are not passed on. This changes the distribution of traits in the population over time (Byars et al, 2010; Price & Grant, 1984; Stearns et al, 2010). Cultural evolutionary theory argues that the distribution of cultural traits is shaped by an analogous process (Cavalli-Sforza & Feldman, 1981; Laland et al, 2000; Mesoudi et al, 2004). Behaviours and practices that exploit local conditions for fitness benefits and/or avoid costs are preferentially learned by others who seek the same benefits and are taught to offspring so that they can continue to acquire fitness benefits (Henrich & Henrich, 2010; Henrich & McElreath, 2003; Nakahashi et al, 2012). Classical replacement experiments have provided many examples of this process. In these experiments, groups of participants are challenged with tasks over several generations. Each generation, most group members are retained, but a few are replaced with new members who are naïve with regard to the task. These experiments typically show that over generations, new members learn the best strategies from the other group members, and task performance gradually increases over generations as new ideas are introduced, explored and kept at a rate approximately proportional to their success (Baum

et al, 2004; Caldwell & Millen, 2008; Efferson et al, 2007, 2008; McElreath et al, 2005, 2008).

Cultural evolutionary theory makes important predictions about economic behaviour that are not part of classical economic theory (Bowles et al, 2006). As cultural adaptations are responses to local conditions, what behaviours are adaptive can be different in different societies. Different social systems or ecologies legitimise different social practices or ways of thinking. This shapes how we react to economic opportunities, in contrast to the traditional economic idea of context-free calculation. For example, when given the chance to choose to keep resources in their own group or give resources to other groups, participants from Fiji, Bangladesh and Bolivia allocate substantially more resources to themselves than participants from Iceland and the United States. This is because of differences in food security within these countries. Individuals from Fiji, Bangladesh and Bolivia have a greater motivation to secure their own needs (Hruschka et al, 2014). Such differences in preferences for how many resources to keep, as well as the fact that no populations studied chose the option that would confer the most personal benefit (which is to keep all the resources for yourself) cannot be accounted for by classical economic thinking, but is consistent with evolutionary pressures causing diversity in peoples' responses to economic opportunities.

Another prediction of cultural evolutionary theory is that economic behaviours can be shaped by information that is inherited culturally. When making economic decisions, we are sensitive to the choices that others make and to the information given to us by others (Baron et al, 1971; Clark & Crockett, 1971; Rockloff & Dyer, 2007). Through social learning, we adopt heuristics or rules that are generally adaptive (Gigerenzer & Selten, 2002).

Cultural preferences, even if arbitrary, can therefore influence economic decisions. While human social learning involves many biases, such as payoff-bias, that work to maximise the probability of adopting adaptive behaviour, social learning can also in theory result in the adoption of maladaptive behaviour (Boyd et al, 2011; Franz & Matthews, 2010), further emphasising that economic behaviour may not simply be the result of rational optimisation.

Institutions and norms

Over the last few decades, institutions have been established as the central influence that determines what economic behaviours are adaptive (North, 1990). Institutions are codified rules that regulate human behaviours (Ostrom, 2000). Human capacity for communication, negotiation and co-ordinated goal setting enables us to create rules that change the nature of our interactions and economic activity by shifting the costs and benefits of our behaviour (Powers et al, 2016). Institutions shape behaviour in a similar way to ecological factors. As we have seen in the case of food security, in different environmental conditions, some behavioural strategies secure lower levels of natural resources and/or risk survival compared to others, and these will be abandoned in favour of more profitable strategies. Institutions involve systems or bodies that inflict social costs on behaviours that violate created rules, and commonly encourage particular behaviours that may be beneficial for the society as a whole (Boyd & Richerson, 2009). For example, a range of societies from traditional to developed have converged on similar solutions to managing common-pool resources such as irrigation systems. This typically involves some degree of centralisation, where allowances for use are agreed upon, monitors can share information about peoples' obedience, and the costs of sanctions for

violators such as fines or ostracism can be shared (Casari, 2007; Ostrom, 1990). This changes the fitness consequences of different behaviours. Institutions can therefore create the conditions for higher individual- and group-level payoffs than those possible without institutions.

The economic and evolutionary literature commonly equates institutions with third-party, centralised bodies that specialise in enforcing laws. Humans are highly motivated to punish as third parties (Fehr & Fischbacher, 2004; Henrich et al, 2006) and this type of punishment is effective at maintaining cooperation (Gurerk et al, 2006), but it is also a cooperative dilemma itself as individuals who do not punish others save personal costs (Boyd et al, 2003; Henrich & Boyd, 2001). Dedicated enforcement bodies can regulate behaviours at a much larger scale than any individual, but these enforcement bodies are also costly and require investment by individuals to maintain. While this presents another cooperative dilemma, the scale of beneficial cooperation made possible by centralised institutions make individually costly systems such as taxation, which are necessary to support the institution, possible and sustainable. One example of this process is the conversion to Islam that occurred in parts of Africa. Most of these conversions were voluntary as it was in the interest of individuals to do so. Islam has high entry costs in terms of religious and other commitments, but overcoming these allowed access to a shared legal structure which enabled the use of credit, which made it ultimately beneficial to pay the costs, allowing Islam to spread (Ensminger, 1997). Similarly, paying taxes to gain access to a network of large-scale cooperation and trade is ultimately beneficial, which allows institutions to overcome the cooperative dilemma inherent in the administration of third-party enforcement.

Another important type of culturally-inherited information that shapes economic behaviours are norms (Keefer & Knack, 2008; Tabellini, 2010). Norms are like institutions in that they regulate behaviour, but instead of being relatively formal and codified laws, they are broad expectations and conventions of what constitutes acceptable behaviour (Ehrlich & Levin, 2005; Fehr & Fischbacher, 2004). The sanctions that are administered by institutions in response to violators tend to be formal, consistent and economic penalties. In contrast, sanctions for violating social norms are more social, such as damaging the offender's reputation or excluding them from subsequent interactions (Kurzban & Leary, 2001; Ostrom, 2000).

Many social norms are learned socially, but their benefits are continually reinforced by the social, institutional or ecological environment. Therefore, norms are most able emerge and persist if they encourage behaviours that are beneficial for the individual or society. For example, norms that permit indiscriminate cooperation with those outside of your kin or ethnic group only tend to emerge in specific ecological or institutional conditions, such as when interactions are governed by formal laws (Hruschka & Henrich, 2013a, b). Societies with weak enforcement and legal institutions tend to limit contracting relationships to kin and ethnic groups. If they do not do so, they risk the costs of being exploited by the other party (Fafchamps, 2000).

However, due to their heritable nature, norms can persist through social learning despite changing conditions, leading them to provide no observable advantage. For example, experimental evidence illustrates that individuals can learn to expect particular economic outcomes, which over time are perceived as fair, even though they are particular to one group (Roth, 1987; Binmore et al, 1991, 1993). A real-life example of arbitrary norms in economic scenarios is

sharecropping contracts. These informal arrangements determine the fractions of harvest owned by landowners and labourers and are widely used in agricultural societies (Stiglitz, 1974; Young, 1996). Within villages, there is very little variation between these contracts. Despite different parties, soil qualities, plot sizes and crops, all of which feed into the relative risk that must be accepted by the landowner and labourers, the vast majority of sharecropping involved a single form of contract (Bardhan, 1984). Most often, contracts took the form of a 50-50 split between labourers and landowners, despite nothing in classical economic theory predicting this outcome given the asymmetric positions of the parties (Young, 1996). These contracts also vary substantially between villages, implying that sharecropping contracts are shaped by culturally-inherited norms that follow the boundaries of social interaction.

Institutions and norms are both inherited in a similar way, through social learning. Migrant studies demonstrate how individuals gradually assimilate normative behaviours and other cultural traits of their new societies (Algan & Cahuc, 2010; Rustagi & Veronesi, 2016). Moreover, societies borrow institutional forms and rules from other societies wholesale, such as the many Chilean political reforms that were adopted in Bolivia, Mexico and El Salvador (Ferguson, 2012). In both of these instances, social learning is payoff-biased. It benefits individuals to adopt norms specifying who one can cooperate with as it can prevent opportunism, and societies mainly copy institutions from others if they are associated with economic benefits.

Institutions and norms can be inherited over many generations. Once an institution is created, it is less costly to maintain it than to build a new institution from scratch, meaning that aspects of institutions can persist for long periods of time (Paik, 2010). Moreover, social norms are considered to be very slow

moving (Roland, 2008) as they are embedded in how we socialise members of society from a young age (Nisbett, 2003; Nunn, 2012). Although it should be noted that in certain circumstances (the precise details of which are not yet clear), norms can rapidly change. Outbreaks of civil conflict decrease trust in others and increase the salience of group differences (Rohner et al, 2013a, 2013b) and long-standing traditions in which merchants police their own transactions are swiftly replaced when state-backed policing becomes possible (Greif, 2000; Greif et al, 1994). This evidence suggests that selection can override persistence. However, norms regulating social and economic behaviours in Central and Eastern European countries altered little with the advent and fall of communism (Roland, 2008), and East and West Germany still maintain cultural differences (Alesina & Fuchs-Schündeln, 2007; Heineck & Süssmuth, 2013) after reunification, despite changes in governance often resulting in changes in norms.

History

Biological evolution shows us that history is important in shaping traits. The structure and form of existing adaptations constrains what subsequent adaptations can be. For example, the position and structure of legs reflect their origins as repurposed fin supports (Anapolitanos et al, 1998). Biological adaptations can also be shaped by historical cultural events. For example, lactase, the enzyme responsible for the digestion of the milk sugar lactose, decreases in production after weaning in most mammals. However, in human populations with histories of herding, lactase production persists into adulthood. This trait would offer fitness benefits for such a population whose cultural niche

provides milk as a major source of nutrition, and its distribution has been traced to historical genetic changes associated with herding (Gerbault et al, 2011).

A similar process affects the diversity in cultural traits. Cultural information can be inherited between generations with relatively high fidelity through vertical social transmission. Consequently, historical events that affect cultures of previous generations can continue to have effects on modern day cultural diversity. As economic decisions are shaped by such heritable cultural information, modern economies are influenced by history. The most well-known application of this theory was to Italy, the northern regions of which are wealthier in the present day than the southern regions. The north has a history of democratic rule, mutual trust between citizens and high political engagement, while the history of the south is characterised by more autocratic rule and feudalism (Englebert, 2000; Putnam, 1993). This historical division is said to have persisted in the contemporary populations of these regions due to vertical cultural inheritance of cultural traits from northern and southern ancestors, driving differences in how the populations behave in circumstances affecting economic growth, such as their confidence in institutions and contracts.

Since then, more examples of the effect of a range of historical events on various cultural traits associated with economic development have been identified. Societies whose ancestors were herding populations instead of large-scale agriculturalists have stronger propensities to defend personal property and reputation in the modern day (Cohen et al, 1996; Grosjean, 2014); societies whose ancestors were governed by regimes that had particularly strong and effective centralised bureaucracies ~200 years ago have more confidence in governments (Becker et al, 2015), stronger governments (Bockstette et al 2002; Paik 2010), and different political ideologies (Grosfeld & Zhuravskaya, 2013) to

other societies; and populations with histories of slavery have lower levels of trust in others (Nunn & Wantchekon, 2011). Furthermore, the density of roads built by Roman populations in a given European region strongly correlates with the region's modern-day economic prosperity (Dalgaard et al, 2018), reflecting how even investments in infrastructure made ~2,000 years ago can have persistent economic effects.

Importantly, it is not only the occurrence of such historical events that shapes culture. It is the timing of these events. Longer histories of particular social or ecological selective pressures imply more time for the emergence and spread of cultural adaptations that are responses to these pressures. For example, societies that adopted statehood and agriculture (Putterman, 2008; Putterman & Weil, 2010) earlier seem to have different economies to those that adopted statehood and agriculture later, as these two changes involve experimentation with new institutions and norms that govern appropriate behaviours. This experimentation takes time to optimise, which results in societies that adopted statehood and agriculture at different times being at different stages of experimentation. Generally, societies that have had the longest time to experiment with systems like statehood are likely to have devised more effective adaptations for living in and governing with states. These adaptations are likely heritable, enabling modern societies to benefit from the experiences of their ancestors. This particular mechanism has been found to be the case with democracy, as analysis of historical and contemporary ethnographic data shows that societies comprised of more individuals who have longer histories of electing leaders by consensus have greater levels of democracy today (Giuliano & Nunn, 2013).

Another way in which history shapes cultural and economic diversity is population divergence and common ancestry (Moore 1994a, b). Over time due to factors such as pressure for space or resources, populations split into subgroups. Splits are often associated with migration or a decrease in contact between the resulting subgroups. This can generate cultural variation (Tehrani & Collard, 2002). Subgroups may migrate to different ecologies which select for different cultural adaptations; and errors in social learning within the subgroups can cause cultural traits that were inherited from the original combined population to change in one subgroup and not another. If there is limited contact between the subgroups, this cultural variation will not spread between the groups, so overall cultural similarity will diminish. Laboratory experiments in language evolution exemplify this process, showing that slight variations in initial ways of communicating particular ideas or concepts can over time create distinctly different languages that are only comprehensible by specific groups, as each group refines its own articulation (Caldwell & Smith, 2012; Faye et al, 2010; Garrod et al, 2007). General cultural variation, which includes variation in economic behaviour, is therefore a function of how recently different populations diverged.

Cooperation

Explaining what causes people to cooperate with others instead of acting selfishly is a key question in cultural evolution (Rand & Nowak, 2013). Humans, at a scale greater than any other species, help others outside of their kin group, even if it is economically beneficial to be opportunistic (Delton et al, 2011). This is puzzling from an evolutionary perspective, as conferring benefits on unrelated others incurs a personal cost with no immediate personal benefit.

Several different approaches have been used to tackle this question, from simulating individuals and populations (Fu et al, 2008) to conducting behavioural experiments in traditional societies (Gachter & Herrmann, 2009; Henrich et al, 2005; Herrmann et al, 2008) to performing large-scale secondary data analyses of modern and historical data on societal development (Nunn, 2012). In any economic transaction, parties have the opportunity to take payment and withhold promised goods, or withhold payment for goods. Contracting and exchange are therefore forms of large-scale cooperation that are vitally important for the development of economies, which makes cultural evolution an informative framework to use to shed light on the variation in economies.

A vast literature of experimental research shows that traditional economic assumptions about how individuals behave break down in cooperative games. For example, in games that take the form of a prisoner's dilemma, pairs of players both receive moderate payoffs if they both cooperate and both receive poor payoffs if they both defect, but if one player defects and the other cooperates, the cheater receives maximum payoff and the co-operator receives a poor payoff. Much like in economic contracts where one can withhold payment to receive goods at no cost, the rational strategy for any individual in this game is to defect, as this maximises their payoff whether the other player chooses to cooperate or defect. However, humans repeatedly and pervasively cooperate in these games, under a variety of conditions designed to minimise any potential economic benefit to cooperating, such as making the games single-shot (Fehr & Fischbacher, 2003).

A large body of research has been dedicated to asking why individuals cooperate in these conditions. Two prominent theories are direct and indirect

reciprocity (Roberts, 2008; Nowak, 2006). Direct reciprocity suggests that people cooperate with people who have cooperated with them in the past and do not cooperate with those who have cheated them. This enables populations of co-operators to emerge and grow because they can freely receive payoffs by interacting with other co-operators while ensuring that they do not give defectors any payoffs (Delton et al, 2011; van Veelen et al, 2012). Indirect reciprocity argues that cooperation is directed towards people who are known for cooperating, which provides people with incentives to cooperate in order to maintain a reputation that invites cooperation from others (Milinski et al, 2002; Panchanathan & Boyd, 2004). These theories, while helpful for explaining some cooperative behaviours, cannot explain why individuals still cooperate even when they are anonymous and know that they will not interact with the same person again.

Institutions and norms are further explanations for cooperation (Ostrom, 2000). Many institutional rules are universally applicable to all members and seek to ensure fairness in transactions, as well as offering recourse for violations. This increases the scale of cooperation by enabling everyone to act according to common principles, which makes behaviour predictable and allows individuals to put themselves in vulnerable positions (such as offering a good) without fear of being cheated (not receiving payment) (North, 1991). A society's ability to enforce rules, often through third parties such as legal systems and police forces, is related to its members' propensities to cooperate at a large-scale (Greif & Tabellini, 2010; Masten & Prüfer, 2014). Experimental evidence not only shows that third-party punishment increases cooperation dramatically, but also that individuals preferentially migrate to conditions in which third-party punishment is available and effective (Gurerk et al, 2006), suggesting third-

party enforcement would likely outcompete alternative systems for maintaining cooperation.

Social norms offer a solution to the dilemma of human cooperation primarily by providing obligations towards helping some people but not others (Greif & Tabellini, 2010). Societies vary in their norms regarding with whom it is acceptable to cooperate, such as those in need, family and group members, or all members of the society (Tabellini, 2008, 2010). This variation is largely attributable to the existence of other social or ecological conditions that alter the prospects for reciprocation and opportunism. For example, when survival threat is high, helping those in need might secure reciprocal aid when personal need is high in future. Furthermore, while cooperating with everyone may maximise the scale of exchange, preferentially interacting with kin or in-groups is often the best way to increase inclusive fitness and avoid cheaters (Hruschka et al, 2014). I will explore in further detail the conditions determining the relative payoffs of these strategies in later sections.

Research on differences in cooperation between societies shows that norms are closely related to institutions. When institutions are non-existent or weakly enforced, individuals cannot cooperate indiscriminately. Therefore, they revert to norms that govern with whom it is permissible to cooperate to avoid being exploited (Ahlerup et al, 2009; Hruschka et al, 2014). This is part of the mechanism of reciprocity, supporting people to channel their cooperation towards those who are invested in maintaining good relations with oneself, such as kin or community members (Tabellini, 2010). For example, in the 1950s and 1960s, nepotism and corruption were rife in Hong Kong and China. Since then, Hong Kong has developed institutions inspired by aspects of effective overseas governments, such as an independent commission against corruption (Khatri et

al, 2006). This has enabled its citizens to rely more on binding contracts and universal rights, removing their reliance on social norms to avoid being exploited. China, by contrast, has continued to rely on pervasive in-group preferences (Khatri et al, 2006; Sun, 2001; Yao, 2002). Such relationships appear to be bidirectional, as social norms also determine the kinds of institutions that individuals create. In the US, property rights institutions established in the 19th century reflected the morals of individualism, reward for effort and respect for property that individuals held (Zerbe & Anderson, 2001). In other comparisons of China, Italy and North Africa, societies with long histories of collectivist, kinship-based moral ties where reputation is highly important were shown to have weaker and more nepotistic institutions today (Grief, 1994; Greif & Tabellini, 2010).

Combining economics and cooperation to explain the development of economies

Supporting large-scale cooperation and developing economies involve the same challenges. The cooperation games used in the evolutionary literature to evaluate the roles of norms, institutions and reciprocity are simplified abstractions of real economic transactions, such as when paying parties have to trust that they will receive the goods they paid for, or when individuals use credit to pay for goods. In real life, taking payment without providing goods or buying something using credit but not repaying the debt secures all the benefits without incurring any costs in economic terms. Therefore, explaining why people use money objects that are valueless tokens of debt and why people uphold contracts requires us to investigate the factors that encourage cooperation, such as institutions, norms and reciprocity.

For money at its origin, institutions, norms and reciprocity are likely to be important underlying mechanisms for the following reasons. Establishing and enforcing rules that prohibit defaulting on debts and creating a system to track the movement of debts allows anyone to use any token as money. The debt that the token signifies is guaranteed to be repaid due to the existence of these rules, which means that accepting the token in exchanges is not accompanied by the risk that one has given away one's goods for a valueless object that will provide no benefit. In the absence of the ability to create such rules, social norms may emerge that determine that individuals should accept tokens from others on the basis of their reputations for repaying their debts. This creates an incentive for people to repay their debts as well as allowing individuals to avoid being cheated by limiting the parties they exchange with to those who are likely to repay. This mechanism requires some means of tracking information about people's reputations as well as a way of recording who owes what to whom.

Norms and reciprocity underpin broader, society-level economic performance in a similar way to how they affect money use. In the absence of legal institutions, individuals invest mostly in their in-group (Hruschka et al, 2014). This is because in-group members are invested in maintaining good relations with other in-group members, not least because one increases one's inclusive fitness by investing in closely-related others (Hamilton, 1964). While this maintains some economic activity, it drastically limits the scale of this activity, reducing the potential for economic growth. Institutions also have a similar effect on economic growth as on money use. Enforcing contracts allows individuals to exchange with anyone without fear of opportunism, which drastically increases the scale of economic activity.

Institutions also affect a further cooperative dilemma at the heart of economic performance, which is the abuse of power (Wahl, 2014). Economies are supported by public goods such as centralised governments and infrastructure that require investment. For any given individual, not investing in these enables one to receive the benefits they provide without paying costs. In addition, when individuals do contribute to these public goods, elites then have to ensure that these resources are allocated in a way that maintains important infrastructure. In the absence of checks on elites, these resources can be allocated inappropriately, often to the personal benefit of privileged elites (Tabellini, 2008). The ability of a society to enforce rules that control corruption correlates strongly with the quality of their infrastructure, their ability to enforce contracts and the effectiveness of their bureaucracies (Tabellini, 2008).

As norms and institutions change in their effectiveness and scope, the payoff structure of cooperative dilemmas central to the development of economies varies. Different ways of acting in economic situations are legitimised, and the extent to which activities such as money use and anonymous exchange can take place is determined. I aim to investigate the role of these various conditions, which can be social, historical or ecological, in the development of economies and the emergence of money.

Specifically, there are a number of questions as of yet unresolved that I seek to answer. The first question is to what extent historical and ecological variables affect economic performance directly compared to through their influence on cultural traits such as institutions and norms. The second concerns to what extent shared cultural history explains modern day variation in economic development, and whether this demands a change in how cross-country modelling is conducted. The third question is whether societal variation

in token money use is explained by institutions and norms, or other factors that affect cooperation such as food stress. This informs further questions about whether the emergence of token money is associated with particular conditions and whether the debt theory of money is viable. The fourth question is whether specific social systems like indirect reciprocity that are known to underpin cooperation can drive the emergence and maintenance of money systems based of valueless tokens. These outstanding questions are the focus of the thesis.

Outline of thesis

The thesis will be structured as follows: I will next present a broad methods section outlining the methodological approaches and statistical techniques used in my analyses. In this section I will introduce experimental and cross-cultural comparative approaches, discuss their advantages and disadvantages, and explain how I use a combination of them both to address the aims introduced in the literature review. I will then present four analysis chapters, which will each contain individual literature reviews, methods, results and discussion sections. The first two analysis chapters will compare hypotheses for cross-national diversity in economic performance and the latter two will test hypotheses for the emergence and use of token money. "**Long-run historical and ecological determinants of economic development mediated by the cultural evolution of effective institutions**" seeks to evaluate the relative contributions of history, ecology, norms and institutions to economic performance, and the causal pathways through which they exert their effects. "**Assessing the importance of shared history in shaping patterns of modern day socioeconomic development**" specifically tests the role of

shared history in economic performance. “**The cultural evolution of token money**” explores the effects of institutions, norms, ecological factors and societal organisation on the probability that traditional societies use token money. “**An experimental test of the tokens-as-debt theory for the evolution of money**” investigates the roles of reciprocity and social information in token money use. The **Discussion** chapter that follows these analysis chapters will contextualise my findings within the broader literature, bring my different analyses together to make more general conclusions, and suggest avenues for future research.

Chapter 2: Methods

In this methods chapter, I will set out the methodological and statistical approaches that are used in the thesis. I will first introduce the two broad approaches that are used in this thesis: cross-cultural comparative methods and experiments. I will discuss their strengths and weaknesses and explain how I use them to test the hypotheses I have developed in a cultural evolutionary framework. I will then introduce two statistical techniques that feature prominently in the thesis: structural equation modelling and multilevel modelling. I will describe their main features and explain how these features make them well-suited to the questions addressed in this thesis. I will also introduce the broader information-theoretic approach that informs all my statistical analyses.

Cultural evolution is a broad theoretical framework, involving different ways of asking questions and finding evidence. Some studies focus on the selection component of cultural evolution, using cross-sectional data to evaluate whether certain ecological or social conditions are associated with cultural traits. Other studies concentrate on inheritance, using experimental studies or longitudinal data to investigate changes in traits over time. I use a combination of these approaches, using cross-sectional analyses, historical data and an experiment.

Cross-cultural comparative analysis

Cross-cultural comparative studies are central to anthropology and cultural evolution (Nunn et al, 2006). Comparing the cultures, social systems, environments and histories of different societies allows us to generate ideas about whether there are common influences that predict similar outcomes. Some conditions may reliably co-occur with a particular cultural trait, while

variation in other conditions may not be associated with the existence of the trait. This enables us to see whether various cultural traits are distributed in ways consistent with hypotheses about how they evolve. This approach has commonalities with the comparative approach used in biology, in which the comparison of different species (whether living or fossilised) is used to draw inferences about the conditions underpinning the emergence of particular adaptations (Nunn, 2011).

Inferences from cross-cultural comparative study are strongest when they are based on a well-chosen and diverse sample of cultures that is appropriate for the questions being addressed. Databases such as D-Place (Kirby et al, 2016; Murdock, 1967) that compile various ethnographic atlases contain data from a large range of traditional societies that vary drastically in their environments, cultures and locations. This means that when consistent associations are found when comparing these societies, they are highly suggestive of functional relationships. These databases also contain large numbers of variables, which enables considerable control over confounding influences and allows one to isolate relationships of interest. This also allows the comparison of multiple competing hypotheses. A related strength of cross-cultural comparative study is that it is well-suited to analysing features at a societal level, where variation between cultures is predominant rather than variation within cultures. Some variables, such as institutions, economic systems and norms are features of the relationships between individuals and are commonly measured and explained at the societal level. For example, the emergence of religions (Sanderson & Roberts, 2008) and mating traditions (Ember et al, 2007) has been the subject of much study that uses the cultural,

ecological and historical diversity within the ethnographic atlases to test a range of evolutionary hypotheses.

The limitations of cross-cultural comparative study are primarily related to their data (Hartung, 1983). The data are normally from ethnographic studies that sought to codify behaviours into categories that are comparable across societies. At the very least, such codifying reduces the sensitivity of the data, concealing behaviours and practices that did not fit easily into pre-existing categories. Furthermore, many topics are described poorly in the ethnographic literature, or not described at all. Variables of interest may not exist, necessitating the use of proxies rather than direct measures which complicates the interpretation of any findings. Related to this is the fact that most ethnographic data are cross-sectional and therefore do not show change over time. Therefore, this makes it more difficult to draw definitive conclusions about the causal relationships between variables. We can only identify when the evidence is consistent with a hypothesis concerning the influence of one variable on another.

Another weakness of cross-cultural comparative methods is that it is difficult to distinguish whether cultural traits emerged independently, were inherited from ancestral societies, or were borrowed from other societies. Therefore, we cannot know whether cultural traits are functionally related to other cultural, environmental or historical factors, or if they happen to have been inherited or borrowed by societies in those conditions. This is made even more problematic by the fact that the societies that are likely to borrow ideas from one another are likely to be close in proximity and to have a relatively recent common ancestor (Currie et al, 2016), which means they share many cultural, ecological and historical traits. As I will elaborate in chapter 4, this can result in

repeated co-occurrences between a cultural trait and a particular ecological factor being interpreted as multiple instances of the same process in which the trait emerged as an adaptive response to the ecological pressure. In reality, this is only one of several explanations. It could be that societies facing similar pressure borrowed the trait instead of having it emerge endogenously, or it may also be that closely-located societies share the cultural trait by virtue of their recent common ancestry, and share the ecological pressure due to their location. In this latter case, the co-occurrence is present in the absence of any functional relationship between the ecological factor and the cultural trait.

In a later section of this methods chapter, I introduce the specific statistical techniques I use to overcome these difficulties with the cross-cultural comparative approach. Structural equation modelling takes steps towards finding firmer evidence regarding the directions of relationships, while multilevel modelling and sampling strategies like that used in the SCCS allow us to minimise the effects of cultural transmission and common ancestry among societies.

Experimental study

Experimental approaches complement cross-cultural approaches by providing a more controlled test of a specific relationship. Cross-cultural approaches seek to capture and account for many of the complexities of societies to establish which variables are related to others. Experimental approaches instead isolate relationships artificially, by creating conditions that systematically remove potential influences and allow the manipulation of only specific variables. As alluded to, the biggest strength of the experimental approach is control. Tightly restricting the factors influencing behaviour and the

behaviours people can make allows tests of the ways in which very specific changes alter how people behave. For this reason, experiments have high internal validity, meaning that the findings are highly likely to be attributable to manipulations made by the experimenter as opposed to any other source.

The primary limitation of the experimental approach is the external validity of its findings. Peoples' behaviours in artificial and highly controlled situations may not be particularly representative of how they behave in the real world where other influences and options are available to them. In many cases, this means that experiments are informative about the effects of variables in unrealistic conditions, but do not apply to any other situation. For example, at a fundamental level, participants change their behaviour when they know that their behaviours are being scrutinised (Levitt & List, 2007), which has been found to cause considerable differences in public goods contributions (among other behaviours) in laboratory and field conditions (Benz & Meier, 2008; Gneezy et al, 2004).

Using both cross-cultural and experimental approaches to address the same question can reduce the impact of their respective limitations. One can use an experimental approach to identify the specific mechanism by which variables are related, and then identify whether this relationship plays out in the real world using a cross-cultural comparative method. This combined approach uses cross-cultural comparative methods to clarify whether an experimental finding is representative, while at the same time using experimental approaches to provide potential explanations for observed relationships in cross-cultural samples. I use this combined approach to investigate the origins of token money in chapters 5 and 6. In the absence of any previous experimentation into token money that provides an explicit test of hypotheses for the emergence of

token money, the findings of any cross-cultural comparative analysis about money are difficult to conclusively explain. Therefore, I conduct such an experiment, seeking specifically to identify a mechanism by which token money can be used based on social information. I can then evaluate the plausibility of my interpretation of my cross-cultural findings in light of this underlying mechanism.

Structural equation modelling, multilevel modelling and the information-theoretic approach

Ordinary least squares (OLS) regression is the most commonly-used technique for statistically analysing the relationship between one or more independent variables and a dependent variable. It is the predominant tool used in cross-national analyses. In short, OLS regression estimates the relationship by producing the linear function that minimises the error between the actual values of the dependent variable and those predicted by the function. OLS regression is suited to the identification of direct relationships, as OLS regression evaluates the relationship between pairs of variables while controlling for other influences.

Cultural traits are not uniformly distributed around the world. Cultural evolutionary theory proposes that patterns of cultural similarity and difference are the result of inheritance and selection of cultural traits. Environmental and historical factors are important in shaping what cultural adaptations can emerge. Not only do they directly determine the success of specific traits, they shape sequences of cultural adaptations by determining the distribution of traits such as institutions or social norms that have knock-on effects on other traits. OLS regression is not well-equipped to deal with these networks of direct and indirect

effects. There are also more general processes underpinning patterns of cultural diversity. Some societies are more similar than others due to borrowing of ideas and recent common ancestry. In OLS regression however, observations of the error term are assumed to be independent, meaning that one society's score on a measure is not related to another's score on the same measure. If this assumption is violated, the clustering of scores resulting from non-independence can inflate estimates of the significance of relationships between variables. Multilevel models can account for these patterns of non-independence, while structural equation models can explicitly model indirect and direct relationships.

While these types of models have begun to gain traction in the evolutionary literature, their justification is often theoretically weak and there is no established protocol for their use. For indirect effects and non-independence in turn, I introduce them as problems for existing statistical approaches and as issues of interest for cultural evolutionary theorists. I then propose a statistical approach based on information-theoretic ideas to guide the usage of multilevel models and SEMs to answer evolutionary questions.

Structural Equation Modelling

Indirect effects in evolutionary theory

The social environment in which humans live and behave is hierarchically structured. Everyday social interactions are located within population-level legal and regulating systems and social norms. These are all seated against an overarching ecological and historical background. Many hypotheses for how these different factors interact and shape one another have been put forward in the evolutionary literature. The environment is considered

one of the central sources of selective pressure on cultural traits, determining the most successful subsistence strategies, social norms and social institutions (Nettle, 2009). Climate, agricultural productivity and disease all have roles in shaping differences in human culture. Historical events can also shape what subsequent innovations are likely and/or possible. For example, the industrial revolution changed the nature of production and labour in ways previously unthinkable. Existing theories about the roles of historical and ecological factors in cultural diversity assume that the most important relationships are direct. Specific factors such as disease levels are directly associated with the prevalence of a particular trait, such as collectivism.

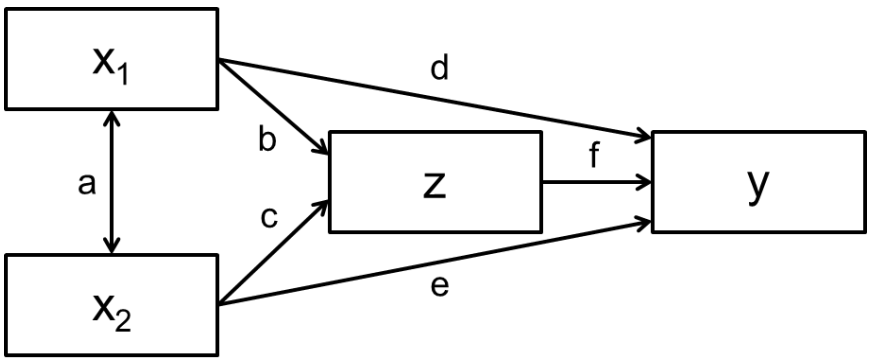
Cultural evolutionary hypotheses, however, are becoming increasingly interested in sequential relationships involving more than two variables. Historical and ecological conditions provide the selective environment for certain cultural traits, the diversity in which then feeds into the likelihood of subsequent cultural adaptations (Leung & van de Vijver, 2008; van de Vijver et al, 2007). For example, polygyny is influenced by variation in a society's sex ratio, and a society's sex ratio is shaped by ecological factors (Nettle, 2009). In this case, it is theoretically important to recognise that the emergence of polygyny is ultimately a reflection of ecological factors. Separating when ecological or historical factors are associated with a given cultural trait directly or indirectly by shaping another aspect of culture is key to investigating a range of evolutionary hypotheses and understanding cultural diversity.

Structural equation modelling:

Structural equation modelling (SEM) is one way to separate direct and indirect effects. SEM is a statistical technique that combines several multivariate

procedures: factor analysis, path analysis and multiple regression. It is characterised by its visualisation as a graphical path diagram that represents the complex network of relationships between observed variables and the unobserved factors that underlie them. The technique has a wide range of applications, and has several key advantages over OLS regression.

SEM's path analysis component enables the user to test hypotheses about causal relationships by creating models that make direct and indirect relationships explicit (Figure 2-1). The ability to simultaneously estimate how much a variable influences another variable directly, through a relationship with a third variable, or both directly and indirectly is in contrast to OLS regression. Mediation analyses in which one tests whether two variables are related directly or through an intermediary variable are possible using OLS regression, but this is a multi-stage process that involves several separate analyses. Multiple comparisons are a known problem in statistics, as null-hypothesis significance testing commonly accepts 5% as the probability that a given finding is a false positive resulting from sampling error, which means that as the number of tests increases, the expected number of false positives increases (Benjamini & Hochberg, 1995). Consequently, SEM's ability to simultaneously estimate parameters makes it an attractive technique to test between direct and indirect effects.



Effects of x_1 on y:	
Direct effect	d
Indirect effect through z	b*f
Indirect effect through x_2	a*e
Indirect effect through x_2 and z	a*c*f
Total indirect effect	(b*f)+(a*e)+(a*c*f)
Total effect	(b*f)+(a*e)+(a*c*f)+d

Figure 2-1: *An SEM path diagram showing the calculation of direct and indirect effects*

Single-headed arrows represent relationships between a predictor variable and an outcome variable. Double-headed arrows represent covariances that do not distinguish predictor and outcome variables.

Separating direct and indirect effects using SEM avoids one common issue with interpreting the results of an OLS regression that emerges when indirect effects exist in the system under study. OLS regression is only concerned with direct effects, so it interprets weak coefficients as an indication that the predictor variable is not important for explaining variation in the outcome variable. By contrast, SEM can distinguish between a weak coefficient that is the result of no relationship between a predictor and an outcome, and a weak coefficient that is the result of the predictor variable affecting the outcome by producing changes in another predictor. Therefore, while OLS regression simply rejects hypotheses concerning the importance of predictor variables based on weak direct relationships, SEM captures when predictor variables are still part of the explanation despite not being directly associated with the outcome variable.

Furthermore, OLS regression cannot explicitly account for specific relationships between different predictor variables. In OLS regression, relationships between a given predictor and the outcome variable are presented as having controlled for the variance in other independent predictors. In SEM, you can explicitly specify the covariation between different predictor variables.

This enables the user to construct a model that takes into account a relatively high level of detail about the variables involved, and estimate parameters based on all the available information.

SEM has been used to investigate a range of questions, including what factors affect fitness in plant populations (Iriondo et al, 2003), the pathways through which hormones affect aggressive behaviour in lizards (Yang & Wilczynski, 2002) and the precise ways in which coping strategies predict positive and negative emotions in humans (Roesch et al, 2010). These and other studies have deployed SEMs in different ways. Some are relatively exploratory, creating detailed models involving every known direct and indirect pathway and evaluating the relationships that are estimated (Iriondo et al, 2003). Others are interested in how accounting for the network of relationships between different predictor variables influences the direct relationships between those predictor variables and the outcome variable (Roesch et al, 2010).

Information-theoretic approach to testing hypotheses

Increasingly, researchers are taking an information-theoretic approach (see Figure 2-2 for a summary) (Burnham & Anderson, 2010) to SEM. This approach broadly involves the comparison of multiple candidate models in terms of their relative uncertainty. This enables explicit testing between multiple competing hypotheses, as opposed to the approach of null hypothesis significance testing which compares the likelihood that a finding supports a single hypothesis or that there is no effect at all. Using the information-theoretic approach, I can also use the valuable information that poorly-supported models provide to improve parameter estimates, as opposed to simply rejecting them.

Aggregate parameter estimates can be created by combining all the estimated relationships weighted by their model fit.

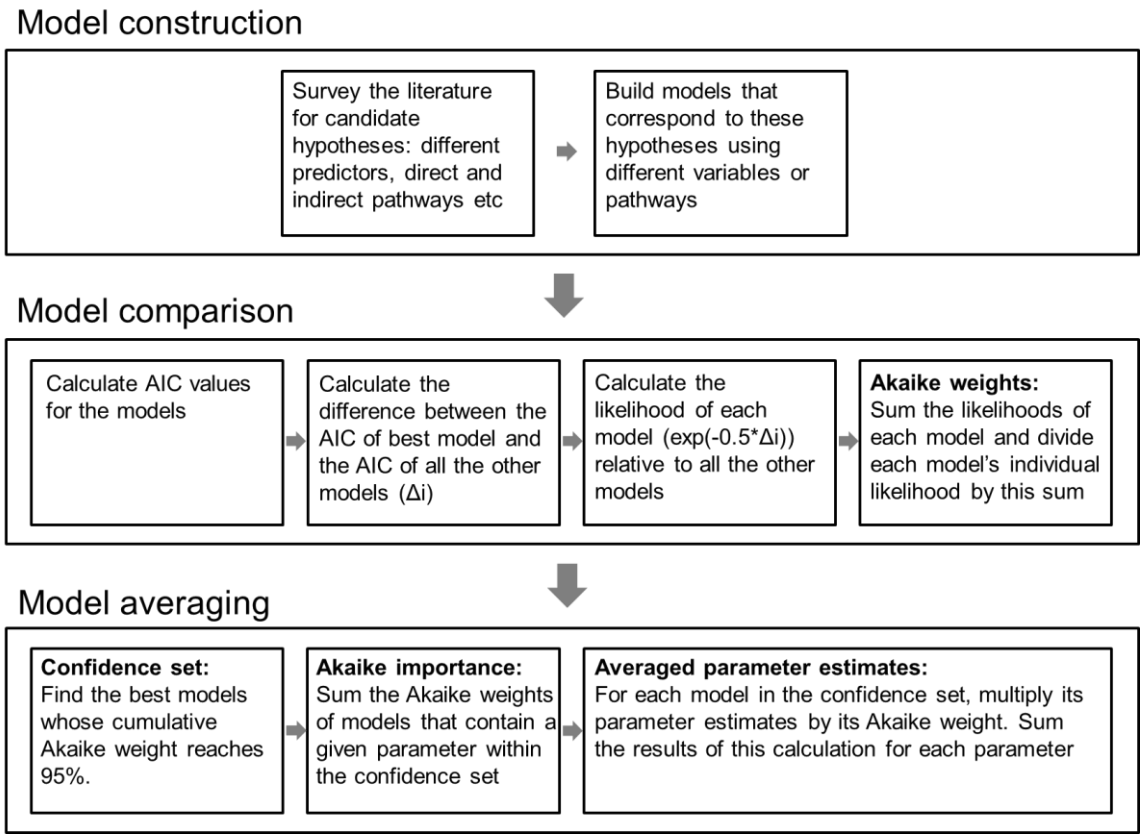


Figure 2-2: *Schematic of the information-theoretic approach*

In the case of SEM, an information-theoretic approach first involves the construction of several different models that correspond to the expectations of different hypotheses in advance of analysis. These models capture different hypotheses by including different combinations of indirect pathways, direct pathways and predictor variables. These models are then compared using indices of model fit. Such indices include the Akaike Information Criterion (AIC), which is a likelihood function that is penalised for the number of parameters estimated. The likelihood value is derived from calculation of the likelihood of finding the observed parameters given the distribution of the data. The penalty

related to parameter numbers generally causes a preference for simpler models over complex ones in terms of the number of parameters estimated.

For example, competing hypotheses about whether a particular ecological or historical factor has a direct influence on behaviour or influences behaviour by changing social norms can be tested by comparing the AICs of models with and without the indirect pathway (Figure 2-3). This approach has the advantage of being necessarily hypothesis-driven, allaying recent concerns about dredging, stepwise approaches and uninformative comparisons so designed as to privilege preferred theories.

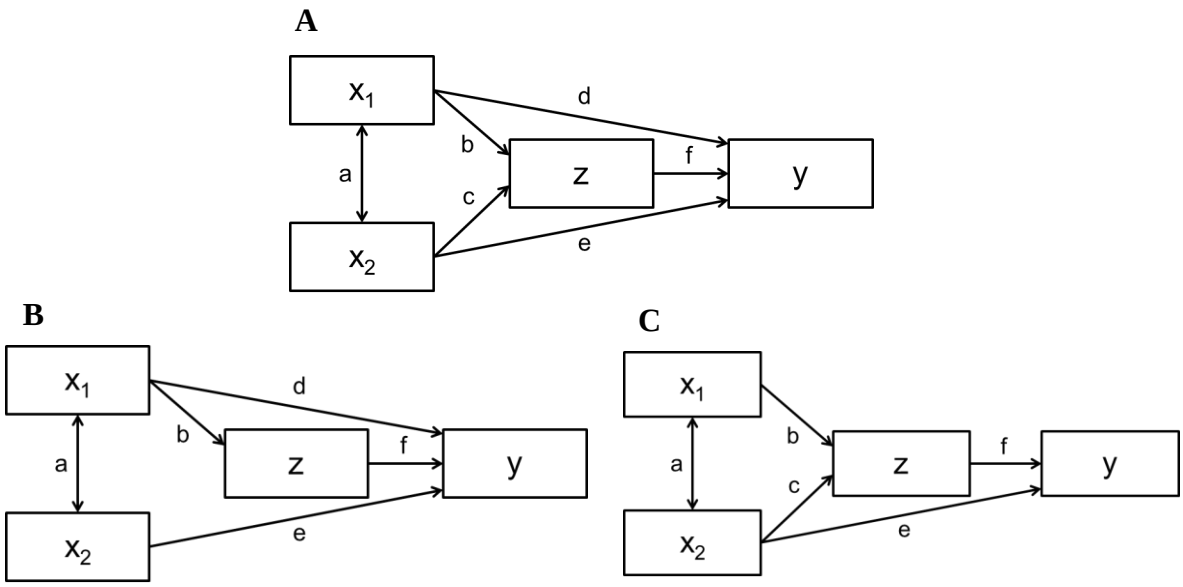


Figure 2-3: *An information-theoretic approach to SEM*

Comparing the fit of models A and B would inform whether the effect of x_2 on y is mostly direct through pathway e or indirect through pathway c. Comparing A and C would inform the importance of a direct effect of x_1 on y through pathway d.

Worked SEM Example:

Figure 2-4 shows a worked example of hypothesis testing using an information theoretic approach to SEM. The pathogen stress theory claims that the frequency of pathogens in the environment influences social behaviour and in particular, the extent of collectivism. A high prevalence of infectious disease

introduces risks to communicating with outgroups because they may harbour novel diseases the contraction of which would be costly to fitness. Global correlations between pathogen prevalence and collectivism have been reported (Fincher & Thornhill, 2012) and disputed (Currie & Mace, 2012; Hackman & Hruschka, 2013). I show how accounting for theoretically-driven mediators enables me to conclude that disease does not directly influence collectivism, but instead helped to shape the global distribution of European populations who are characterised by individualism.

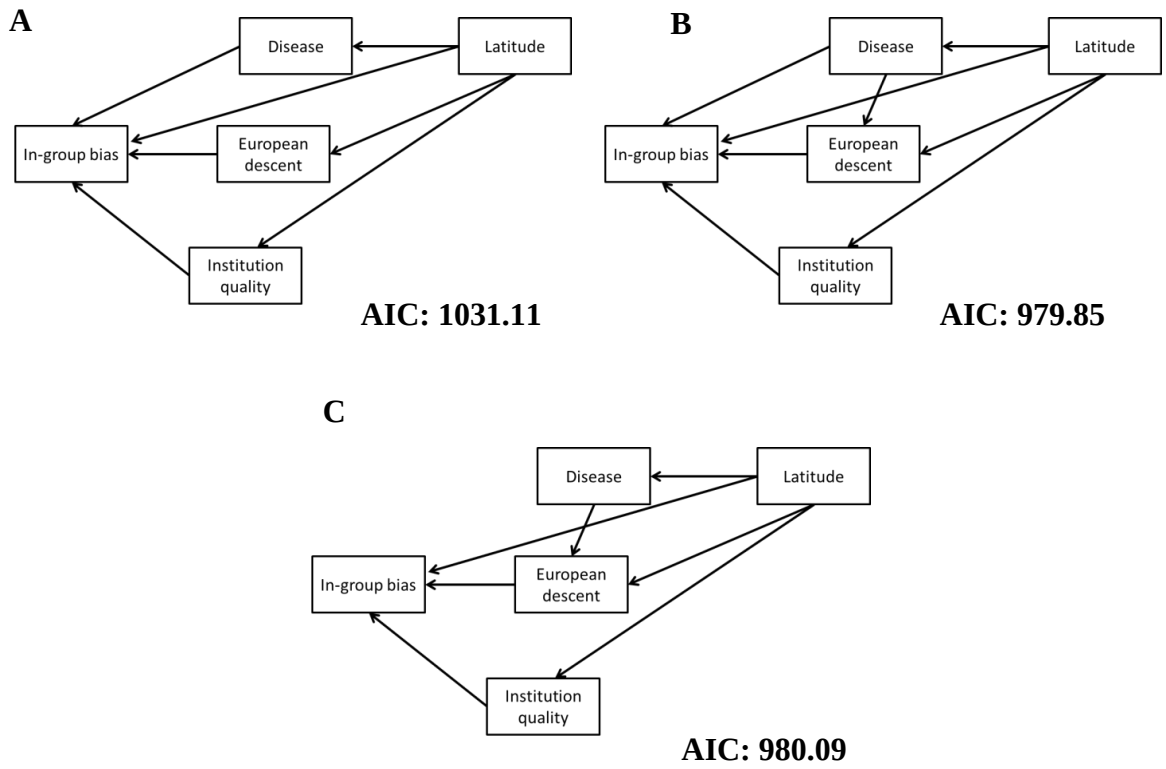


Figure 2-4: *An information-theoretic model comparison using SEM*

In panel A, I present a baseline SEM containing simple hypotheses. Disease (and my other predictor variables) is modelled as directly influencing collectivism and as varying with latitude. The remaining panels present the hypothesis test. In panel B I introduce an alternative hypothesis, in which disease shapes patterns of European migration. Accounting for this pathway

greatly improves model fit. In panel C, I show that removing the direct pathway from disease does not substantially worsen the fit of the model in panel B. Comparison of these models supports the idea that disease has a meaningful influence on European descent, which has knock-on effects for collectivism, but less support is shown for the importance of a direct pathway between disease and collectivism.

Table 2-1: *Method of computing Akaike weights from AICs in the example model comparison*

Model	AIC	Δ_i (AIC-lowest AIC in sample)	exp(-0.5*Δi)	w_i (exp(-0.5*Δi)/sum(exp(-0.5*Δi) for all models)
A	1031.11	51.26	<0.001	<0.001
B	979.85	0	1	0.53
C	980.09	0.24	0.89	0.47

From such a model comparison, one can compute Akaike weights, Akaike importance values and weighted parameter estimates. Akaike weights are derived by scaling the difference between the AICs of each model and the best-fitting model between 0 and 1 to provide a measure of the probability that a given model is the best-fitting model among the candidate models (Table 2-1). In the right-hand column of Table 2-1, I show that model A is extremely unlikely to be the best-fitting model, while models B and C are highly likely with model B being the most likely. Summing the weights for all the models that include a given variable gives the Akaike importance value for that variable, which provides an indication of whether the variable tends to appear in the best-fitting models or worse-fitting models, and therefore the likelihood that the variable contributes to the explanation of variation in the outcome. Finally, the parameter estimates provided by a given model can be weighted by the probability that the model is the best-fitting model (the Akaike weight) which enables the creation of

parameter estimates that take into account differences in model fit (Table 2-2). In Table 2-2, I show that this model comparison approach allows one to account for when strong coefficients tend to be found in poorly-fitting models. Any of the coefficients found in model A do not contribute much to the weighted parameter estimate, as model A was very unlikely to be the best model. Parameter estimates from models B and C contribute more to the weighted parameter estimate as they were highly likely to be the best model. In this case, European descent had its strongest parameter estimate in one of the best-fitting models, which suggests that European descent is likely to be an important predictor. In general, the averaging process involved in computing these statistics aims to account for uncertainty about the best model. This is unlike null hypothesis significance testing, which can only conclude that a single model is preferable to no model, and accept the parameter estimates of the former model on this basis. It should be noted that this is an overly-simplified and unrealistic example of a model comparison, as most model comparisons with so few variables should have a balanced set of models where all variables appear the same number of times. This balance allows researchers avoid bias in their findings, as it prevents the artificial inflation or deflation of weighted parameter estimates that may occur when variables only appear in the best or worst fitting models.

Table 2-2: *Method of calculating weighted parameter estimates from the example model comparison*

Outcome Predictor	Model A	Model B	Model C	Weighted estimate
Ingroup bias				
Disease	0.16 (<0.001)	0.16 (0.08)		0.08
European descent	-0.06 (<-0.001)	-0.06 (-0.03)	-0.13 (-0.06)	-0.09

Numbers in brackets represent the parameter estimate multiplied by the Akaike weight of the model shown in Table 2-1. The weighted estimate is the sum of the numbers in these brackets.

Multilevel models

Non-independence in evolutionary theory

Indirect effects are one expectation that emerges from a cultural evolutionary framework. Another is that some societies are more similar than others in measurable ways. Phenomena at different scales such as individual behaviours, local norms, broad ecological factors and shared historical events have traditionally been analysed independently due to statistical convenience and a history of independently-working disciplines (van de Vijver et al, 2007). As such, studies of human behaviour have been predominantly single-level, meaning that they are concerned with sources of variation only at the level of the individual or country, for example, but not both.

Another important reason for the dominance of single-level methods is the statistical assumption of independence. Commonly-used techniques such as OLS regression assume that an individual or society's score on a measure is not related in any way to another individual or society's score on the same measure. Recognising that different individuals come from the same geographical region, and that these regions are grouped within the same country violates this assumption, which encourages researchers to focus on a single level of analysis and ignore potential groupings at other levels. Statistically, independence is an important assumption that is made to avoid finding spurious relationships. If observations are similar by virtue of some dependence between them, they do not provide different pieces of separate information in the same way observations that are completely independent would. If several dependent observations are treated as independent data points, their clustering on measures of interest can strengthen the extent to

which certain variables appear to covary with one another, leading to erroneous inferences about existing relationships. This is known as Galton's problem.

While the assumption of independence aims to exclude any systematic similarities and differences between individuals or societies from the analysis, these cultural similarities and differences are of interest to cultural evolutionary theorists. Many evolutionary hypotheses are specifically concerned with the processes that make some societies more similar than others. The likelihood of sharing ecologies or cultural traits is associated with the recency of shared cultural history. Over time, populations diverge to form new populations that share most or all of the cultural features of the original population. Repeated bouts of this divergence, along with cultural innovation in daughter societies, leads to cultural phylogenies analogous to the evolutionary trees used to explain biological diversity. Outside of all other influences, societies that separated more recently will be more similar than those that separated longer ago. These sources of statistical non-independence between individuals and societies mean that we need a different method to recognise and adjust for the fact that some data points are more similar than others.

Multilevel modelling

Multilevel models are designed to account for hierarchical structure in a dataset. These models separate predictor variables on the same scale as the outcome variable (fixed effects) from grouping variables at a different level that categorise observations into different groups based on theories for why some groups of observations might be more similar to each other than to others (random effects). This enables potential relationships between observations to be accounted for, as opposed to assuming independence for statistical

convenience. While OLS regression can have similar controls by including categorical grouping variables as predictors, there are statistical and theoretical reasons to prefer multilevel modelling. In OLS regression, imbalances between the numbers of members of different groups can compromise statistical power, and grouping variables are treated as another parameter to estimate. In multilevel models, groups can have any number of members, and the groups are considered a general underlying source of variability in the outcome variable rather than having a directional effect on it.

Multilevel models are being used increasingly in the behavioural sciences. Schools, countries and other variables have been used to group observations in ways that capture similarities in their behaviour (Kreft & de Leeuw, 1998). Analyses using multilevel models have revealed that several well-publicised theories are based on spurious relationships that reflect pseudoreplication of non-independent observations rather than associations between two variables. For example, the global relationship between infectious disease and collectivism is non-existent within geographical regions (Currie & Mace, 2012), reflecting the fact that Western European countries that are both individualist and have effective health services were inappropriately treated as independent data points despite being very closely related.

Despite these statistical advantages, accounting for the hierarchical structure of a dataset increases model complexity relative to a single-level OLS regression and therefore requires detailed justification. The extent of non-independence between observations and how best to account for it is an empirical question, especially as observations simply being close in space or time does not necessarily entail similarity (Schank & Koehnle, 2009). The grouping variables used to account for the hierarchical structure of data

therefore need to be as theoretically motivated as any other variable included in the model. As of yet, there is no precedent that has established what particular causes of non-independence are most important to account for. Many analyses use convenient grouping variables to capture non-independence, such as states or zip codes (Kakkar & Sivanathan, 2017). But they tend not to justify the theoretical reasons why these particular grouping variables should cause scores on variables of interest to cluster. They also often fail to establish, in the absence (and presence) of all other effects, whether there is any clustering at the level of the grouping variable and therefore whether the grouping variable can correct for non-independence in the data.

Cultural evolutionary theory provides a theoretical framework that can be used to identify meaningful sources of non-independence in models of human behaviour. Shared ecology, shared history and shared social ties predict cultural similarity and delineate the boundaries of idea-borrowing. Broad grouping variables can be used as random effects to capture these sources of non-independence. For example, continents delineate broad regions of ecological similarities (within which cultural traits may have been more readily borrowed), language families offer a measure of the recency of societies' common ancestry and shared religions provide an indication of communication and borrowing between populations. These different sources of non-independence also span different timescales. Ecological differences between the modern-day continents have existed for millions of years, the diversification of human languages began on the order of tens (to hundreds) of millennia ago (Dediu & Levinson, 2013), and different organised religions have spread between human societies for the last few millennia.

Language families can be used as a proxy for cultural inheritance because they capture instances of cultural diversification. As discussed in the introductory chapter, population splits are associated with the onset of cultural differentiation due to ecological changes resulting from migration of subgroups and errors in social learning of existing cultural traits within subgroups. These errors in learning can also affect aspects of language. This leads to linguistic differences between groups that co-occur with the emergence of cultural differences. In other words, societies that share the same language likely maintain language similarity through communication and sharing of culture. Those that differ in their languages are likely to have separated a sufficiently long period of time ago to allow cultural differences to accumulate, which also means that those that separated longer ago have had more time for greater cultural differentiation to take place. In support of this cultural evolutionary mechanism, the diversity in political systems (Currie et al, 2010), subsistence strategies (Mace & Holden, 2005) and material culture designs (Tehrani & Collard, 2002) (among other cultural traits) have all been found to be related to linguistic differences between societies. Many of these studies have used detailed phylogenetic comparative methods in which the data on linguistic or cultural traits are used to generate a most-likely phylogenetic tree of societies, which is argued to represent their shared ancestral relationships. However, modern countries are comprised of numerous populations and so it is not straightforward to represent the relationships between countries using a phylogenetic tree. Using language families as random effects is one way of at least partially tackling this issue by grouping countries based on features of their populations. Therefore, in chapter 4, I seek to develop a protocol for using language families to adjust for statistical non-independence between countries

and to partition the variation in cultural traits between modern societies and historical groups based on shared history that can be easily adopted in subsequent research. Consequently, I focus on the use of language families as a random effect as opposed to using phylogenetic comparative methods.

Like SEM, multilevel modelling can be undertaken using an information-theoretic approach. The intra-class correlation coefficient (ICC) is a measure of the variation in the outcome variable explained by the grouping variable. Examining changes in the ICC and changes in the estimates of fixed effects between models that include or exclude a random effect and have different combinations of fixed effects offers two insights. First, it tells us how much variation is being captured by the grouping variable; and second, it indicates whether any of the variation explained by the fixed effects is independent of the variation captured by the grouping variable. This second insight provides information about how pseudoreplication that is now being accounted for by the grouping variable had been contributing to observed relationships. If including a random effect reduces the strength of the relationship between two variables, this suggests that the relationship was in part caused by the underlying structure of the data in which some observations cluster together. Including random effects can also increase the strength of relationships, which indicates that the grouping variable correlates more strongly with the residuals of the fixed effects model than with the raw outcome variable itself.

Worked Multilevel Model Example

Social norms such as collectivism are said to be associated with ecological conditions, historical events and the composition of a society's population, particularly with regard to immigration of relatively individualist

Europeans (Eisenberg & Hayes, 2011). In addition to these influences, societies that diverged more recently are likely to be generally more similar in their social norms, including collectivism. Below I present an example analysis using multilevel modelling that emphasises the importance of accounting for this general similarity before evaluating the role of any other predictor variables.

Table 2-3: *Comparison of parameter estimates with and without multilevel modelling*

Outcome Predictor	Without random effect	With random effect (language family)
Ingroup bias		
European ancestry	-0.23	-0.39**
State history	-0.23*	-0.12
Timing of agriculture	0.29**	0.05
Disease	0.44***	0.25*
Latitude	0.11	0.07
Language family (ICC)	-	0.39
AIC	262.17	**230.99**

*Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

Table 2-3 shows that my example illustrates the important outcomes of accounting for variation in collectivism that is the result of clustering in the dataset. Accounting for the clustering using language families improves model fit and it causes meaningful changes in parameter estimates. If I fail to account for the structure of the data, my model leads me towards state history, the timing of agriculture and disease as important predictor variables. Once I take the data structure into account, my interpretation changes to include effects of European ancestry and a much-weakened effect of disease. The ICC value illustrates the reason for this, showing that there is substantial variation at the level of the language family (39%) which is driving patterns of variation.

In summary, SEM and multilevel models can be used to address two long-standing issues in cross-cultural research. SEMs can account for detailed networks of direct and indirect effects, and multilevel models can establish and control for the extent of statistical non-independence in the data. These issues are particularly important from a cultural evolutionary perspective, which anticipates that some societies are more closely-related than others, and that many ecological (and cultural) changes may have indirect effects on many aspects of culture and behaviour by shaping behaviour-regulating mechanisms such as traditions, norms and institutions. In the next chapter, I show how SEM and multilevel modelling can be combined to simultaneously investigate networks of direct and indirect effects while controlling for statistical non-independence.

The following four chapters will be my analysis chapters. The first three will be secondary data analyses and the last one will be an experiment. Each of these chapters contains their own specific methods sections. In these sections I will provide greater detail on the specific variables and statistical tests of my secondary data analyses, and elaborate on the design and testing of my experiment. The information-theoretic and multilevel approach will be adopted in every one of my analyses.

Chapter 3: Long-run historical and ecological determinants of economic development mediated by the cultural evolution of effective institutions

Abstract

A huge number of hypotheses have been put forward to explain the substantial diversity in economic development. There is growing appreciation that cultural evolutionary processes may have played an important role in this emergence of this diversity. Historical factors such as the length of time societies have had experience with centralized political governance, or how long they have employed agricultural subsistence strategies have been presented as explanatory factors that have contributed to present-day economic performance. However, it is not clear whether duration of agriculture and ancestral statehood have exerted a direct effect on modern productivity, or whether they influence economies indirectly by shaping the evolution of norms or formal institutions. Here I use structural equation modelling and a global nation-level dataset to test between hypotheses involving a range of direct and indirect pathways. I show that the historical timing of agriculture predicts the timing of the emergence of statehood, which in turn affects economic development indirectly through its effect on institutions. Ecological factors appear to affect economic performance indirectly through their historical effects on the development of agriculture and by shaping patterns of European colonization. These results support the idea that cultural evolutionary processes have been important in creating effective institutions that enable large-scale cooperation and economic growth in present-day societies.

Introduction

Economic development is not equally distributed around the world. In 2017, the total GDP of the top 6 countries in the world exceeded the total GDP of the remaining countries (IMF, 2018). Economists and other researchers have long debated the proximate causes of development in terms of the technological and policy factors that create economic growth. In the last few decades, institutions that encourage the participation of more of the population in economic affairs, enable markets and provide incentives have become the central explanation (Acemoglu & Robinson, 2012; Milgrom et al, 1990; North, 1990; Rodrik et al, 2004). More recently, researchers have sought to understand how historical (e.g. Bockstette et al, 2002; Michalopoulos & Papaioannou, 2013; Putterman, 2008; Putterman & Weil, 2010; Spolaore & Wacziarg, 2013) and geographical (e.g. Bonds et al, 2012; Hibbs & Olsson, 2004; Sachs & Malaney, 2002) factors have shaped the development of societies and their institutions. However, the causal pathways through which historical processes have shaped economic development are heavily disputed.

Here I employ cultural evolutionary theory (Boyd & Richerson, 1985; Henrich, 2016; Mesoudi, 2011) as an organising framework to examine how these alternative explanations fit together and to test between competing hypotheses. My cultural evolutionary approach is complementary to existing approaches in economics and economic history, helping us to understand the general processes of how factors affect economies over time (Currie et al, 2016; Spolaore & Wacziarg, 2013; Wilson, 2002). Employing an evolutionary approach helps us to distinguish between the features of current societies that affect economic growth (proximate explanations) and the processes that have occurred in the past that have shaped the modern day situation (historical

explanations) (Currie et al, 2016; Tinbergen, 1963; Wilson & Gowdy, 2013) (Table 3-1). Within the historical explanations I distinguish between events or factors that have directly shaped modern day economic outcomes from more indirect pathways where historical processes have shaped the evolution of proximate determinants (e.g. modern institutions are themselves shaped by previous institutions and the social and ecological conditions in which past societies evolved). Indirect effects have featured in previous theories of economic development (Rodrik et al, 2004; Spolaore & Wacziarg, 2013), but these theories are yet to be matched with statistical techniques specifically designed to identify the importance of indirect effects relative to direct effects. Consequently, the relative importance of the different causal pathways in Table 3-1 remains unclear.

Proximate Explanations

A number of different factors have been argued to be important in directly determining economic development. I can divide these into the features of the populations themselves (endogenous factors) and the external context in which populations are situated (exogenous factors). Theories involving these proximate factors tend to be short-term in focus, arguing that changes in culture or the ecology will have immediate knock-on effects for economic performance.

Endogenous

Social rules (institutions) and norms govern social interactions and enable cooperation between individuals and organisations (Bowles & Gintis, 2011; Boyd & Richerson, 2009; Fehr & Fischbacher, 2004; Henrich & Boyd, 2001; Hruschka & Henrich, 2013a, b; Ostrom, 2000; Powers et al, 2016;

Table 3-1: *Hypothesised pathways through which endogenous and exogenous factors can influence the global distribution of economic development and its determinants. These factors can directly influence GDP, or can shape the evolution of other endogenous factors*

		Factors	
		Endogenous	Exogenous
Types of explanation	Proximate	*Direct* • **Institution quality** allows large-scale cooperation and provides incentives for labour and skill accumulation. • **In-group preferences** introduce risks of opportunism in certain scenarios and nepotism. • **Human capital** knowhow and technology aids productivity. *Indirect* • **Institution quality** determines the need for **in-group preferences** (and vice versa).	*Direct* • **Disease** affects labour productivity and investment. • **Climate** affects agricultural productivity. *Indirect* • **Disease** shapes **in-group preferences**
	Historical	*Direct* • Longer histories of statehood (**"state history"**) give a head-start to development. • Earlier transitions to agriculture (**"timing of agriculture**") give a head-start to development. *Indirect* • Longer histories of statehood ("**state history"**) gave societies more time to develop **effective institutions**/**norms** and to build-up **human capital**. • Earlier transitions to agriculture ("**timing of agriculture")** lead to earlier evolution of states.	*Direct* • Natural endowments of **resources** give a head-start to economic development. *Indirect* • **Favourable ecological conditions** lead to earlier **transitions to agriculture.**

Richerson & Henrich, 2012), and are central to the function of markets and governments; enabling contracts to be enforced, providing checks on potentially predatory elites, and shaping incentives for investment and improvement (Acemoglu & Robinson, 2012; Aoki, 2001; Greif, 2006; North, 1990; Rodrik et al, 2004). Such institutions can be supported by social norms such as trust (Ahlerup et al, 2009; Fukuyama, 1996; Greif, 1994). On the other hand, some social norms such as in-group preferences can lead to opportunism and corruption, which stymies economic activities (Gorodnichenko & Roland, 2011; Kyriacou, 2016). In addition to institutions and social norms, the more general body of knowledge, education and technology known as human capital may also be important in enabling economies to grow (Easterly & Levine, 2012).

Exogenous

The latitudinal patterning of economic development around the world is potentially suggestive of the importance of exogenous effects on economic performance. Countries nearer the equator are generally poorer than those at temperate latitudes. Environmental factors such as rainfall, temperature, and soil type may influence economic development due to their effects on the types of crop grown and productivity of agriculture (Lanzafame, 2014; Mayshar et al, 2015). Infectious disease may also be a major contributor, as high rates of disease reduce labour productivity and raise uncertainty (Sachs & Malaney, 2002). A recent example of this was the 2014-2016 Ebola epidemic, which drastically cut the income growth estimates of Guinea, Liberia and Sierra Leone, implying forgone income of $1.6 billion for the countries combined (World Bank, 2016).

Historical Explanations

Direct

Longer-term, historical events and the experiences of ancestral societies may exert persistent effects on the economies of their descendants. The fact that some societies developed agricultural forms of production (herding and cultivation), centralised states or industrialisation earlier than others may have provided a head-start to those societies (Diamond, 1997; Putterman & Weil, 2010) and may have given them an advantage over other societies by allowing them to establish and maintain favourable positions in networks of interactions. For example, some European countries profited from establishing colonies in other parts of the world that extracted resources and exploited native populations (Acemoglu & Robinson, 2012; Nunn, 2008).

Indirect

Another possibility is that historical processes such as the development of agriculture and the emergence of states have influenced the evolution of modern institutions, norms, technology and human capital. Cultural traits such as norms and institutional rules are inherited across generations and are shaped by those that preceded them (Currie et al, 2016). Complex collective action problems may not be easy to solve directly through conscious forward planning. Instead they may require long periods of experimentation and progressive refinement in order to develop the kinds of norms and institutions that lead to positive economic outcomes (Henrich & Richerson, 2012; Currie et al, 2016). For example, democratic traditions in ancestral societies predict how effective the democratic systems of their descendants will be (Giuliano & Nunn, 2013). In a similar way, the development of institutions that allow more people

to participate in economic and political activities such as the rule of law may lead to the development of further such inclusive institutions (Acemoglu & Robinson, 2012).

Owing to these cultural evolutionary processes, features of states may contribute to the development of traits associated with economic success in a number of ways. The centralization of institutions is thought to be an important mechanism for facilitating cooperative interactions and enabling the coordination of individuals over large geographical areas (Mattison et al, 2016; Powers et al, 2016; Spencer, 2010; Turchin et al, 2013; Turchin & Gavrilets, 2009) and is argued to be a key feature that supports inclusive institutions (Acemoglu & Robinson 2012). A long history of statehood may also reduce lower-level in-group biases and lead to the emergence and spread of impartial social norms. States also create public goods and infrastructure that lead to increases in human capital and facilitate technological innovation and production (Murtin & Wacziarg, 2014; Sokoloff & Engerman, 2000).

Another pathway to consider is that the management of crops leads to sedentism, specialisation of labour, increased population densities and more complex forms of political organisation and eventually the evolution of 'bureaucratic' states (Johnson & Earle 2000; Mattison et al, 2016). These features may in turn be advantageous in competition between groups and give some societies a head-start (Turchin et al, 2013). Furthermore, the earlier societies developed agriculture and state-level organisation the more time they have had to develop institutions and culturally-inherited social norms that can help solve collective action problems and set the foundations that facilitate economic development. Variation in the timing of the development of agriculture

and the emergence of states may in turn be influenced by environmental factors.

Another indirect pathway involving environmental factors that has been studied involves the processes and effects of European colonialism. Broadly speaking, Europeans settled in large numbers in regions where existing populations were at low density with less complex forms of socio-political organisation and where there was less exposure to unfamiliar diseases (i.e. North America, Australia, New Zealand) (Acemoglu & Robinson, 2012; MacNeill, 1977; Diamond, 1997). As they settled they transplanted their domestic institutions and human capital. In colonies where large-scale societies had already existed (e.g. Central America, Peru) or where disease burdens were high (e.g. malaria in West Africa (Crosby, 2004)), Europeans settled in smaller numbers, normally as an elite, and established institutions that extracted labour and resources from the native populations. The larger, more inclusive colonial societies and/or the human capital that settlers brought with them are thought to be more conducive to economic growth than the kinds of societies settled only by an extractive elite. Under this view environmental differences shaped economic development indirectly by affecting the evolution of institutions and culture.

Testing Alternative Hypotheses using Structural Equation Modelling

The discussion above demonstrates that there are a number of alternative hypotheses and a number of different causal pathways through which different factors may affect economic outcomes. In order to make all of these hypothesised pathways explicit I employ SEM. SEM allows the construction of models that contain both direct and indirect pathways, making

numerous candidate models possible given the same set of variables. Unlike multiple regression, SEM clarifies how much of a given variable's effect on another is through a different variable and estimates direct and indirect effects simultaneously, allowing me to evaluate the relative importance of different pathways involved in economic development.

Using SEM, I focus on whether state history and the timing of agriculture affect economic development (GDP) directly or indirectly through institutions and in-group bias. To do so I compare all combinations of these pathways. Before this comparison I use standard linear models to establish important relationships between other variables that need to be accounted for throughout my comparison. I use GDP as my measure of economic development, cross-national survey data of institution quality and in-group bias, historical economists' estimates of state history, agriculture timing and European ancestry, and estimates of historical disease prevalence from ethnographic atlases (see Methods).

Shared History

Another insight that cultural evolutionary theory provides is that societies may share features in common because they have inherited them from a common ancestral society (Mace & Pagel, 1994). For example, common elements of social and political organisation across many Pacific Ocean societies can be traced back to an ancestral Polynesian society that existed ~3000 years earlier, and which subsequently diverged into separate, but related populations (Kirch & Green, 2001). For economic issues, this is important in understanding how societies come to possess traits that lead to positive economic outcomes. Even in cases where traits are borrowed from another

society, traits may spread more readily to societies that are more closely related historically as they share other aspects of culture in common that make the new traits more effective (Spolaore & Wacziarg, 2009). This is important for practical purposes as cross-country analyses often fail to account for shared cultural history and treat societies as independent data points. However, clustering due to shared history violates the assumptions of standard statistical techniques such as ordinary least-squares regression, and can inflate parameter estimates, leading to spurious inferences (Felsenstein, 1985; Harvey & Pagel, 1991). For example, Fincher and Thornhill (2012) find a correlation between in-group assortativeness and parasite stress across countries. However, examination by Currie and Mace (2012) revealed that there was strong cultural-geographic clustering in the data and that relationships between these variables disappeared when looking within clusters.

To address such issues cross-cultural comparative researchers have incorporated knowledge of historical relationships between societies in the same way that biologists use knowledge of evolutionary relationships between species when conducting comparative analyses (Holden & Mace, 2005; Currie, 2013). Here I apply a multilevel modelling approach (Acerbi et al, 2017) to my SEM framework, and designate countries as belonging to a wider historical grouping (following other studies in cultural evolution I base these groupings on being members of the same language family). Taking this approach, I estimate model parameters while explicitly modelling the expected covariation within designated groups.

Methods

I conduct secondary data analysis of cross-national measures of historical, social, ecological and economic variables. I investigate the network of direct and indirect pathways between these variables using SEM, seeking in particular to establish the pathways through which state history and the timing of agriculture affect modern-day GDP.

Variables

Table 3-2 describes the data, their sources and any statistical transformations that took place prior to my analyses. My GDP, institution quality, in-group bias, disease and latitude variables have commonly been used in previous analyses. Due to their relatively strong correlation (see Appendix 1-3 for multicollinearity checks), I provide more detail on the data sources for the institution quality and in-group bias variables. My institution quality variable is ultimately sourced from the World Bank. They aggregated 32 different data sources measuring perceptions of governance and assigned them to six broad categories. My institution quality variable concerned the category 'Rule of Law', which measured perceptions of confidence in the rules of society, contract enforcement, courts and the police. My in-group bias measure is taken from Van de Vliert (2011), who used data on compatriotism, nepotism and familism from three different sources (the World Values Survey, the World Economic Forum and the GLOBE study respectively) to calculate an estimate of in-group bias.

The World Values Survey and the GLOBE study are independent of the World Bank data on institution quality. Although the World Economic Forum data is one of the 32 different data sources used by the World Bank, the

nepotism component is assigned by the World Bank to the category of 'Corruption', a category that is separate to the 'Rule of Law'. Therefore, the in-group bias and institution quality variables are informed by different measures and measured different things.

Table 3-2: *Descriptions and sources of the variables included in the analysis*

Variable	Source	Description	Transformation (if applicable)*
GDP	World Bank (2011)	GDP per capita for the year 2011.	Log transformed for normality and comparability to other studies
Institution Quality	Nunn & Puga (2012) – originally sourced from World Bank.	Perceived confidence in rules of society, including quality of contract enforcement, property rights and courts.	
In-Group Bias	Van de Vliert (2011)	Cross-national survey data on compatriotism, nepotism and familism aggregated to a single score for in-group favouritism.	
European Ancestry	Nunn & Puga (2012)	Percentage of population in year 2000 descended from people who resided in Europe in 1500. Calculated from Putterman & Weil's (2010) migration matrix.	
State History	Putterman & Weil (2010)	Aggregation of scores for the extent to which there existed governance beyond the tribal level in the geographical locations of present-day countries.	Ancestry adjusted using Putterman & Weil's (2010) migration matrix.
Timing of Agriculture	Putterman & Weil (2010)	Estimation of the year when the first region within present-day countries underwent a transition from hunted food to cultivated crops and livestock.	Ancestry adjusted using Putterman & Weil's (2010) migration matrix.
Disease	Murray & Schaller (2010)	Infectious disease prevalence data compiled from various historical ethnographic atlases.	
Latitude	Nunn & Puga (2012)	Latitude of the geographical centre of the country.	

**All variables were scaled and centred for the SEMs.*

European ancestry captures the percentage of a country's population that is descended from people who resided in Europe in 1500. This variable serves a dual function as it is able to capture two variables, which is particularly valuable because SEMs estimate a large number of pathways and therefore do not have many spare parameters free to estimate. Firstly, it allows me to control for the influence of colonial activity on economic development. Secondly, it has been argued that the main thing Europeans brought to their colonies was human capital (Easterly & Levine, 2012; Glaeser et al, 2004), and as such the variable European ancestry also captures variation in human capital. I recognise that using a proxy for human capital such as education is a possibility but would impede my ability to control for colonial activity, whose impact on economic development is considerable.

I also conducted an ancestry adjustment procedure on the state history and timing of agriculture variables. In previous study, nation-level estimates of state history and the timing of agriculture were derived from the geographical locations of historical states and agricultural societies (Putterman & Weil, 2010). This was problematic because it did not account for large-scale migration. For example, state societies appeared relatively late in the geographic regions of North America and Australia and are associated with the arrival of Europeans rather than being native developments. Therefore, assuming that experience of statehood is in some sense a heritable trait, their modern populations have longer state histories than their geographic locations alone suggest. Following Putterman and Weil (2010), I transformed state history and agriculture timing scores based on the country of origin of the foreign nationals in every nation. Specifically, Putterman and Weil (2010) provide data on the state history and

timing of agriculture for modern nations, and for each of these nations I found the proportion of different nationalities that comprise its population, then combined each of the state history (and timing of agriculture) scores for each of these nationalities, weighted by their representation in the nation's population.

SEM

There are a large number of potential combinations of variables and pathways that could be tested using SEM. Therefore, as a practical step, I conducted a two-stage analysis. First, I tested each hypothesised pathway in linear models. In separate models, economic development (GDP) and its potential mediators were the outcome variables, and their hypothesised determinants were predictors. From this, I constructed an SEM that only contained the significant pathways found in these linear models. This captured the important relationships between each of the variables and allowed me to reject unimportant pathways that would compromise model fit before testing my hypotheses.

I used this SEM as a foundation to test my hypotheses. Keeping the rest of the pathways the same, I created different SEMs that included every combination of pathways from state history and the timing of agriculture to GDP. These were direct and indirect through institution quality and in-group bias. In the case of the timing of agriculture, I also included an indirect pathway through state history. Through model comparison (Burnham & Anderson, 2010), I evaluated if a given pathway or combination of pathways improved the fit to the data.

Figure 3-1 illustrates my SEM foundation and the pathways I manipulated for my hypothesis testing. The pathways in black represent those

that were supported by the first-stage linear models, and therefore appeared in every single SEM I conducted. The pathways in red were those relating to my main hypotheses about whether the effects of state history and the timing of agriculture are direct or indirect. My model comparison was a comparison of SEMs that always included the black pathways, and had every different combination of the red pathways.

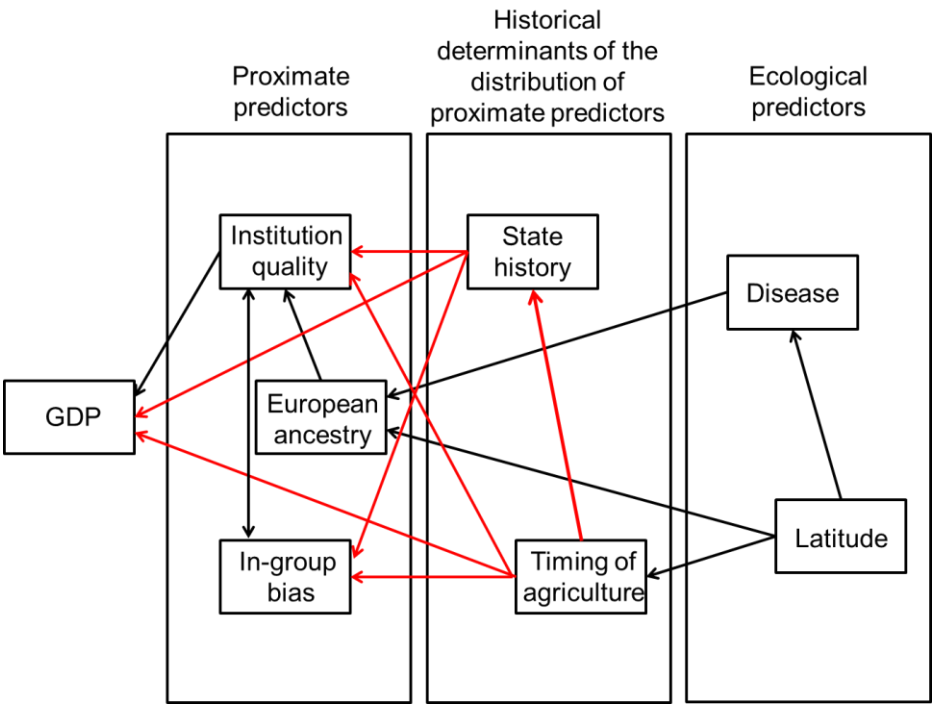


Figure 3-1: *Path diagram highlighting the pathways that were manipulated*
This diagram does not present the results of any SEM: the thickness of the arrows is constant.

Language families were used as random intercepts in every linear and structural equation model to account for shared history. I used the linguistic affiliation of the majority of the population of a nation as the nation's language family. I recognise that this is a more difficult exercise in nations that contain several language families (e.g. Chad) compared to more homogeneous nations (e.g. Japan). But I argue that it is the simplest way to capture important features of the shared cultural history of as much of the economically-active population

as possible. In the case of the Indo-European family, I used sub-families. This is because the over-representation of the Indo-European languages in my dataset compromised its ability to capture meaningful patterns of non-independence (my findings are not influenced by the decision to use subfamilies: see Appendix 1-7 for models conducted with the Indo-European family instead of subfamilies).

Results and discussion

Despite several variables showing correlations with GDP, the only significant direct predictor of GDP when including all variables in a linear model is institutional quality (Table 3-3). This result provides evidence against many of the hypotheses that propose a direct effect of certain factors on economic development. There is no support from these analyses for direct effects on GDP of in-group bias, European ancestry, state history, agriculture timing, disease and latitude. The strong relationship between institution quality and GDP leaves little variation that can be explained by these other variables. This guides me towards potential indirect relationships, as I can turn my attention to which variables explain the variation in institution quality, and in turn, step further back to examine what factors explain variation in those variables.

Table 3-3: *Linear models testing individual stages of hypothesised pathways. Each outcome variable was assessed in separate models including all the predictor variables listed alongside it*

Outcome variable	Predictor variable	Coefficient	p
GDP	Institution quality	0.56	<0.001**
	In-group bias	-0.09	0.23
	European descent	0.14	0.09
	State history	0.04	0.52
	Agriculture timing	0.11	0.09
	Disease	-0.09	0.26
	Latitude	0.03	0.60

Institution quality	In-group bias	-0.54	<0.001**
	European descent	0.25	0.02*
	State history	0.15	0.04*
	Agriculture timing	0.06	0.45
	Latitude	-0.05	0.49
In-group bias	Institution quality	-0.56	<0.001**
	European descent	-0.17	0.13
	State history	-0.02	0.84
	Agriculture timing	0.12	0.17
	Disease	0.09	0.34
	Latitude	0.01	0.93
European descent	State history	0.06	0.24
	Disease	-0.17	0.03*
	Latitude	0.17	0.002**
State history	Agriculture timing	0.55	<0.001**
	Latitude	0.07	0.47
Agriculture timing	Latitude	0.38	<0.001**

*Coefficients represent standardised coefficients. p<0.01**; p<0.05**

Higher quality institutions are predicted by lower levels of in-group bias, higher proportions of European descent, and longer state histories. This offers support for 1) the suggestion that strong institutions and in-group biases reduce the benefits of one another and 2) the hypothesis that institutions are among the cultural traits that European populations transmit. It also supports the theory that longer histories of statehood provide more time for the development of effective institutions. State history, in turn, is strongly related to the timing of agriculture but not latitude. This is consistent with the idea that sedentism and increased population density historically led to changes in political organisation. The timing of agriculture is related to latitude, in line with the suitability of agricultural subsistence being dependent on climatic and other ecological factors. I find no support for a relationship between disease and in-group bias, suggesting that disease does not influence GDP by creating avoidant norms. However, disease is associated with European ancestry, in line with the hypothesis that the extent of settlement by colonists was dependent on the disease environment.

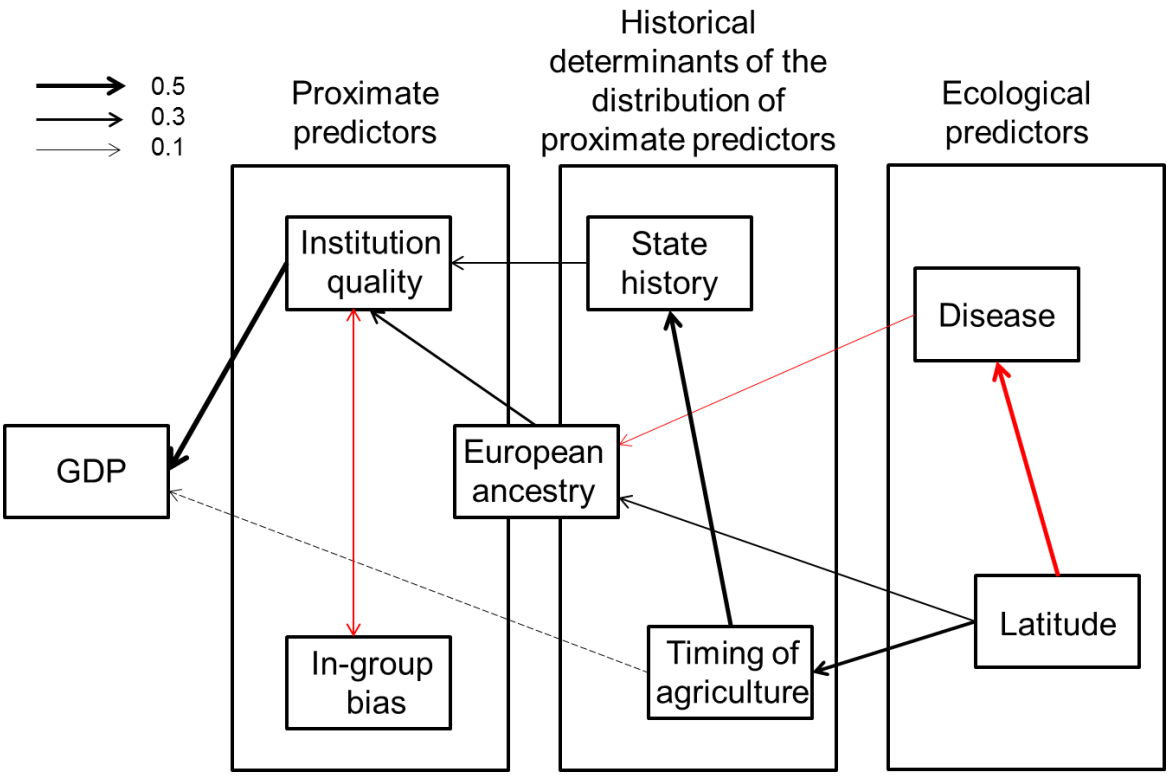


Figure 3-2: *Pathways which receive statistically significant support in model comparison of alternate SEMs*

Red arrows represent negative correlations and black arrows positive correlations. Line widths are proportional to the Akaike weighted coefficients of the pathways (see key). The dotted pathway from timing of agriculture to GDP was non-significant in the linear models but was supported in the SEM model comparison.

Based on the results of these linear models I ran a series of SEMs to assess the importance of different pathways using model comparison techniques. Figure 3-2 summarizes the direct and indirect pathways that receive support from these analyses. For state history, an indirect pathway to GDP through institution quality has greater statistical support than an indirect pathway through in-group bias or a direct pathway (Table 3-4). Comparing the Akaike importance scores (by dividing the Akaike importance score for one pathway by another) shows that a pathway from state history to institution quality is 2.93 times more likely to be in the best model than a pathway from state history to GDP. This provides evidence for the theory that state history has

a persistent effect on economic development because it shapes the evolution of institutions instead of providing a direct head-start.

I also found that a pathway from the timing of agriculture to state history was highly important, and this pathway appeared in all of the best-fitting models. Indirect pathways from the timing of agriculture to in-group bias and institution quality were not supported by my analysis. Surprisingly, I found support for a direct pathway between the timing of agriculture and GDP in my model comparison, despite little evidence for this pathway in my linear models. Supplementary exploration of this direct relationship suggests that it should not be interpreted as support for the head-start hypothesis, because the direction of the relationship between the timing of agriculture and GDP is inconsistent across different geographical regions (e.g. there is a negative relationship between these variables within Europe; Olsson & Paik, 2013; see Appendix 1-8).

My model comparison reveals the pathways through which ecological factors do and do not influence GDP. From these analyses there is no evidence for direct effects of the ecological variables on GDP. Instead they appear to affect GDP through indirect effects on mediating variables. Latitude and disease both appear to influence European ancestry, which in turn affects GDP by shaping institution quality. Latitude also strongly predicts the timing of agriculture.

A relatively robust finding in my SEMs is that the effect of state history on economic development is mostly indirect, through its relationship with institution quality. Similarly, although there is some weak evidence for a direct effect of the timing of agriculture, its most important pathway to economic outcomes appears

Table 3-4: *Direct and indirect effects of state history and timing of agriculture on GDP in the SEMs within 2 AIC units of the best-fitting model*

		Variables							
	Predictor	Institution quality	State history			Timing of agriculture			
	Outcome	GDP	GDP	Institution quality	In-group bias	GDP	Institution quality	In-group bias	State history
AIC	Akaike weight								
1511.15	0.13	0.67	-	0.21	-0.12	0.14	-	-	0.58
1511.31	0.12	0.67	-	0.16	-	0.14	-	-	0.58
1512.76	0.06	0.67	-	0.17	-	0.14	-	-0.06	0.58
1512.93	0.05	0.67	-	0.19	-0.12	0.14	0.04	-	0.58
1513.07	0.05	0.67	-	0.14	-	0.14	0.05	-	0.58
1513.09	0.05	0.67	0.02	0.21	-0.12	0.13	-	-	0.58
1513.15	0.05	0.67	-	0.21	-0.12	0.14	-	0.003	0.58
Akaike Importance		0.95	0.29	0.85	0.44	0.79	0.32	0.29	0.95
Weighted Parameter Estimate		0.62	0.01	0.15	-0.05	0.11	0.02	-0.01	0.52

Values represent standardised coefficients taken from the specific SEMs. All Akaike statistics were calculated using the SEMs in the 95% confidence set of SEMs.

to be indirect. This contrasts with previous research that shows that historical conditions, including state history, exert direct effects on economic development (Putterman & Weil, 2010). These findings are consistent with the idea that culturally transmitted rules and norms that facilitate large-scale organization develop in a cumulative manner (Currie et al, 2010; Henrich et al, 2010; Spencer, 2010). This evolutionary process takes time and the emergence of centralised governance may be characterised by cycles of success and collapse as innovations are attempted and abandoned (Currie et al, 2010; Gavrilets, Anderson & Turchin, 2014; Richerson & Boyd, 2001; Turchin et al 2018; Wright, 2006). My findings suggest that societies that exhibit effective institutions in the modern day do so, at least partly, because the societies from which they have descended had more time in which to the develop the social, economic and political conditions from which these institutions have emerged.

These findings highlight the insights that can be gained from the methodological approach of using SEMs to bring together all direct and indirect effects simultaneously. SEMs estimate a realistically complex network of pathways as opposed to a collection of direct effects on the same outcome. Unlike multiple regression, this allows a distinction to be made between variables that are not influential and those that appear not to be influential because their effect is indirect. Given this it is unsurprising that previous analyses using multiple regression (Hibbs & Olsson, 2004; Putterman & Weil, 2010; Sachs & Malaney, 2002) have found that historical and ecological factors have strong direct effects, while my SEMs find that indirect effects are more important.

In my SEM and model comparison approach I explicitly acknowledge different potential explanations and different routes by which variables may

exert an effect (Currie et al, 2016; Platt, 1964; Dunbar, 1995). By pre-specifying my hypotheses of interest I avoid making too much of spurious relationships, and by calculating weighted parameter estimates across the range of models I take into account the fact that multiple sets of hypotheses might be equally plausible given the data. It should be noted, however, that although I tested meaningful combinations of variables and pathways, other variables and combinations that reflect different theoretical interests are possible. For example, in Table 3-1 I specified natural resource endowments as a direct, exogenous, historical factor. However, this is not a hypothesis I tested, and the only ecological variables I included were disease and latitude. It is possible that the inclusion of other variables could reveal different effects on economic development than I have identified. Indeed a general limitation of my SEM approach is that estimating a greater number of pathways comes at the cost of limiting the number of variables that can be analysed.

It is also possible that broader conclusions concerning the roles of social norms and human capital may be different with different measures of such factors. Measures that unambiguously distinguish between the effects of institutional rules, social norms, and human capital are difficult to find in practice (Diamond, 2014). The variables I have employed in this study are best thought of as culturally-inherited factors that are proposed to have some causal influence on economic development rather than pointing towards strong statements about the relative importance of institutions versus human capital, for example. Other practical considerations in relation to variable choices also have to be considered. For example, I justify the use of European ancestry both as a proxy for human capital and as a variable that gives some control for colonial activity, because it helped to minimise the already high number of

parameters the SEMs estimated. I recognize, however, that several other proxies for human capital or social norms exist, and these may give more specific insights into what aspect of human capital or non-institutional aspects of culture are important in economic development.

Another issue is to recognise the possibility of reverse causality in interpreting the relationship between institution quality and GDP. However, my analysis follows a long history of other lines of evidence establishing institutional quality as causally precedent (Rodrik et al, 2004). Furthermore, I conducted supplementary instrumental variable analysis using settler mortality data following Acemoglu and Robinson (2012) and the results were consistent with this interpretation (see Appendix 1-10). Perhaps more importantly, the strong correlation between institution quality and GDP points to a more general statement about institutions and economies: namely that strong institutions and successful economies are connected features of societies that are characterised by large-scale cooperation. Indeed, strong institutions are a marker of societal development regardless of GDP, and perceptions of personal freedom, safety and societal safety nets feature in developmental indices that explicitly exclude economic variables (e.g. Social Progress Index).

In summary, I show that indirect pathways associated with cultural evolutionary processes are important in explaining why historical and ecological conditions are associated with modern GDP. The evolution of modern institutions is shaped by historical experience of statehood, which is in turn associated with how early the transition to agriculture took place. This chain of pathways provides an explanation for why historical variables exert persistent effects on economic development. I demonstrate how a methodological framework for testing alternative evolutionary hypotheses reflecting multiple

causal pathways and patterns of shared cultural history can be adapted to address a range questions concerning how ecological, geographical, and historical factors have shaped the world we live in today. Questions of economic development have generally not been a major focus for researchers working in the field of cultural evolution (but see Henrich, 2016; Wilson & Gowdy, 2013), yet this is an area to which cultural evolutionary theory and methods can have important insights and add to existing approaches (see Spolaore & Wacziarg, 2013). Cultural evolutionary research can benefit from further incorporating theory, methods, and data from researchers work in economics, political science, and related fields. More generally, the theoretical framework of cultural evolution can help connect insights and findings from across a range of disciplines involved in investigating economic and social development (Currie et al, 2016) as well as connecting to important practical applications in areas such as sustainability science (e.g. Kline et al, 2018) and public policy (Wilson & Gowdy, 2013).

Chapter 4: Assessing the importance of shared history in shaping patterns of modern day socioeconomic development

Abstract

Numerous explanations have been put forward for why nations vary so substantially in their socioeconomic development. Many hypotheses concern modern-day factors such as ecological differences and social norms, but there is growing interest in more 'ultimate' explanations that view modern-day economic diversity as an outcome of cultural evolutionary processes acting over many generations. Societies may share many cultural features in common because they have either: 1) inherited features from a common ancestral society from which they have diverged; or 2) borrowed featured from others. Whether these processes also explain patterns of economic similarity and difference is not clear. Here I use multilevel modelling and a global nation-level dataset to partition the variation in development between modern-day factors, and historical and social factors that reflect patterns of shared history. I group countries based on: 1) language families to reflect deep common ancestry; 2) world religion to reflect more recent contact and borrowing; and 3) continent to reflect contact and borrowing within regions of ecological similarity. I show that grouping societies based on their language families explains more than half of the variation in modern-day economic development, even when controlling for other factors. Religion as a grouping variable explains about 40% of the variation, but continent does not explain any variation once country-level predictors are included. These findings are consistent with the idea that processes of cultural inheritance have shaped the distribution of socioeconomic development throughout history and into the modern day.

Introduction

The world today shows a high degree of economic inequality. Many different factors have been argued to be important in determining economic development including: the presence of institutions for enabling large-scale market activity and providing checks on executives (North, 1990; Rodrik et al, 2004), in-group bias (Kyriacou, 2016), disease (Sachs, 2003), and human capitals such as specific technologies and bodies of knowledge (Easterly & Levine, 2012; Glaeser et al, 2004). Patterns of global economic inequality also appear to be highly persistent. Historical estimates of GDP suggest the same eight regions (China, India, Japan, USA, France, Germany, Italy and Britain) have together accounted for around 60% of the world's economic productivity from 1AD to the present day (Maddison, 2007). Researchers have begun to argue that the present-day distribution of economic development may be, at least partly, the result of longer-term historical factors.

Historical explanations of economic development have often been tied to specific events. Perhaps most well-known is the industrial revolution, in which technological breakthroughs created previously impossible economic opportunities and propelled Western Europe and North America to a new level of economic production. Research in economic history has since shifted focus to less recent historical events. Estimates of the date at which agriculture (Hibbs & Olsson, 2004) and statehood (Putterman & Weil, 2010) emerged in a society's history predict its modern day economic performance (see chapter 3; Flitton & Currie, 2018). Similarly, the societies that adopted important technological innovations earlier in their history are the richest today (Comin et al, 2010).

The specific reasons for these long-term effects are still debated. Cultural evolutionary theory provides a general framework with which to develop, integrate, and test hypotheses about the historical processes that may explain the present-day distribution of socio-economic development (Currie et al, 2016; Spolaore & Wacziarg 2013; Wilson, 2002). Cultural evolutionary theory argues that the diversity in cultural traits is explained by evolutionary processes analogous to the evolution of biological adaptations, in which inheritance occurs through social transmission and selection is driven by ecological and social conditions that shape the success of different behaviours. For example, the fact that certain key innovations or events (such as the development of agriculture) happened earlier in some parts of the world has given some societies more time to subsequently develop and retain cultural adaptations (particular institutions, norms or technologies) that are beneficial in agricultural societies. If these adaptations are also important for developing economies, this would have given some societies a head-start over others and a competitive advantage that persists to the present day (Bockstette et al, 2002; Putterman & Weil, 2010).

Here I examine the idea that the extent to which societies share common history may have important consequences for explaining the present-day distribution of economic performance. Societies may be culturally similar due to convergent cultural evolution towards similar solutions to similar adaptive problems. For example, domestication of plants and animals happened independently in several places around the world during the Holocene (Richerson et al, 2001). Long-term historical analyses of societies from around the world show that in response to the need to deal with increasing population size societies have developed similar functional solutions, such as establishing hierarchical organization, increasing division of labour, developing specialized

political offices, and creating accurate recording systems (Turchin et al, 2018). However, the institutions, norms, or other socio-cultural factors that countries possess are often not independent innovations but rather share a common origin with institutions, norms etc. from other countries. These similarities can come about due to two aspects of shared history: ancestry and contact.

Shared ancestry results from the process by which populations diverge to form new populations. Although the new populations may seek to differentiate themselves in terms of their identity, they will tend to share the vast majority of features of the original population as many ways of living are persistent and slow to change (Mace & Holden, 2005). Repeated bouts of population divergence over time, along with cultural innovation or 'mutation' in daughter societies, at least partly explains the broad-scale patterns of cultural diversity we see in the world today. The process is analogous the emergence of biological diversity, and means that societies are more similar to some societies than others in terms of the socio-cultural traits they possess (Currie, 2013; Mace & Holden, 2005; Mace et al, 2005). The relatedness between species can be represented in the form of phylogenetic (or evolutionary) tree and the shared ancestral relationships between human societies can also be represented using phylogenetic trees. Empirical work shows that the extent of this shared ancestry between societies predicts their similarity across a large and diverse range of cultural traits (Dow & Eff, 2008; Dow, 2007; Guglielmino et al, 1995; Hewlett et al, 2002, Mace & Jordan, 2011), and may potentially explain some of the variation in economies and the ways in which economies develop (Matthews et al, 2016; Spolaore & Wacziarg, 2009; but see Sookias et al, 2018).

Societies may also share cultural traits due to contact with other societies. Neighbouring groups may borrow key innovations from each other, or

other traits may diffuse between groups (Rogers, 2003). Packages of several traits may also be transmitted together such as when a society adopts the religion of another society. For example, the introduction of Islam into many regions of Africa brought a new money system, an accounting system and a legal code for adjudicating contracts (Ensminger, 1997). Groups may also dominate or subjugate other groups leading them to adopt many traits of the victor (occasionally the victorious group may take on the traits of the defeated group, for example the Mongol emperors of China—specifically the Yuan dynasty—adopted many aspects of Chinese political culture and political theory, as well as religion (Khan, 1995)). In general, this kind of contact is expected to occur between societies that are closer together in geographical space, and geographical proximity has been shown to be a good predictor of cultural similarity (Dow & Eff, 2008; Dow, 2007). Although as transport has technology has improved over the years this form of transmission can occur over increasingly longer distances.

The processes of shared ancestry and contact are not mutually exclusive and may interact in interesting ways. For example, Spolaore and Wacziarg (2009) argue that traits are likely to be borrowed more easily between groups that are more closely related (i.e. have a higher degree of cultural ancestry) as they will fit in the existing cultural traits of the receiving society. Using cross national data, they show that differences in historical and contemporary income between societies correlate with the genetic distance between them, even if the societies are geographically close together (Spolaore & Wacziarg, 2009). As genetic differences in separated populations accumulate over time, genetic distance is closely related to how recently societies diverged. Spolaore and Wacziarg (2009) suggest that therefore, genetic distance proxies for cultural

differentiation and the existence of cultural barriers to the diffusion of traits that shape income. Others have argued that societies may also exchange or borrow cultural traits more frequently and easily from societies within the same ecological region as these are more likely to be relevant to the socio-ecological environment (Diamond, 1997). To the extent that culturally transmitted traits affect development it is possible that processes of shared history may help explain global patterns of economic performance we observe in the world today.

Many quantitative studies of the causes of economic development are conducted using country-level data. However, the above discussion indicates that variation between countries across a range of variables including socio-economic development and its predictors may be shared between countries. An outstanding question is to what extent shared history explains variation in development independently of country-level variation in institutions, culture or ecology. Furthermore, in practical terms, commonly used techniques such as Ordinary Least-Squares multiple regression assume that the data points have no underlying structure and that the residuals are statistically independent. Shared history may violate this assumption. At worst, this can lead to the appearance of spurious relationships because closely-related societies are effectively pseudoreplicated data points (i.e. Galton's problem (Mace & Pagel, 1994); see chapter 2). Not controlling for this issue could lead to predictors in such models being estimated poorly, meaning that parameter estimates could fluctuate or even reverse in their effect (e.g. Olsson & Paik, 2013).

I seek to address the following questions in this chapter: 1) to what extent variation in economic development and its potential predictors is shared across countries due to shared history? and 2) does accounting for potential sources of non-independence due to shared history provide affect estimates of

the relationships between economic development and its predictors? I address these issues by analysing a global level dataset of information on economic development and several of its hypothesized predictors. I examine the variation in these measures as falling either: between modern countries, or between groupings of countries based on shared cultural history. I then explore whether accounting for these potential sources of non-independence affects inferences about the predictors of economic development.

Methods

I conduct secondary data analysis, using multilevel models to estimate the proportion of variation in modern-day economic development attributable to country-level factors and higher-level groupings based on deep common ancestry (based on language family affiliation), more recent historical contacts (based on religious affiliation), and contact based on geographical proximity (based on shared environments). My aim is to establish how much variation in economies is due to shared cultural history, which will inform both to what extent cultural evolutionary processes shape economies and the degree to which previous single-level analyses have been compromised by non-independent data.

Variables

The nation-level variables used in this chapter were largely the same as those used in chapter 3, but with two additional variables and other transformations to make the models tractable and interpretable. As this chapter investigates the variation in economic development attributable to shared history, it is not concerned with evaluating specific hypotheses about factors

driving variation at the country-level. Country-level variables are only included to ensure that all the variation in economic development attributable to country-level factors is being accounted for appropriately, so that it is not misattributed to shared history. Therefore, I performed two principal components analyses (PCA) to extract one factor that captures general country-level variation in the ecology (62% of the variance), and another factor that captures country-level variation in the timing of important historical events (79% of the variance). To create a robust ecology factor, I included two new country-level variables: precipitation levels and the degree of tropical climate (Nunn & Puga, 2012). The ecology and history factors will be included in my models as country-level predictors of variation. I also include European ancestry at the country-level, as this covaries with cultural norms, bodies of knowledge and technologies. I also performed a PCA to create the outcome variable capturing economic development which combines institution quality, GDP and social norms for in-group bias (83% of the variance) (Figure 4-1). The causal pathways between these variables are multiple in terms of both number and direction, and my current analysis is concerned with explaining the more general societal development they characterise, not with disentangling their causal relationships. Each of these PCAs used the PRCOMP function from the Stats package in R which uses eigenvector decomposition to derive variance-maximising principal components. It calculates the most informative factors and provides values for these factors to be used as variables.

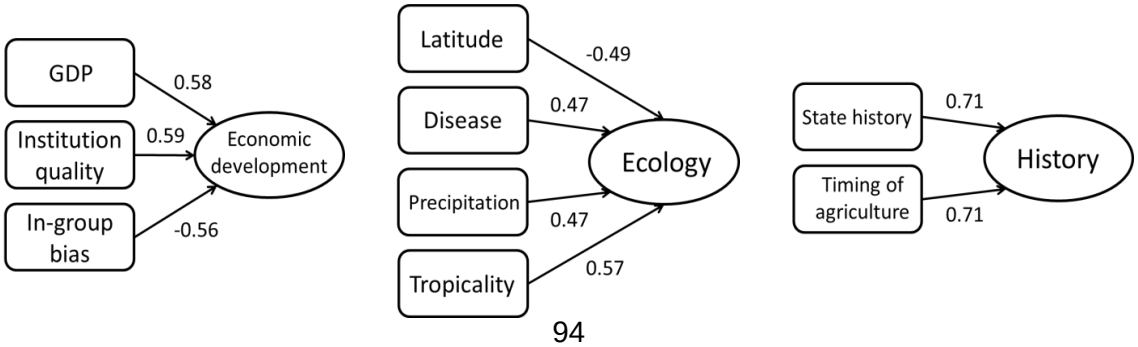
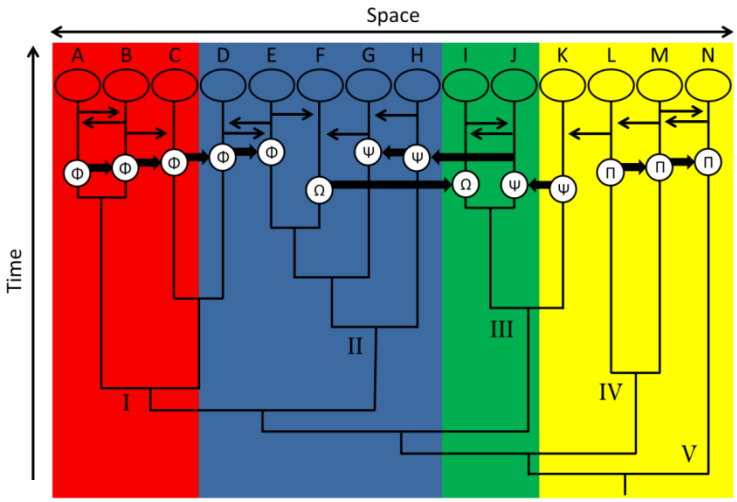


Figure 4-1: *The factors used in the analysis. The economic development factor was the outcome variable and the history and ecology factors were fixed effects Numbers represent factor loadings.*

To evaluate the role of shared history, I also identified and operationalised three general factors that may lead different countries to share history. The first is cultural relatedness due to shared ancestry. This is generally proxied using linguistic affiliation: languages show hierarchical (i.e. tree-like) patterns of relatedness and are grouped into language families. These patterns of similarity are thought to be the result of ancient population expansion and divergence. The second is more recent historical relationships due to substantial contact and the spread of packages of cultural traits across a number of groups. Here I focus on one prominent form of such relatedness that applies to large parts of the world: religion, particularly the spread of so-called world religions (Norris, 2015; Norris & Inglehart, 2004). It is important to note that such relationships could also come about for a number of other reasons such as incorporation into a large empire, or the spread of political ideologies such as communism. The third is geographical proximity: societies from the same geographical region are likely to be in closer contact with each other and borrow cultural traits. This will be amplified if these regions are also similar ecologically and traits are more suited to these regions than to others.



Country	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Language family	I	I	I	I	II	II	II	II	III	III	III	IV	IV	V
Continent	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Green	Green	Yellow	Yellow	Yellow	Yellow
Religion	Φ	Φ	Φ	Φ	Φ	Ω	Ψ	Ψ	Ω	Ψ	Ψ	Π	Π	Π

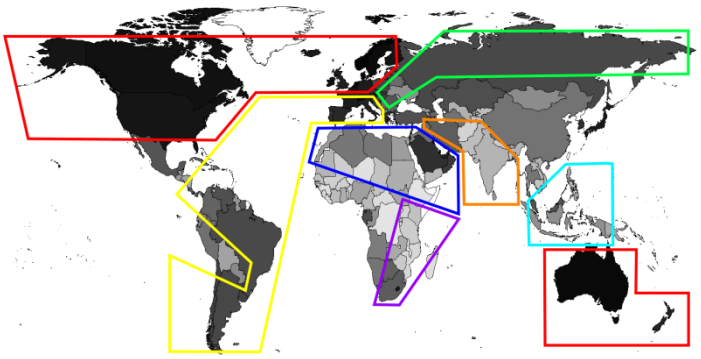
Figure 4-2: *Schematic of the ways in which different sources of shared history create patterns of non-independence between modern societies*

Figure 4-2 illustrates how these different historical processes may give rise to clusters of societies that share many features in common. For each of these three general factors I select a proxy variable. Following much recent work in cross-cultural comparative analyses I use linguistic relationships as a proxy for shared cultural ancestry. Specifically, I classify countries according to the language family to which the majority language spoken in that country belongs. Given the size of the Indo-European family, I divided it into subfamilies. I also conducted additional analysis to classify South and Central American countries. Owing to population movements and colonialism, countries from this region are particularly difficult to classify into individual linguistic groups. Many have considerable indigenous populations, while others are predominantly of European descent. In chapter three, I categorised countries based on their largest language family. However, this may obscure important differences both between European and South American populations and between populations within South America. To address this, I created a dataset compiling the various populations in these countries using Putterman and Weil's (2010) population matrix. Indigenous language families are rarely the largest in South American countries, but often exceed a third of the population. Therefore, in this analysis, I categorised countries as their indigenous language family if members of this language family comprised over a third of the country's population. Supplementary robustness checks using the original language

family classification used in chapter three showed that changing this classification had no effect on the results (Appendix 2-2).

For more recent sources of shared history, I use historical religion, classified as the predominant religion of a country's population (Norris, 2015; Norris & Inglehart, 2004).For shared history due to shared ecology and geography, I use continents. Continents are considered natural barriers to the diffusion of information (Spolaore & Wacziarg, 2009) and demarcate broad ecological differences. I consider Europe and Asia different continents as factors such as crop differences are useful for demarcating distinct cultural regions (Kitayama et al, 2016) (robustness checks in Appendix 2-3 indicate that different assumptions about definitions of continents made little qualitative difference to the findings). As Figure 4-3 illustrates, these general factors may overlap (language families may be distributed predominantly within a particular continent, or religions may be practiced only within a particular language family).

A)



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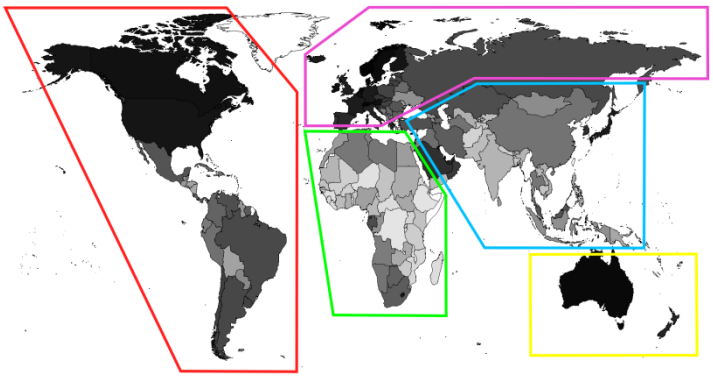

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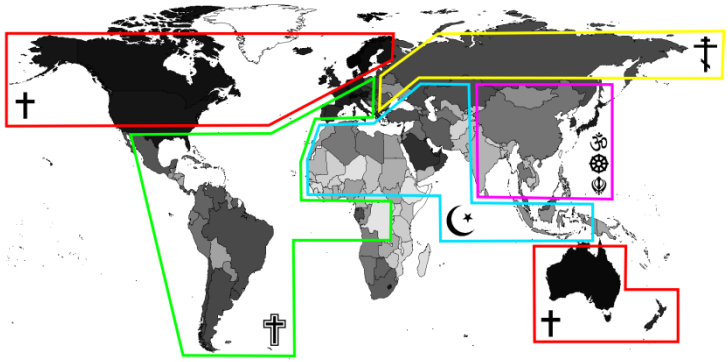


Figure 4-3: *World maps of our grouping variables*

Panel A shows the categorisation of major language families; Panel B shows continent groupings; and Panel C shows religious groupings. Different colours represent different groups in each case.

Multilevel models:

Multilevel models allow me to estimate country-level predictors of economic development as fixed effects, while simultaneously modelling the expected co-variation between countries within groupings as a random effect. Multilevel models can therefore provide an estimate of the relationships between country-level predictor variables and economic development given the underlying structure to the data that is the result of patterns of shared history.

For my analysis, using multilevel models to account for grouping variables is preferable to the alternative method of including grouping variables as fixed effects. Conceptually, I do not consider specific language families, continents or religions to have unique effects on economies or institutions, and so it is consistent with my theoretical expectations to treat grouping variables not as another parameter to estimate, but as a more general underlying source of variability in scores. Furthermore, as a practical consideration, language families, continents and religions vary in the number of countries they have as

members, and imbalances between groups compromise the statistical power of fixed effects models.

I compare seven models. For each of the three general factors, I conduct two separate multilevel models. Each of these two models contains the general factor as a random effect, but one contains no country-level fixed effects while the other includes all of the fixed effects. Comparing these models enables me to evaluate both how much variation is explained by the different general factors, and whether the general factors explain variation that is not attributable to any country-level variable. I also present a single-level OLS-regression model with all of the fixed effects but no general factor, to investigate whether including shared history is justified considering the extra model complexity it introduces.

Results and discussion

My model comparison (Table 4-1) shows that even though they increase model complexity, proxies for shared history largely improve model fit by accounting for variation that is not explained by any country-level source. Before including fixed effects, language families account for 63% of the variation in socio-economic development. Only a small proportion of this is because language families proxy for variation in the ecology, history or European ancestry of different countries, as over half of the variation in development is still explained by language families even after fixed effects are introduced. The variation in the development between continents, on the other hand, is entirely due to continental differences proxying for differences in country-level variables such as European ancestry. After accounting for country-level variation, development does not differ between continents. Religion presents a similar but weaker overall picture to language families,

consistently accounting for a large amount of variation in development that is not attributable to country-level variables (Figure 4-4).

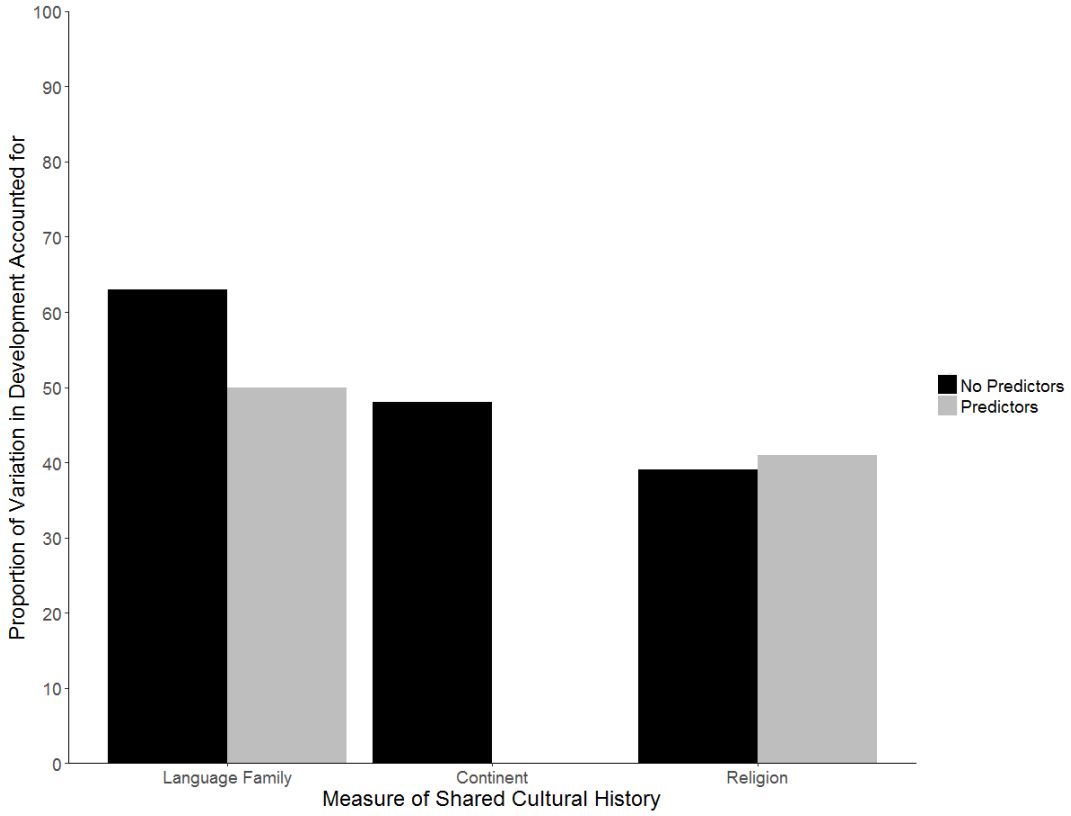


Figure 4-4: *Bar chart presenting the proportion of variation in socioeconomic development attributable to the general factors in different models*
Black bars refer to null models with no country-level predictor variables included. Grey bars refer to full models with all country-level predictors included.

Including continents as a general factor weakens model fit relative to a single-level model. This is because continents do not explain any variation in development that country-level variables cannot, so the variable does not provide any benefit to model fit that would justify the extra model complexity it introduces. Including religion does improve model fit relative to a single-level model, suggesting that it accounts for variation that country-level variables cannot. The same can be said for language families, the inclusion of which improves model fit the most.

Table 4-1: *Model comparison*

	Grouping Variable						
	None	Language family		Continent		Religion	
Predictor of development							
European descent	0.82***	-	0.54***	-	0.81***	-	0.65***
History	0.10	-	0.18*	-	0.09	-	0.25**
Ecology	-0.13	-	-0.13	-	-0.13	-	-0.14
ICC	-	0.63	0.52	0.48	0.00	0.39	0.40
AIC	336.69	302.54	290.06	352.11	338.69	349.90	304.02

*Cells contain parameter estimates. Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

Although I am not concerned with specific country-level hypotheses in these analyses, my model comparison illustrates the effect of assuming independence between countries on parameter estimates. The single-level model, which is a simple OLS regression such as those commonly used in the scientific literature, overestimates the direct role of European ancestry and underestimates the role of history when compared to the best-fitting model that properly accounts for shared history using language families.

I find that the language family to which a society belongs predicts how similar the society is to other societies in terms of socio-economic development. Membership of the same language family can reflect common ancestry going back several thousand years. However, the emergence of modern forms of political governance and economic systems is generally thought to have occurred much more recently and after the divergence of different cultures (i.e. these traits have emerged near the tips of a phylogenetic tree rather than at some point deeper in the past). The findings indicate that it is the presence of other aspects of culture with much longer time depth that may partly explain modern economic performance. This follows evidence that the diversity in many cultural traits, from subsistence strategies (Mace & Holden, 2005) to systems of

marriage and inheritance (Cowlishaw & Mace, 1996) to traditional political systems (Currie et al, 2010), exhibit a phylogenetic signal (i.e. patterns of similarity or co-occurrence can be explained by linguistic relatedness). Traits such as these may have facilitated the emergence, adoption or successful implementation of modern political and economic institutions and led to shared patterns of economic growth seen in the data. At the moment it is unclear what features of shared history are actually important or the precise mechanism by which this occurs, and this remains an important avenue for future research.

The analyses demonstrate that both deep cultural ancestry and more recent shared history could be important in explaining similarities in modern economic development. Examining the AIC and ICC values indicates that language family explains more of the variance than does shared world religion. However, there may an overlap in membership within categories between language families and world religions (e.g. countries associated with Germanic languages tend also to have Protestant religions) such that both classifications may be proxying for the same mechanism. Attempts to include both groupings in the same model (see Appendix 2-6) found that this improved model fit even further, which suggests that language families and religions are capturing different sources of variation. However, caution must be exercised with the interpretation of such models, as they used these groupings as fixed effects as well as random effects, which increases the risk of biased parameter estimates due to the imbalanced levels of the variables. Further insight into this question has been made by previous study showing that changes in linguistic affiliations correlate with changes in political institutions, and that linguistically-related societies are likely to experience cultural change in concert (Matthews et al, 2016). This potentially indicates that language families are related to cultural

variation because they demarcate the boundaries of information transmission. In my analysis, I used religions as a proxy for these boundaries, indicating that there may indeed be some overlap between the categories. However, I did also find that language families explain more variation than religions. To the extent that religions are effective proxies for the limits within which ideas tend to be borrowed, this suggests that there may be an additional mechanism by which historical linguistic affiliations shape modern cultural variation. Therefore, teasing apart the relative importance and mechanism by which different historical factors may affect modern day economic outcomes is an important area for future research.

I also find that continents do not account for any variation in socio-economic development that cannot be explained by society-level differences. This may be because continents do not easily capture networks of past interactions based on shared environments, as there can be substantial within-continent variation in ecological factors. For example, Asia contains tundra, desert and tropical ecosystems. Future work could explore this issue more by creating classifications based more explicitly on ecological similarity (e.g. the WWF's Biome classifications of terrestrial ecosystems (Olson et al, 2001)). Another solution could be to examine measures of geographic distance or connectivity (Spolaore & Wacziarg, 2009). My finding regarding continents may in fact further illustrate that it is the deepness of shared history that is particularly important. Many continents were populated relatively recently due to large-scale migration. For example, Oceania contains countries with large native populations such as Papua New Guinea, as well as countries like Australia which are made up predominantly of migrants originally from European countries. Therefore, continents can contain numerous societies

whose divergence occurred relatively early. Continents have been used as a control variable in economic studies (e.g. Ashraf & Galor, 2013) as well as other types of cross-national study (e.g. Fincher & Thornhill, 2012), however the findings from the present chapter suggest that it may not be the most relevant factor for understanding socioeconomic development.

My analysis has other important implications for cross-national statistical analyses. These analyses are common in numerous disciplines and mostly use single-level OLS regression models that assume that all the data points are independent from one another. I show that the best-fitting models are multilevel, containing appropriate controls for shared history. In addition to being the best-fitting models, these models produce different parameter estimates to single-level models which change the nature of the results. Through my comparison, I show that language families explain a substantial degree of variation in culture, and attributing this variation to shared history as opposed to society-level predictors is an important part of generating accurate estimates of the effects of other variables. Similar effects of multilevel correction on models of economic development have been demonstrated in the past, but at different scales. For instance, multilevel analyses are typically conducted on individuals nested within countries, and illustrate how country-level variation affects individual economic circumstances (e.g. Given & Jorgenson, 2011). In my analysis, I show that a similar process must be considered to occur at the country-level, and that modern nations, just like individuals, cannot be considered in isolation of their broader context. Specifically, comparisons of modern nations must account for the fact that different patterns of shared history create relationships between the populations that comprise nations, which means that modern nations are ‘nested’ within broader cultural groupings.

My analysis has a number of limitations. One limitation of using language families as a grouping variable is that it does not fully account for patterns of shared ancestry within language families. Having a more fine-grained description of ancestral relationships in the form of phylogenetic trees (e.g. Currie et al, 2010) would help in this respect and is a priority for future research. This task is not straightforward however, due to the fact that countries may be home to multiple languages and cultures, and there is sometimes significant mixing of cultures such as in the case of creole languages (Swigart, 1994).

Furthermore, as I am not concerned with evaluating hypotheses about country-level predictors in these analyses, I conducted PCAs to create variables that would capture ecological and historical variation. These variables ensured that I did not misattribute variation to shared history that should be attributed to country-level predictors. However, using factors necessarily results in some variation not being accounted for. The factors explained between roughly 60-80% of the variance in the variables that comprised them. Despite this concern, supplementary analyses showed that using raw variables instead of factors made no change to the results, suggesting that my use of factors did not drive the results (see Appendix 2-4).

Although applicable to most modelling analyses and virtually impossible to fully resolve, another potential issue is omitted variables. As my main aim is to appropriately partition variation between different levels, it is important that I do not omit relevant country-level variables. Doing so leads to the possibility that variation I find to be attributable to language families or religions is actually explained by country-level variables that I have not included, and is therefore not representative of shared history. This would cause me to overestimate the role of shared history. I minimise this risk by including a diverse range of

variables covering history, ecology and demography. My findings are also robust to changes in the variables I use (Appendices 2-4 & 2-5). This suggests that in line with my hypotheses about the role of shared history, language families and religions will always account for variation that cannot be explained by the kinds of society-level variables that have been commonly invoked in previous comparative studies of economic development.

Another limitation concerns the construction of my religion variable. The dataset used to categorise countries by their religion collapsed various mostly African societies into a single “Other” category, reflecting the fact that their religions are not one of the major religions (Norris, 2015). In this case these countries are modelled as if they share a single religion, which is not the case. However, their religions are diverse and the linkages between them are difficult to identify. I modelled this by not grouping any of these religions with any other. It is important to re-emphasise that I used religions in this study to proxy for systematic patterns of contact and transmission of ideas, norms and institutions, rather than focusing on the content of these religions. By categorising these religions as distinct in this way, my analysis therefore assumes that these kinds of contacts were not present in this region and that any similarities between religions are due to deeper shared ancestry. There is therefore a possibility of missing more recent contact and shared history in this region. However, supplementary analyses show that using “Other” religions as a single category does not give me different results (see Appendix 2-7), which suggests that the results are relatively robust to such modelling assumptions.

It is important to note that the types of relationships between societies that I used religion to proxy for can occur for a number of other reasons. The spread of political ideologies such as communism or of empires across

societies also implies transmission or exchange of ideas, institutions and other cultural traits. These may spread in different directions to religion, indicating that religion alone misses many societal relationships. One particularly important reason why I used religion as the proxy for borrowing between societies is because large, multi-national studies have shown that the content of different religions does not appear to have any clear systematic effect on economic development (Durlauf et al, 2012). This is unlike communism, which does appear to influence economic growth in various ways (Harrison, 2012). Consequently, variation in socio-economic development that is attributable to religion is likely to be related to the ability of religion to proxy for shared history, while variation attributable to communism may be confounded by the effects of communism itself on economies.

This study also potentially has implications for improving economic development in poorer countries. Rather than indicating that societies are trapped at a certain level of economic performance due to their historical relations with other societies, my findings highlight that attention has to be paid to the broader cultural and institutional context in which institutions play out. These findings suggest that attempting to introduce ideas or policies from other countries directly may not be successful if they do not match well to existing practices. This insight chimes well with arguments from socio-ecological systems which state that this “blueprint thinking” is ineffective in natural resource management, and that consideration needs to be paid to local conditions (Ostrom et al, 2007). In order to understand these processes further, future comparative studies could examine more explicitly cases when institutions are transmitted between societies and the extent to which existing traits and practices affect their adoption or their effectiveness.

In summary, I show that understanding shared history between countries is important in explaining patterns of diversity in modern-day socioeconomic development. Although further work is required to tease apart the specific causal mechanisms and relative importance of deep cultural ancestry and more recent contact, the study highlights the ways in which cultural inheritance extending over potentially thousands of years may have persistent effects on how societies develop, adopt and enact policies that shape economic systems. More broadly, this study further demonstrates the value of cultural evolutionary theory in bringing together different perspectives in order to develop and systematically test hypotheses about how the world in which we live today has come to be.

Chapter 5: The cultural evolution of token money

Abstract

The origin and diversity of money systems is one of the oldest questions in the field of economic history. Traditionally, money systems were seen as founded on the principle that intrinsically-valuable objects were desired by everyone, and so could be used as money in any exchange. Recently, an alternative theory that money originated as valueless tokens of debt has gained traction in the literature. An unresolved question about this theory is what prevents people issuing tokens to acquire goods and then defaulting on their debts, which would remove the perceived value of tokens of debt and threaten their sustainability as a money system. The cultural evolutionary literature argues that social sanctioning and enforcement systems such as institutions maintain this kind of cooperation, while more traditional ideas focus on factors such as access to markets as the most important explanations for money use. I use a model comparison approach and a database of diverse traditional societies to evaluate what factors affect the variation in token money use. I find that sanctioning institutions are the strongest predictor of token money use. This is consistent with the idea that token money use involves a cooperative dilemma, as well as the more fundamental claim that early money systems were based on tokens of debt instead of intrinsically-valuable commodities. These findings show that cultural evolutionary processes are central to explaining the diversity in money use among traditional societies, and that these processes offer valuable insights into the mechanisms that likely enabled the emergence and spread of money use at its origin.

Introduction

Money has featured in human societies for millennia. There is considerable diversity in the types of money systems that different societies have adopted. While some societies have not adopted any money system, many traditional societies use commodities as money, while others, including modern nation states, use tokens that have no intrinsic value (Einzig, 1966; Graeber, 2011). Various environmental and social factors predict the utility of exchange and the use of money, such as markets and ecological pressure (Kiyotaki & Wright, 1989; Smith, 1776/1976). But the puzzle of how some societies come to use valueless tokens in exchange for costly goods and services is unresolved. Recent theory argues that token moneys emerged from credit relationships, as a means of signalling outstanding debts (Graeber, 2011). But an unresolved dilemma of this theory is that tokens are not costly to issue as they have no intrinsic value, and also do not give the issuer any obligation to repay the debt they signify. Taking a cultural evolutionary perspective, I propose that this makes token money use a cooperative dilemma that is vulnerable to exploitation, as there is an incentive to issue tokens in exchange for desired goods and never repay the debts, unless there is some additional mechanism enforcing repayment. Here I investigate how the cultural evolution of certain social norms and institutions may have resolved this dilemma.

Exchange of goods

To fulfil individual or societal needs such as defence, ceremony or subsistence, societies extract or create commodities, tools and other objects (Dorward, 1976). However, due to geographical variation in resources, or a lack

of skills, knowledge or facilities, creating desired objects is often not possible. This creates diversity among the goods and services different societies can offer, and means that in many circumstances, exchange between societies is the only mutually beneficial way to acquire desired goods and services (Einzig, 1966; Quiggin, 1979) (conquest and plunder being the non-mutually beneficial alternative). For example, a notable early economic relationship was the supply of horses from Turkic populations to China in exchange for silk. Their respective ecologies generated this pattern of supply and demand, as steppe environments were more conducive to livestock breeding than agriculture, while the contrary was true for most of the environment in China (Beckwith, 1991).

Commodity money

While exchange exists everywhere (Earle, 2002), the nature of this exchange varies. In direct exchange, what matters is that an individual is able to locate another party who both offers desired goods and wants goods that the individual can offer. As the exchange is instantaneous, it can take place between anyone provided they both want what the other has. This mutual fulfilment of needs is called the ‘double coincidence of wants’, and has been central to traditional theories of money that have been established for several centuries (Smith, 1776/1976). A central dilemma with direct exchange is that the goods that parties desire and those that they can offer fluctuate over time. This means that more often than not, one party wants what the other does not have, which precludes any exchange. Alternatively, in reciprocal exchange, exchanges can involve a time delay, where a party can give a good to another party on the promise that they will receive something in return in future. This

requires some level of social relationship between the parties, so they can keep track of who owes them repayment.

Maximising the probability of two parties wanting what each other has was the fundamental motivation for the emergence of commodity money according to much traditional theory (Jevons, 1897). Objects such as metal rods, cattle, horses, clothes and medicines are of sufficient intrinsic value to be consistently desired by many parties. Consequently, these commodities can be used in exchanges even if they are not desired by the parties involved, as the parties can be confident that the commodities can be exchanged in subsequent exchanges for items that they do directly desire (Bohannan, 1955; Kiyotaki & Wright, 1989; Sillitoe, 2006). This is the fundamental mechanism by which commodity money works.

As commodity money emerges to resolve the double coincidence of wants, it is likely that the frequency of attempted exchanges that fail due to the absence of the double coincidence of wants drives the need for commodity money (Jevons, 1897). Therefore, explaining the variation in money use requires us to consider the ecological and social conditions that affect the frequency of general exchange behaviour. Three such conditions I will consider are 1) ecological threat or food stress; 2) nomadism; and 3) market development.

The frequency and severity of threats to survival caused by food shortages increases the pressure that individuals face to secure usable commodities and resources to buffer themselves against fluctuations in food (Minnis, 1985). Exchange is one of the four major categories of strategies human societies use to cope with food stress (the others being diversification of resources, migration and storage) (Halstead & O'Shea, 1989). Increasing the

size of their network of trading partners allows an individual to use exchange to acquire the resources they need to survive. For example, records of the strategies of North Alaskan Iñupiat populations up until 1800 show that inter-regional trade became common during episodes of severe food stress, despite inter-regional contact being in defiance of normal social boundaries, as it gave them access to resources they could not secure by themselves (Mine & Smith, 1989). Although there are no previous studies specifically examining how food stress predicts the emergence of money, its effect on exchange makes it an important variable to consider in explaining money use.

However, it should be noted that archaeological evidence has emphasised the importance of storage over exchange, and it has been suggested that low food security may lead to intergroup violence and territorial defence with the aim of conserving and protecting resources (Broughton et al, 2010). Therefore it may be the case that low food security actually shifts priorities away from exchange. This conclusion is perhaps expected from archaeological study given that it is easier to demonstrate storage over exchange in the archaeological record, and this survivorship bias makes it difficult to establish whether exchange or storage is a more common response to food stress. Consequently, the effect of food stress on money use is unclear.

Another condition shaping the utility of commodity money is nomadism. In the absence of commodity money, individuals need to accumulate stocks of tradeable goods to ensure they can satisfy the potential wants of an exchange partner. Nomadism may limit the extent to which individuals can accumulate such possessions as they must transport all of their belongings (Shultziner et al, 2010). Indeed, there is evidence that sanctions against the accumulation of personal possessions are common in such societies (Woodburn, 1982). When

societies adopt commodity money, individuals who are only carrying limited commodities can still participate in exchange by using money. Therefore, commodity money may be adopted preferentially by nomadic groups.

However, it should be noted that there are some notable exceptions to the claim that nomadism limits the accumulation of goods, such as pastoral nomads who use pack animals to transport resources. For example, the Beritanlı of Eastern Turkey transport many possessions that are used to provide living conditions for 40-50 people, including tents, hearths and cauldrons (Cribb, 2004). This makes it difficult to conclude that nomadic groups would be more likely to adopt commodity moneys than other groups. Moreover, permanent settlement is a precursor of economic specialisation (Svizzero & Tisdell, 2016). There is evidence that this specialisation motivates individuals to engage in exchange with others to a greater extent, in order to acquire specific goods (Kaiser & Voytek, 1983). Therefore, the extent to which sedentism or nomadism drive the emergence of money is also unclear. It must also be considered that a society's nomadism may be related to its ability to escape or produce enough food to survive famine, indicating that an interaction between fixity and famine may confound any independent effect of either variable (Testart et al, 1982).

It is similarly unclear whether societies that have market-based economies are more likely to use money. Markets are dedicated locations where individuals offering different goods and services congregate, and using markets implies a greater frequency and breadth of exchanges. Societies vary in their engagement with markets, with some trading in markets that cover large geographical regions and others using more localised markets or not trading in markets at all. Traditionally, it has been argued that access to larger-scale markets would increase the utility of commodity money as without it an

individual would need an ever-increasing stock of tradeable goods to satisfy the needs of the large number of parties they exchange with (Kiyotaki & Wright, 1989). Therefore, large-scale market-based economies are considered predictive of the adoption of commodity money. However, it could also be argued that larger-scale marketplaces increase the likelihood of there being more individuals who possess desired goods. This creates more opportunities to exchange with people for desired items directly, and therefore reduces the need for intermediary commodities. Consequently, it remains an empirical question whether market engagement is important in explaining money use.

As mentioned in chapter three, another variable that is important to consider when seeking to explain the variation in economies and cultures is latitude. Latitudinal patterns in many traits including economic development have been said to reflect the covariation between ecological factors with latitude (Bonds et al, 2012) or the covariation between latitude and patterns of societal division, spread and differentiation (Olsson & Paik, 2013). These relationships suggest that latitude may be associated with money use. As mentioned, there is evidence that money use is shaped by ecological factors. Furthermore, as there is evidence that money systems can be inherited from other societies (Comaroff & Comaroff, 2005), a society's distance from a money-using society in terms of latitude may capture its likelihood of using money, because this implies a more distant common ancestor or relatively limited communication. Although the nature of the effect of latitude prevents me from making specific hypotheses regarding its role in money use, latitude is at the very least a useful control variable to isolate the effects of the more specific hypotheses of interest from more general processes of cultural change.

Token money

While many of the theories seeking to explain the origins of money focus on commodity money, most modern societies (and many traditional ones) do not use commodities as money. Instead, they use tokens that have no intrinsic value. Clay tablets and metal ingots that were used several thousands of years BC, tally sticks in the late Middle Ages, and modern coins and notes are all examples of objects that were used in exchanges as money despite the fact that they have no use or value (Graeber, 2011). The use of these objects as money cannot be explained by the commodity money theory that people accept money objects because they will eventually be of use to other parties in subsequent exchanges.

The use of token money in exchanges is puzzling as in doing so, individuals give up objects that have intrinsic value in exchange for those that have no intrinsic value. Recent theory however, suggests that these tokens acquire value by signifying outstanding debts. Debt represents an alternative way of resolving the double coincidence of wants (Peebles, 2010). An individual who does not have goods desired by others can receive the goods they desire by becoming indebted to the other party, and signalling this debt with the transfer of a token. The token signifies the existence of an outstanding repayment, and can therefore be offered to others in subsequent exchanges (Graeber, 2011; Mitchell-Innes, 1914; Wray, 2004). As the token simply signals debt, the token itself is immaterial, allowing objects such as tally sticks, notes and clay tablets to be used as money. The use of token money is more closely related to the category of reciprocal exchange than direct exchange, as it is a social system involving the maintenance of social relationships to keep track of exchanges rather than immediately fulfilling the double coincidence of wants.

There is a growing body of evidence in support of this debt theory. Archaeological study shows that the tablets, ingots and tally sticks mentioned earlier always detailed the names of creditors and debtors, as well as the amounts owed, consistent with the idea that they signified the existence of outstanding debts (Graeber, 2011; Mitchell-Innes, 1914; Sahlins, 1974). Another historical example is the use of written notes as payment in 17-19th century West African trading posts (Stiansen & Guyer, 1999). Initially, traders were hesitant to accept such documents from Europeans due to the potential for repayment to be withheld, but after social relations strengthened and trust was created, notes replaced cowries as the most used money object. A more recent example is the circulation of cheques during the Irish bank strikes (1966-1976). Although these cheques were unable to be cashed and therefore had no monetary value, they were accepted as payment as long as they were signed by an individual whose reputation suggested they would be able to pay in future (Graeber, 2011). Furthermore, Rai stones that were used as currency in Micronesian islands also demonstrate the importance of debt over the money object itself. These stones circulated as tokens in exchanges but their history of ownership was maintained through gossip. Due to their size, the stones themselves were rarely moved. Indeed Rai stones that had been lost in the ocean were still used in exchanges (Frisby, 2014). As the stones simply signalled who owes what to whom, whether the stones themselves were retrievable was unimportant.

While the debt theory is consistent with how past and present populations all over the world have used money, the assumptions of the theory require further investigation. Evolutionary signalling theory places great importance of the reliability or honestly of signals (Zahavi & Zahavi, 1999). If

signals are easy to fake, they lose their ability to signal an underlying trait. As tokens of debt have no intrinsic value, they can be issued at no cost to secure desired goods, and also do not intrinsically give the issuer any obligation to repay the debt they signify. This creates an unlimited incentive to issue tokens and not repay debts, which would eliminate the value of the tokens as money by disconnecting the acquisition of a token from any kind of payoff (Shubik, 1986). Therefore, understanding money use requires examination of why debts are accepted and why individuals decide to cooperate by repaying debts instead of defaulting. This introduces three additional factors that may keep money stable: reputation, enforcement and taxation.

Social mechanisms that enable cooperation and the cultural evolution of token money

The cooperative dilemma introduced by the potential for exploitation in token money use offers links to the evolutionary literature. Research into the evolution of cooperation has proposed many mechanisms by which cooperation can occur (Nowak, 2006). Most cooperative behaviours tend to be attributed to either kin selection, direct reciprocity, indirect reciprocity or institutions. Kin selection proposes that natural selection can favour increasing the fitness of others at a cost to oneself if the recipient's genetic relationship to the giver is sufficient to mean that reproduction by the recipient passes on genes possessed by the giver, thereby increasing the giver's fitness (Hamilton, 1964). However, this cannot explain money use as money use occurs between unrelated individuals. Direct reciprocity is based on the idea that one's actions towards another influence how they will act in future. Specifically, one may cooperate with individuals who have cooperated in the past, but cheat those

who cheated (Trivers, 1971). One difficulty with this explanation is that decisions about whether one should cooperate with a given person depend on remembering what they did in the past. Therefore, direct reciprocity cannot easily account for cooperation in populations that are too large to allow individuals to remember how everyone else has behaved in the past. Below I outline and explain potential explanations for money use based on indirect reciprocity and the emergence of third-party institutions that change the payoff structures for individuals and therefore facilitate cooperative outcomes via the use of money.

Reputation:

A potentially important mechanism for maintaining cooperation is indirect reciprocity. If individuals are able to channel their cooperation towards those who are known for cooperating, not only do they personally avoid free-riders, but they create incentives for individuals to cooperate in order to develop a good reputation (Fu et al, 2008; Panchanathan & Boyd, 2004). The extension of credit similarly relies upon reputations for repayment. As individuals are not obliged to exchange goods with others, they can selectively exchange with parties who are invested in maintaining a reputation for repaying their debts. This ensures that the tokens of debt they receive will secure repayment in future. It is for this reason that in many traditional and developing societies, credit relations tend to be extended between individuals or populations that are sufficiently connected to allow knowledge about their reputations to be shared (Fafchamps, 1997, 2000; Pospisil, 1958; Sahlins, 1974; Shubik, 2001). Indeed the Irish bank strike mentioned earlier illustrates this reputation-based system, as it was people's confidence in the ability of the issuing individual to repay that

determined whether or not the cheque had any value. The importance of reputation in token money use sets it apart from the direct exchange mentioned earlier. Direct exchanges concern the fulfilment of the needs of the two parties involved, without affecting other exchanges. The indirect reciprocity that is likely important for token money use involves more than two individuals, as the reputation one acquires in trading with one individual transfers to subsequent interactions with others.

One of the major ways in which information about one's reputation is transmitted and managed is through gossip (Dunbar, 2004). Across different cultures, social topics account for approximately 65-78% of speaking time (Dunbar et al, 1997; Haviland, 1977). Much of this gossip is dedicated to keeping track of other individuals and policing free riders (Dunbar, 2004), which limits the spread of cheating and defaulting behaviour (Enquist & Leimar, 1993). Indeed, the quantity of gossip received about individuals' reputations strongly predicts who cooperation is directed towards (Sommerfeld et al, 2008). This suggests that a society's use of gossip is closely related to its ability to enforce cooperation using indirect reciprocity, and therefore, that gossip may be associated with token money use.

Third-party institutions:

An important aspect of the reputation-based system is that it does not necessarily involve the administration of physical or financial punishment to those with a reputation for defaulting. Providing individuals who do maintain good reputations with access to exchange provides them with an incentive to ensure they repay their debts. An alternative way of maintaining cooperation is through third-party institutions that have the capacity to sanction individuals who

violate societal rules through fines or other dedicated punishment systems, such as police forces. These institutions remove incentives to infinitely issue token money by imposing costs on those who default on their debts. Consequently in many small-scale societies, ineffective law enforcement is considered the main reason for the failure of credit schemes (Znoj, 1998). Therefore, this invites the expectation that effective institutions may underpin the emergence and maintenance of token money.

Taxation:

Reputation and third-party institutions illustrate that imposing costs on defaulters is one way of sustaining token money. Another way is to give the tokens a specific social value so they can circulate like they are a commodity. It is through this process that taxation may predict the emergence of money. If tokens are issued by centralised governing bodies and/or are accepted by these bodies as payment for taxes, the tokens have value to everyone as acquiring them enables the payment of tax (Bell, 2001). This means that potential cheaters cannot benefit by issuing a token with no intention to repay the debt, as giving away a token reduces their ability to pay tax and therefore introduces the potential for costly sanctioning. China's IOU crisis (1992) demonstrates this idea. In this period, the state used IOUs ("white slips") in lieu of cash to pay farmers for commodities. However, the state that issued these tokens could not guarantee their value: they were only accepted by state-run stores at substantial discounts. As a consequence, the IOUs did not take on the status of a token that could be used in exchanges, which ultimately drove many farmers to poverty (Wedeman, 1997).

Despite being a topic of long-standing interest, there have been no systematic, quantitative comparative analyses of the cultural evolution of token money. Consequently, empirical evidence for the debt theory of money is lacking, as is an examination of the conditions that shape the emergence of token money. Here I attempt to evaluate the relative importance of reputation, third-party punishment, and taxation as drivers of the cultural evolution of token money. In evaluating these hypotheses I also assess the potential role that the ecological factors of food stress and mobility, and the presence of markets may have had in creating the need for money in exchanges more generally. Table 5-1 sets out the different hypotheses indicated in the above discussion and the predictions that follow from these hypotheses. In order to test these ideas I conducted secondary data analysis of a cross-cultural database using model comparison to investigate which variables predict the presence of token money use.

Table 5-1: *Hypothesised pathways through which social and ecological variables influence the probability of money use*

Hypothesis	**Prediction**	**Predictor variable (levels)**
Reputation and gossip ensures that tokens of debt have value by making defaulting costly	More gossip → greater probability of token money use	Extent of gossip (scale 0-4)
Third-party enforcement institutions ensure that tokens of debt have value by making defaulting costly	Greater sanctioning power of third-parties→ greater probability of token money use	Extent of enforcement and sanctioning power (none, for restricted decisions, for any decision)
Taxation backs the value of tokens, allowing them to be treated as commodities	Existence of taxation systems → greater probability of token money use	Political hierarchy (zero, one or two, three or greater)
Food stress shapes preferences for exchanging with others	Greater famine frequency → change in probability of money use	Occurrence of seasonal famine (low, medium, high)
Money allows nomadic	More fixed territory →	Settlement fixity

populations to trade without needing to accumulate stocks of tradeable goods	greater probability of money use	(nomadic, semi-nomadic, permanent)
Market places suggest more exchange, which indicates either easier double coincidence of wants or more opportunities to use money	Use of marketplaces → change in probability of money use	Locality of marketplaces (none to regional, supra-regional)

Control variables that predict the greater exchange (and therefore the need for commodity or token moneys) in grey

Methods

Variables

The variables used in this chapter (Table 5-2) are taken from the Standard Cross Cultural Sample (SCCS), which was sourced using the online D-Place database (Kirby et al, 2016). The SCCS is a database of the 186 societies from Murdock's (1967) ethnographic atlas for which there are the most records. The sample was designed to be representative of all world regions, in an attempt to control for statistical non-independence between the sampled societies. The SCCS is comprised of observations by ethnographers of various pre-industrial societies, quantified into nominal categories or ordinal scales to enable comparison of different societies on the same measures. From this database I use measures of money use, political structure, institutional enforcement, gossip, market use and environmental factors. As these variables differ in their coverage of different societies, our analysis is limited to 60 societies.

Table 5-2: *Variables used in the analysis with transformations*

Predictor variable (levels)	**Transformation**

Money use (not used, used)	Collapsed usable objects, tokens, foreign coinage/paper currency, indigenous coinage/paper currency into the “used” category.
Extent of gossip (scale 0-4)	
Extent of enforcement and sanctioning power (none, for restricted decisions, for any decision)	Collapsed no sanctioning power and no or few means of sanctioning into the “none” category.
Political hierarchy (zero, one or two, three or greater)	Collapsed one and two levels into “one or two” and three and four levels into “three or greater”.
Occurrence of seasonal famine (low, medium, high)	Collapsed very low and low into “low” and very high and high into “high”.
Settlement fixity (nomadic, semi-nomadic, permanent)	Collapsed semi-nomadic, rotating, semi-sedentary and impermanent into “semi-nomadic”.
Locality of marketplaces (none to regional, supra-regional)	Collapsed none, local and regional into “none to regional”.
Latitude	-

The SCCS’ money use measure is a categorical variable capturing 5 different kinds of money: none, objects that are usable, and three kinds of token money: tokens, foreign coinage or paper currency and indigenous coinage or paper currency. The distribution of data between these variables is that most societies use some form of token money, closely followed by no money. Only few societies have usable objects as money. As the sample is relatively small, having 5 separate categories for an outcome variable would likely cause issues with model convergence and the robustness of model estimates. Consequently, I collapse the variable into two categories for the analysis: money and no money (I also conducted analyses breaking the variable down further into foreign and indigenous tokens, and dropping the usable articles category entirely, neither of which changed my findings (see Appendix 3-2 & 3-3).

The institutional enforcement variable is an ordinal variable capturing 4 different extents of sanctioning possible within the societies: no formal enforcement or sanctioning power available, no or few means of coercion,

means of coercion restricted to certain types of decisions, and coercive means to enforce all decisions. Again, for statistical tractability, I collapsed categories that were not distinguishable with respect to how I expect them to affect the outcome. Specifically, I combined the societies with no formal sanctioning power and no or few means of coercion into one category.

The SCCS contains few variables that pertain specifically to taxation. However, as the SCCS is an amalgamation of different ethnographic atlases, some different variables may be available for many of the same societies, while some variables will only cover societies that other variables do not. Most of my variables cover the same societies, allowing me to maintain a relatively large sample given the size of the database. However, there is relatively little data on taxation for many of the societies. This introduces a trade-off between substantially reducing the sample to use a variable relatively more specific to my hypothesis, or maintaining the sample and using a theoretically-informed proxy for taxation. Given the relative complexity of my models due to the categorical nature of the variables, I opted for maximising the sample and using a proxy. The consolidation of resources through tribute or taxation is associated with political hierarchy. Maintaining a system in which governing power is centralised requires the continual investment of resources from the population to a centralised authority. This can be achieved in several ways, such as by coercing others to invest as a form of submission, or through tribute arrangements where surplus production is passed up the hierarchy (Flannery, 1976; Smith, 2004). This latter system may take the form of taxes, where payment to a centralised authority is framed as funding and enabling access to resources and institutions under the authority's control, such as contracting law, sanctions and accounting systems (Johnson & Earle, 2000; Smith, 2004;

Sokoloff & Zolt, 2007). Generally, societies with fewer levels of hierarchy than chiefdoms have no such centralisation of resources; chiefdoms are associated with tribute; and states are associated with taxation (Carneiro, 1970). Political hierarchy was a variable in the SCCS that allowed me to maintain my full sample, so it was taken as a proxy for taxation. The variable itself featured 5 categories: no levels, one level, two levels, three levels and four levels. Following the commonly-used categorisation of societies into small groups, chiefdoms and states, I collapsed this variable into three categories: no levels, which represents small groups; one to two levels, representing chiefdoms (“simple” and ”complex”); and three and over levels, representing states (Carneiro, 1981; Flannery, 1999; Wright, 1977).

The market exchange variable captured the extent to which societies accessed and engaged with trading posts, and the geographical scale of the parties with whom they traded. The categories of this variable were particularly imbalanced, with many societies engaging in trade with the highest level of geographical reach. Consequently, I recategorised this variable into limited market engagement (all types of trade up to restricted local trade) and extensive engagement (trading with the largest supra-national region).

The SCCS’s settlement fixity variable originally contained 6 categories, from completely migratory, to several types of semi-nomadism such as rotating and periodically moving, to permanent. The distinction between nomadic and permanent is of the most theoretical importance, so I collapsed the different semi-nomadic categories together to produce three categories: nomadic, semi-nomadic and permanent.

The famine measure was the SCCS’s occurrence of seasonal famine variable, which originally contained 5 categories: very low, low, moderate, high

and very high. These variables were imbalanced, with the categories “low” and “high” having few cases. Given this and their similarity to the categories “very low” and “very high”, I combined these variables to produce three categories: low (containing very low), moderate and high (containing very high).

Finally, I did not transform the gossip variable .This variable is an ordinal ranking scale capturing the extent to which members of the societies share information about other members’ behaviours. Debate concerning the treatment of ordinal variables as continuous in linear models continues (Long & Freese, 2006; Pasta, 2009; Williams, 2018), with the trade-offs between interpretability and potentially erroneous statistical assumptions being contended. On the one hand, treating ordinal variables as continuous requires the strong assumption that the categories are equally spaced. On the other, it has been argued that the effects of violating this assumption are marginal, and that treating ordinal variables adds much needed parsimony and interpretability (Williams, 2018). Ultimately, the effect of treating ordinal variables as continuous depends on the data itself, as categories may be more or less equally spaced. Therefore, the simplest way to ascertain whether this treatment is driving results is to compare separate analyses, one that treats the variable as continuous and one that treats it as categorical. Appendix 3-4 shows that for my models, treatment of gossip as continuous or categorical had no meaningful effect on the results. Consequently, for interpretability, below I report results from modelling that treats gossip as a continuous variable.

Modelling

Models in previous chapters have sought to account for non-independence statistically, using appropriate controls to capture hierarchical

structure. The SCCS, however, has taken non-independence into account by sampling disparate and largely separate societies from all over the world. For example, many societies are the only members of their specific language subfamilies, suggesting that they diverged sufficiently long ago to prevent any meaningful relationships that could drive my results. However, some analyses have shown that autocorrelation is still present for some measures in the SCCS data (Dow, 2007; Eff, 2004).I conducted checks using multilevel models including language families as a random effect, but found that my variables leave little variation that can be attributed to language families or other proxies for shared history (see Appendix 3-5). Consequently, the analyses presented below are single-level.

I used binomial logistic regressions for my analysis, using a model comparison approach. Initially, I conducted bivariate logistic regressions to evaluate the baseline effects of the predictors on token money use before including other predictors that would compete for the variation. The models I compared range from full models containing every variable to models containing single variables. I created models using a primarily top-down approach, where I assumed a full model containing all the predictors and evaluated the effect of dropping individual variables. I also used the same top-down protocol but removed categories of variables as opposed to individual variables, such as political constructs (sanctions and hierarchy), exchange mechanisms (markets and sanctions) and the ecology (latitude and famine). I calculate Akaike weights and importance scores to evaluate relative model fit and the contribution of each of the variables to model fit. Furthermore, I report Nagelkerke's effect size estimations to ensure that the findings are ecologically valid. Without these estimates, there is the risk that the best model is only the best relative to other

models, and that it actually explains a small proportion of variation in money use in absolute terms. Nagelkerke's effect size is commonly used for logistic regressions. It is derived from log likelihoods and is consistent with more traditional R^2 effect size estimations in the sense that it is interpretable as the proportion of explained variation in the outcome variable (Nagelkerke, 1991).

Results and discussion

My initial logistic regressions (Table 5-3) show that the third-party enforcement, hierarchy, fixity and latitude variables all have significant associations with money use. Societies with restricted and greater means of enforcing decisions have a significantly greater probability of money use than societies with no such enforcement. Societies with the ability to enforce any decision are 16.5 times more likely to use money than those with no enforcement. Societies with greater than one level of hierarchy also have a significantly higher probability of using money relative to societies with no hierarchy. Societies that are permanently settled have a significantly higher probability of using money compared to nomadic societies, although semi-nomadic societies are not more or less likely to use money compared to nomadic societies. My regressions also suggest that there is a slight but significant latitudinal gradient to money use. Market activity, famine and gossip do not correlate significantly with money use. The log odds for each of these variables are greater than one, suggesting that they have some impact, but to a much lower degree than the other variables.

Table 5-3: *Bivariate logistic regressions for each predictor variable and money use*

Variable	r	odds	d.f.	p

Enforcement (reference category: None)			60	
Restricted	1.86	6.42		0.02
All	2.80	16.50		<0.001
Gossip	0.01	1.01	60	0.96
Hierarchy (reference category: no levels)			60	
One-two levels	1.94	6.94		0.002
≥Three levels	3.25	25.71		0.005
Market activity (reference category: local-regional)	0.98	2.65	60	0.07
Settlement fixity (reference category: Nomadic)			60	
Semi-Nomadic	-0.17	0.84		0.85
Permanent	1.67	5.32		0.02
Famine (reference category: Low)			60	
Moderate	1.06	2.88		0.13
High	0.76	2.14		0.22
Latitude	0.04	1.04	60	0.01

Figure 5-1 uses the predicted probabilities from these initial logistic regressions to illustrate how the probability of money use changes with different levels of the predictor variables. It shows that even restricted ability to enforce decisions drastically increases the probability of money use, although there is some variation in the probability of societies with restricted enforcement using money. In contrast, societies that have the ability to enforce all decisions have a very high probability of using money and very little variation in this probability.

My model comparison (Table 5-4) shows that third-party enforcement is the strongest predictor of money use. This variable appears consistently in the best-fitting models, with models containing only this variable appearing relatively high in the ranking of model fit. More generally, complex models fit the data better: of the two models within 2 AIC of the best-fitting model, the best model contains every variable but famine, and the second-best contains every variable but hierarchy. At first glance this suggests that these two variables are not necessary to create a model that fits the data well. However, as the AICs

are very close together, Akaike weights are necessary to provide a better estimate of the average contribution of these variables across the comparison.

The Akaike weight values suggest that the best model is 2.2 times more likely to be the best model than the second best model, giving me confidence that this is the best-fitting model in the comparison. The Akaike importance scores confirm the importance of enforcement, as this variable has the highest importance score. These scores also show that fixity and latitude feature in many of the best models. Moreover, despite hierarchy being excluded from the second-best model, it appears in many of the best-fitting models, giving it a relatively high importance score. Famine has the lowest importance score, as it appears mostly in worse-fitting models.

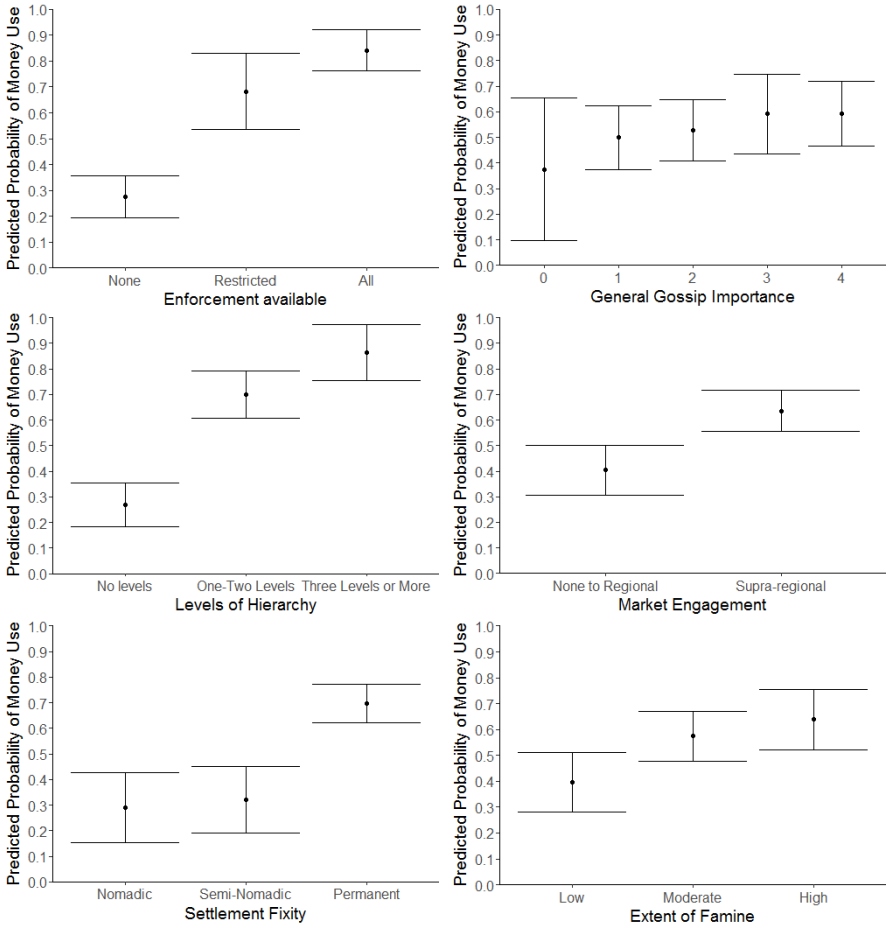


Figure 5-1: *Boxplots (mean, se) showing the predicted probabilities of money use with different levels of the predictor variables*

Table 5-4: *Model comparison for different combinations of predictor variables*

AIC	Effect size (Nagelkerke)	Enforcement		Gossip	Levels of hierarchy		Market	Fixity		Famine		Latitude	Akaike weight
		None → Restricted	None → All		Zero → One-Two	Zero → ≥Three		Nomadic → Semi-nomadic	Nomadic → Permanent	Low→ Moderate	Low→ High		
66.06	**0.64**	**4.37**	**3.57**	**0.83**	**1.83**	**5.58**	**1.46**	**0.10**	**1.89**	**-**	**-**	**1.05**	**0.35**
67.61	**0.62**	**4.79**	**6.89***	**0.78**	**-**	**-**	**1.35**	**0.09**	**2.21**	**1.12**	**0.92**	**1.05**	**0.16**
68.33	0.64	4.19	3.22	-	1.97	7.96	1.30	0.12	1.69	1.46	0.97	1.04	0.11
68.35	0.64	4.05	3.63	0.86	1.82	5.65	-	0.13	1.86	1.43	0.94	1.05	0.11
69.47	0.45	3.76	6.69*	-	3.90*	4.04	-	-	-	-	-	-	0.06
69.72	0.59	-	-	0.82	3.29	12.22	1.81	0.23	2.17	1.66	0.79	1.05	0.06
70.19	0.64	3.82	3.16	0.85	1.86	5.79	1.39	0.14	1.87	1.41	0.97	1.05	0.05
70.30	0.37	5.67*	13.99***	-	-	-	-	-	-	-	-	-	0.04
72.09	0.38	5.25*	12.06***	-	-	-	1.37	-	-	-	-	-	0.02
72.29	0.37	5.58*	13.41***	1.06	-	-	-	-	-	-	-	-	0.02
72.52	0.34	-	-	-	6.38**	17.31**	-	-	-	-	-	-	0.01
74.39	0.53	2.16	3.12	0.98	4.69*	6.05	1.51	-	-	2.03	0.89	1.03	0.01
76.69	0.85	3.92	2.63	0.96	1.82	8.48	1.57	0.08 INT	0.95 INT	0.36 INT	1.94 INT	1.05	0.002
79.65	0.17	-	-	-	-	-	-	-	-	-	-	1.03	<0.001
80.01	0.21	-	-	-	-	-	-	0.87	4.86*	-	-	-	<0.001
82.23	0.20	-	-	-	-	-	-	-	-	2.25	1.36	1.03	<0.001
82.36	0.24	-	-	-	-	-	-	0.94	4.59*	2.39	1.76	-	<0.001
84.75	0.07	-	-	-	-	-	2.57	-	-	-	-	-	<0.001
87.57	0.06	-	-	-	-	-	-	-	-	2.71	2.07	-	<0.001
88.15	0.06	-	-	1.01	-	-	-	-	-	-	-	-	<0.001
Akaike importance		0.89		0.72	0.74		0.73	0.83		0.49		0.83	

Cells contain odds ratios. INT=interaction between fixity and famine included in model. Reference category for market variable: local-regional. *Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

The effect size estimates suggest that the best-fitting model explains over 60% of the variation in money use. This suggests that my findings are not simply an artefact of comparing a set of models that were not well-justified given existing theory and therefore generally poorly-fitting in absolute terms.

The findings from the model comparison are reiterated by the predicted probabilities from a full model. These measure the probability a society that has a certain type of one variable, such as restricted means of enforcing decisions or two levels of hierarchy, uses money after controlling for all the other variables. Table 5-5 shows that societies with third-party enforcement or several levels of hierarchy are the most likely to use money, while societies that are nomadic or have undeveloped markets are among the least likely.

Table 5-5: *Predicted probabilities for money use calculated from results of the full GLM*

Variable	Levels	Probability of money use
Enforcement	None	0.45
	Restricted	0.76
	All	0.72
Gossip	0 (low)	0.54
	1	0.49
	2	0.45
	3	0.41
	4 (high)	0.37
Hierarchy	Zero	0.45
	One-two	0.60
	≥Three	0.83
Market	None to regional	0.37
	Supra-regional	0.45
Fixity	Nomadic	0.31
	Semi-nomadic	0.06
	Permanent	0.45
Famine	Low	0.46
	Moderate	0.54
	High	0.45

Predicted probabilities for a given variable are calculated with all other variables set to their modal level

My analysis is the first attempt to generate and test hypotheses that investigate the logic of the debt theory of money. A cultural evolutionary framework views token use as a cooperative dilemma that requires conditions similar to the conditions that are required for large-scale cooperation. I show that societies that have effective third-party enforcement mechanisms and systems of taxation are the most likely to use token money. Market engagement, gossip and fixity are less important predictors of token money use, and famine does not strongly predict token money use.

My findings are consistent with the idea that the debt theory of money hinges on a cooperative dilemma. Valueless tokens can be issued in exchange for goods at no personal cost if the issuer has no intention to repay their debts. Because of this, social systems that make it costly to issue tokens without intending to repay the debt they signify are needed to support the emergence of token money. Enforcement achieves this by enabling the imposition of costs on individuals who default on their debts. Therefore, societies able to dedicate more resources to maintaining third-party bodies that impose sanctions can provide the conditions needed for token money to emerge. Importantly, my multivariate approach allows me to disentangle the role of enforcement from factors such as political hierarchy, giving me confidence that it is specifically enforcement and its function in cooperative dilemmas that predicts token money use.

An additional component of my findings regarding enforcement is that there is no difference in token money use between societies that have third party enforcement of a restricted number of decisions in society, or enforcement of all decisions in society. A potential explanation for this could be that the decisions that are enforced by societies that can only enforce a restricted

number of decisions relate to debt and resource distribution, as these are important components of societal development. In this case, the categories restricted and all are equivalent with respect to how they support token money.

My findings also support the idea that systems of taxation aid money use. Taxation supports the emergence of token money by giving the tokens intrinsic value (Bell, 2001). This makes it costly to give them away, which removes incentives to issue them infinitely. Taxation co-occurs with hierarchical political organisation as consolidating resources is necessary to support centralised governance. As the levels of hierarchy increase from local bands to chiefdoms to states, the need for taxation increases. This is consistent with my finding that states and chiefdoms are far more likely to have token money than societies that are not hierarchically organised. It should be noted that my use of hierarchy as a proxy for taxation in the absence of a well-defined measure of taxation could potentially introduce some noise into my interpretation. Hierarchy correlates with many societal developments, such as increased population size and greater investment in infrastructure (Turchin et al, 2018). These may independently play roles in supporting the use of money. However it should be noted that due to my multivariate approach, I can be confident that this noise is not confounding my interpretation of the role of other variables such as enforcement. A more explicit measure of taxation that has a comparable sample size to other variables in the SCCS would enable future research to make clearer conclusions about the role of taxation in the emergence of token money.

While gossip does not correlate with token money use in univariate analyses, it does contribute to model fit. But in these models, low levels of gossip predicted token money use. This finding contrasted with my hypothesis that gossip is a mechanism that supports token money systems and was

surprising given the evolutionary research illustrating the key role of reputation in maintaining cooperation (Dunbar, 2004; Enquist & Leimar, 1993; Sommerfeld et al, 2008). This negative correlation could reflect difficulties in quantifying and measuring gossip. The gossip variable was a composite score of the extent of gossip that occurs about a variety of subjects in the absence of a specific measure of gossip about people's tendencies to repay their debts. Therefore, its relationship with cooperation is not clear. Furthermore, while the variable itself showed variation in the level of gossip, this variation may be overstated as societies that do not use gossip to track social standing at all are likely to be very rare. Consequently, the gossip variable may not be capturing the use of gossip to track reputation that is theoretically important for money use.

However, this does not explain the observation of apparently systematic decreases in the probability of money use as gossip increases in more complex models. An alternative explanation for this negative correlation is that the societies that use token money tend to be hierarchical, sedentary and governed by third-party institutions, which suggests that they no longer need gossip to maintain cooperation. Several studies have illustrated the negative correlation between reciprocity- or reputation-based mechanisms for maintaining cooperation and formal institutional means of doing so, because the latter makes the former obsolete (Hruschka & Henrich, 2013a; Hruschka et al, 2014). In other words, decreases in gossip may be proxying for changes in an underlying, unmeasured variable relating to the scale of cooperation that correlates with money use.

I find that societies with greater levels of market engagement are marginally more likely to use token money. This is consistent with traditional theory on money use, which claims that market exchange is the central

dilemma that money solves. This could be because larger markets enable individuals to take part in exchanges with a greater number of people. As this number increases, it becomes harder to exchange goods for goods, as the diversity in peoples' preferences and possessions increases. When debt can be mobilised as payment using tokens, variation in preferences and possessions becomes relatively unimportant. However, given the correlative nature of my analysis, caution must be exercised regarding reverse causality in this relationship. An alternative explanation may be that the role money plays in increasing the efficiency of exchange facilitates the emergence of market activity. Although my analysis does not permit me to make firm conclusions about this direction, there is considerable evidence of market activity preceding the emergence of money (examples of which I introduced earlier), and most theory on the evolution of money considers money to be a mechanism that increases the efficiency of existing exchanges (Earle, 2002; Kiyotaki & Wright, 1989; Smith, 1776/1976).

I also find that permanently settled societies are more likely to use token money than nomadic societies. This is consistent with the idea that permanent settlement supports economic specialisation and exchange. However, I find that nomadic societies still have a relatively high probability of using token money, suggesting that the alternative idea that adopting money is particularly beneficial for nomadic societies that cannot easily transport stocks of tradeable goods may also play a role for these societies. It should be noted that I find that semi-nomadic societies have a very low probability of using money relative to both nomadic and permanent societies. It is unclear why this intermediary stage of sedentism should predict such a large change in money use, which suggests

that this finding is the result of my limited sample size and the distribution of the data across the levels of the sedentism variable.

Famine has no real effect on the probability of token money use. Societies with low or high famine have equal probabilities of having token money. This could be indicative of a number of possibilities. Potentially, food stress does not predict increases in exchange, and therefore does not drive the adoption of money. This is consistent with the idea that food stress encourages territorial defence rather than expansion of one's social network, and also follows a growing line of research showing that ecological factors are less important for economic behaviour than social factors like institutions and norms (Rodrik et al, 2004). On the other hand, it may be that food stress does predict increases in exchange, but only exchange of goods for other goods instead of exchanges that involve money. However it should be noted that there is limited evidence for the existence of any economy outside of modern prisons that is based on such direct exchange (Humphrey, 1985). Perhaps the most likely explanation is that responses to famine are highly variable between societies. Some societies become inactive and insular while others call in debts and expand their activity to secure provisions from any source (Dirks, 1980). In the context of there being no consistent effect of famine on economic or social behaviour, it follows that it would have no consistent effect on token money use.

The primary limitations of my analyses relate to the data. In the SCCS there is much variation in the number of observations informing different variables. Consequently there is a trade-off between including many relevant variables to ensure that different hypotheses are separable and testable, and the size of the sample. The relatively small sample size means that my results could be affected by sampling error. However, I found strong effects, including

very high probabilities of money use across the sample when third-party enforcement institutions exist, which suggests that I can be confident in my findings. This confidence is strengthened by the fact that the SCCS is designed to contain unrelated and statistically independent societies from disparate locations around the world. That I found such strong effects across such a diverse sample suggests that my findings are representative.

Another potential issue is my categorisation of money. In the SCCS, variation in a society's money system is divided into several categories covering no money use, use of indigenous moneys and use of foreign moneys. I collapsed this variable into a binary between having no money and having money for statistical tractability given the number of categorical variables in my analysis. While most of the money used in these societies is token money, I nevertheless lose detail about the kinds of money systems that are used that may have affected my interpretation. For instance, societies that use foreign money may not be able to tell us about how money emerges endogenously in the same way that societies that use their own money can. However, supplementary analyses showed that categorising the money variable in different ways that accounted for the distinction between foreign and indigenous money made no difference to my findings (see Appendix 3-2). This suggests that my findings are not driven by the way I have categorised my data.

A broader limitation is that all of the variables were taken from ethnographic atlases and therefore are relatively subjective in how they were initially measured. This makes it difficult to test specific theoretical ideas. For example, the third-party enforcement variable distinguished societies that can enforce a restricted number of decisions or all decisions. What is captured in the restricted number is impossible to glean, which denies me access to specific

factors that may be of key importance for the emergence of money. Similarly, the market variable is concerned with the existence and geographical reach of market places that are used for exchange, which leaves out many details such as how many people engage in these exchanges, who they are and what kinds of things they exchange. With respect to my study, this makes my conclusions less specific and clearly defined compared to studies that use variables measured using standardised and reliable techniques. Adopting a more quantitative and comparative focus in future field studies may alleviate these limitations (Borgerhoff Mulder et al, 1985). Another potential solution may be to re-code the original data sources considering new theoretical ideas, but this does not resolve the fact that the original researchers collected their data with particular theoretical concerns in mind.

In summary, in the first explicit test of the debt theory of money, I find greater support for the debt theory compared to traditional commodity money theories. Institutional economics has so far focused primarily on modern day economies, overlooking the importance of cooperation during earlier stages, such as the adoption of token money. I show that in the same way that institutions support modern economies by enabling large-scale cooperation, institutions allow token money to be adopted by preventing individuals from defaulting on their debts. Institutions are therefore central to economic development from the inception of economies in small-scale societies to modern, globalised economies. In line with cultural evolutionary ideas about trees of cultural traits representing how different societies respond to different conditions, the importance of institutions for token money use suggests that the adoption of money is not an inevitable optimisation, but instead a potential adaptation to specific conditions.

Chapter 6: An experimental test of the tokens-as-debt theory for the evolution of money

Abstract

How money systems work and why societies use money are long-standing questions in economic history. Evidence has been growing in support of recent ideas that money originated as tokens of debt, not intrinsically-valuable tokens as traditionally thought. However, what is not yet clear is how these token-based money systems are sustained, given that parties could issue tokens to acquire goods then default on their debts to avoid paying any costs. The cultural evolutionary literature shows that reciprocity-based social sanctioning may be one mechanism that prevents this kind of non-cooperation. Here I conduct an experiment in which participants engage in a real-time multiplayer game based on exchanging real payoffs for valueless tokens, to examine how reciprocity may be used to sustain token money systems. I vary the amount of information participants have access to about parties with whom they are interacting, such as means of identification and details of past defaulting, to create conditions where reciprocity is more or less possible. I find that token money is used more successfully when parties can track who they are interacting with in a given exchange compared to when they are anonymous. Attempts (including failed attempts) to use token money in exchanges did not vary between the conditions, suggesting that people are more discerning about engaging in exchanges involving token money when they can track people's past behaviours. This finding shows that social strategies shown in the cultural evolutionary literature to sustain cooperation in

general likely contribute to the emergence, maintenance and spread of money systems at their origin.

Introduction

Many societies use tokens that lack intrinsic value as money instead of commodities that have some utility. As we saw in the last chapter (and the introduction), it has recently been argued that tokens can signal debt and thus allow exchanges to take place when one party does not possess a good the other wants. While the tokens-as-debt hypothesis is consistent with some archaeological and anthropological evidence, the logic of this theory has not yet been scrutinised. An evolutionary perspective on this issue suggests that to keep tokens of debt meaningful, a system is required that prevents individuals from paying for goods using debts that they do not intend to repay. In other words, signals should be honest (Zahavi, 1977; Zahavi & Zahavi, 1999). Furthermore, monetary exchange can be viewed as a cooperative behaviour, and needs to occur between multiple non-related individuals. Indirect reciprocity is a potential mechanism by which such cooperative interactions could occur, with individuals needing to acquire and maintain reputation as a reliable cooperator who does not default on their debts in order to gain the long-term benefits of exchange (Roberts, 2008; Nowak, 2006). Although in chapter five I found that variables related to indirect reciprocity like gossip were not important in explaining money use, the role of indirect reciprocity is still unclear for two reasons. Firstly, the gossip variable in chapter 5 was not very well defined and therefore difficult to interpret. Secondly, the findings of chapter five do not rule out the idea that a reciprocity-based system may have provided the initial conditions for the emergence of money, after which other mechanisms such as institutions may have taken over to continue enabling cooperation. Here I adapt an experimental protocol that has previously been used to examine the use of tokens in a cooperative game. I extend this approach by adding different levels

of social information to evaluate whether reputation influences the use of tokens of debt.

Honest signalling:

Evolutionary theory argues that signals—such as tokens as signals of debt—need to be honest to be meaningful (Zahavi, 1977). Using the potential for future payment as immediate payment introduces risks of default. If an individual can receive the goods they desire by issuing a valueless token of debt, they can receive all the benefits without paying any cost if they do not repay the debt that the token signifies. This incentivises individuals to issue tokens with no intention of repaying the debt they signify, which limits the ability of tokens to reliably signal that a debt exists. This makes the use of tokens of debt a cooperative dilemma. Explaining why they are used requires us to explain why individuals choose to cooperate by not defaulting on their debts.

Cooperation is one of the largest topics in the evolutionary literature. One well-studied explanation for cooperation is reciprocity, which can be direct or indirect (Nowak, 2006). Direct reciprocity is the formation of tit-for-tat relationships between two individuals. As long as individuals can keep track of who they are interacting with, they can exclude those who do not cooperate and cooperate with those who do (Rand et al, 2009). Indirect reciprocity is the channelling of cooperation towards those who have reputations for cooperating with others. This provides incentives for individuals to create and maintain reputations for cooperating (Nowak & Sigmund, 2005). An important component of indirect reciprocity is that it requires individuals to be able to keep track of who they are interacting with, the past behaviours of these parties towards oneself, and their reputations (Nowak & Sigmund, 1998).

Debts are a form of cooperative behaviour, and there is evidence that they are created and maintained using direct and indirect reciprocity (Ingham, 1996). In many different societies, credit is mostly confined to specific networks of individuals (Fafchamps, 2000; Pospisil, 1958; Sahlins, 1974). These networks are typically comprised of people who are motivated to cooperate because they are kin or have existing reciprocal relationships exclusion from which would mean losing access to resources that may be necessary for survival (Sahlins, 1974). For example, a case study of Javanese and Rejang traders illustrates how extending credit to customers of one's own ethnic affiliation can ensure repayment as the customers' investments in maintaining good relations with their community motivates them to avoid defaulting on their debts (Znoj, 1998). Similarly, the extension of credit can be conditional upon sharing religions, as this ensures that defaulting is damaging to one's standing in the religious community in which one is invested (Ensminger, 1997; Hopkins, 1973). Historical study of early (Medieval-Renaissance) European governments suggests that individuals and institutions are reluctant to accept government-issued money if the government has developed a reputation for defaulting on its debts, as this suggests that debts it issues will not be repaid (Wray, 2012). In another historical example, during the Peninsular war, Wellington was able to purchase supplies and secure local needs by paying with Bank of England notes that were readily accepted by the Spanish due to the bank's creditworthiness. Napoleon, by contrast, had to pay in gold because Spanish merchants distrusted French currency (Wheatley, 2013). Study in Southern Africa populations further illustrates the functional similarities of debt systems across different societies. The Southern Tswana calculate all transactions in terms of cattle instead of coinage. This is because cattle are owned by specific

individuals who guarantee their value (Comaroff & Comaroff, 1990). Such a guarantee offers recourse for the parties in the exchange, as if the intrinsic value of the cattle is compromised, the issuer faces damage to their reputation unless they ensure that the debt is repaid. Coinage, by contrast, has no such ownership in these societies and no guarantee of value. Using them as money therefore introduces the risk of another party issuing money but never repaying the debt.

The ability to spread information about debtors and creditors determines the effectiveness of indirect reciprocity and therefore likely plays a role in the emergence and stabilisation of tokens of debt. In small-scale societies debts are often preserved using gossip or more formal means of disseminating knowledge about defaults and payments. For example, elders may be responsible for maintaining and disseminating oral records of who issued what tokens to whom (Kocherlakota, 1998). Tokens themselves may also contain details of the issuers, which can be used to make information about outstanding debts public (Yudin & Pavlyutkin, 2015). This makes defaulting costly for one's reputation. These reputation-based systems also exist in more developed economies. The *cobrador del frac* is a traditional means of collecting debts in Spain, using extravagantly-dressed individuals whose conspicuous presence damages the debtor's reputation. Anecdotal reports suggest that this service has grown in popularity as the Spanish economy has slowed and unpaid debts have increased (Bloomberg, 2018; The Independent, 2008).

The cultural evolution of tokens: an experimental approach

Previously, Camera et al (2013) developed an experiment that examined how individuals use intrinsically valueless tokens in exchanges. They found that

the introduction of tokens into an otherwise typical cooperation game increases the level of altruism that can be sustained across groups of different sizes, despite there being no obligation to use the tokens and no intrinsic benefit to possessing tokens (Camera et al, 2013). This finding indicated that when individuals developed trust in the idea that others will reciprocate help in exchange for a token, the token could be used as money. In other words, tokens acquire the value needed to be used as money if they have a real or perceived guarantee of being able to secure repayment (Read, 1959).

One limitation of Camera et al's (2013) approach is that it is unclear why individuals developed trust in these tokens. Importantly, the tokens could not have been reliable signals of debt. This is because participants were anonymous and there was no way for participants to tell who issued a token. Therefore, they could not use information about who issued a token to decide whether returning the token to the player who issued it was likely to result in repayment, which is central to the debt theory of money. When there is no obligation to accept or use a token, individuals can give their own tokens value by repaying their debt by cooperating with those who possess a token that they issued. Doing this encourages others to accept their tokens, because they can return them in exchange for real payoffs when they meet them again. Therefore, knowledge about a person's past behaviours towards oneself and others is likely to influence expectations about whether a token they issue signifies a debt that will be repaid. Furthermore, it may be that it takes time for participants to realise that tokens can be issued in return for personal gain but do not place the issuer under any obligation to repay, introducing the question of how stable token use is over time. A related issue is also that tokens may have an effect in Camera et al's (2010) game because the participants live in a money-based

society and thus already have an expectation that monetary tokens store value, even if this is explicitly denied in the context of the experiment.

As of yet unknown is whether and to what extent social mechanisms known to maintain cooperation can shape token money use. Answering this question would inform how money systems emerge and provide evidence for the debt theory of money. I explore how direct and indirect reciprocity influences the likelihood of a money system emerging and spreading by testing if changing the information individuals can access about others influences how tokens are used. I predict that allowing participants to know who they are interacting with will enable them to gauge the value of tokens they receive from others and increase the use of tokens in cooperative exchanges. Furthermore, giving participants access to information about how every player acts in every round should give an even greater incentive to cooperate. More importantly, this should also provide more information about the value of tokens issued by certain participants, incentivising repayment to those to whom one has issued a token and therefore making the use of tokens beneficial. Therefore, cooperation and token use should be lowest when individuals do not know who they are interacting with, and should increase when individuals can keep track of who they are interacting with and how these other parties have behaved towards them and others in previous interactions. Predictions regarding any interaction between social information and the ability to use tokens are less clear. On the one hand, as token use is itself a cooperative dilemma, it should be affected by social information in the same way that a cooperative dilemma that does not involve tokens would be, which suggests no interaction. On the other hand, if tokens depend on social information, the introduction of tokens should differentially affect cooperation between social information conditions.

Consequently, my prediction regarding an interaction is two-tailed. I also predict that a participants' cooperation will positively predict the extent to which their tokens circulate in the population.

Methods

I conducted a laboratory based experiment investigating the role of social information in the emergence of money systems that use valueless tokens. The experiment replicates a previous study by Camera et al (2013) which tested cooperation in exchanges involving token money and real payoffs. I implemented changes to this original protocol that were designed to elicit whether different levels of social information about other players influenced the emergence of token money, and whether the ability to use tokens affects cooperation regardless of social information.

Participants

I sampled 92 student participants from the University of Exeter Cornwall campus (40 female, 52 male; mean age=22.87 (SD=5.16)). 73 of the participants reported having no experience with cooperation games, 13 had played a cooperation game before, and 6 reported that they had experience of more than one cooperation game. They were randomly sampled using online advertisements circulated in departmental communications and on social media, as well as physical advertisements distributed around campus. Participants took part in the experiment in groups of 4. This group size was chosen because in Camera et al's (2010) previous experiment, groups of 4 were shown not to differ in their levels of cooperation when they had tokens and when they did not. Therefore, my findings should not be driven by group size.

Each participant was randomly allocated to a group with three other players, and only played the game once, within this group. This random allocation minimised the potential for variation between the experimental groups in the extent to which their members were familiar with each other and each other's behaviour, as it was possible that, if not randomised, groups could have been comprised of individuals who knew one another which may have affected their behaviour. The experiment was double-blind, as each group was randomly allocated to be one of the six conditions and neither the experimenter nor the participants were aware of to which condition any given participant had been allocated (Table 6-1 shows the numbers of participants in each condition).

Procedure

Participants were arranged in specific seating plans so that they could not see one another at their computers. Specifically, participants were arranged in corners of the same room, facing away from one another. Participants were first given an introductory presentation on the rules of the game, how to interact with the computers and ethical information (see Appendices 4-1 to 4-4 for materials). They then completed consent and participant information forms. During the experiment, participants were not allowed to communicate and chose their responses by selecting radio buttons that presented the options available to them each round on the computers. As the experiment was structured into rounds and multiple players were playing together in real time, participants often had short (10-15 second) periods of time between rounds while they waited for the participant they would play with next to finish their previous round. During these periods, the experimenter ensured that the participants did not communicate. After the participants completed the

experiment, their final score was presented to them on their own computer screen. Participants were debriefed and given forms to record qualitative feedback about their strategies and thoughts. Participants were then paid relative to their final score. It was ensured that the minimum possible winnings were not less than the amount specified in the University of Exeter's participant payment guidelines as appropriate compensation for participants' time. Each trial lasted approximately 20 minutes. However, there was some variation in the time each trial lasted as the game was multiplayer, which meant that the slowest participant dictated the speed of the game as other participants waited for their decision.

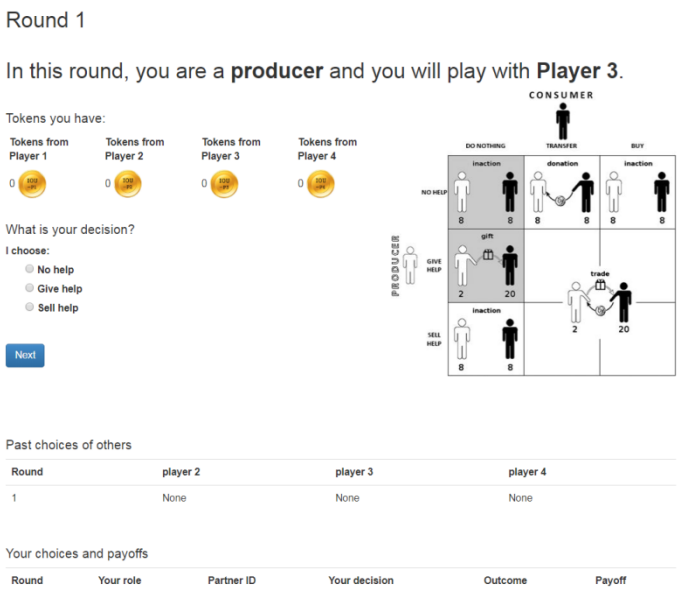


Figure 6-1: *Screenshot of the interface participants used in the experiment*

This screen is from the token and full social information condition, showing the payoff matrix, the tally of different tokens from different other players, the options available and the two tables, the first showing everyone else's behaviours every round and the second recording the player's choice, partner and payoff every round.

Design

My experiment involves a computer-based cooperative game that partially replicated Camera et al (2013). Their original game was comprised of repeated exchanges in which participants must decide whether to help a participant with whom they are randomly matched. Helping a participant increases the recipient's real monetary payoff while reducing the helper's (see Figure 6-2 for the payoff matrix used in the experiment). Participants were randomly allocated to be either a "consumer" or a "producer", and were randomly matched with another participant who was allocated to be the other role. In the control condition, producers could choose whether to help the participant with whom they have been matched or not, while consumers could not make any decision. This simple choice of whether to help the other party or not was the extent of what the participants could do in the control condition. This presents a cooperative dilemma, because if everyone helps at every opportunity, payoffs for each individual (and the group as a whole) are maximised. This is because the payoff to the recipient of help is considerably larger than the payoff available to those who do not receive help. However, for a given producer in a given interaction, not helping is the most personally beneficial option. In the token condition, consumers were given the ability to give a token. This gave them the following options every round: do not give a token, unconditionally give a token, or only give a token if their partner gives help. Producers were also given an extra option, which was to only give help if their partner gives a token. Therefore, there was a distinction between unconditionally helping (giving help) and only helping if a token was offered (selling help). Tokens do not intrinsically add to the participants' winnings, and participants are under no obligation to use tokens. I did not change these fundamental game mechanics in my experiment.

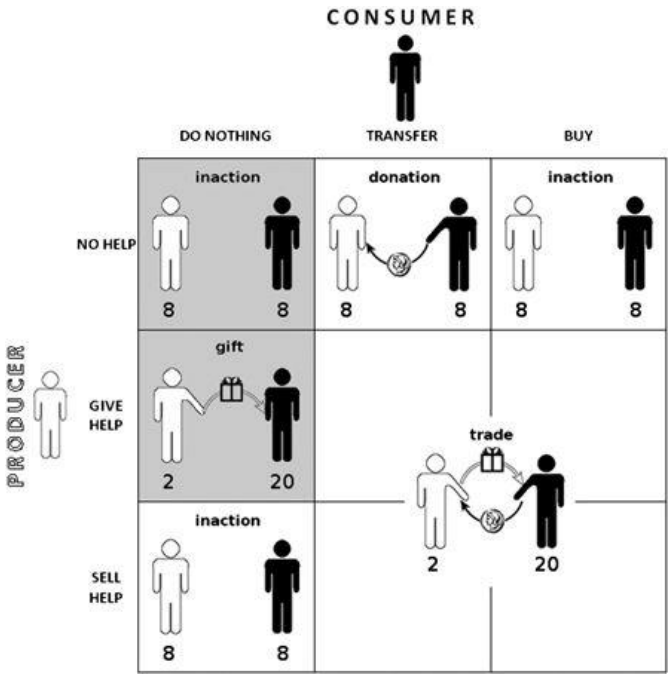


Figure 6-2: *Payoff matrix used in the experiment*

The values below the figures represent the payoffs each party received from each outcome. Each point was worth £0.02 in real money paid after the experiment. The shaded cells represent the possible choices in the control conditions. In the token conditions, every cell was possible.

I add three manipulations to the game. First, I give participants different amounts of social information. Second, I compare the effects of social information when tokens are able to be used and when they are not, to check whether any increases in cooperation are simply the result of the ability to use tokens. Third, I make tokens 'signed' by individuals, so participants know who issued the tokens they have and can use anyone's tokens in exchanges with other parties. For example, if a player plays with participant A and this participant gives them a token, they will receive a token identifiable as being issued by participant A. They can then choose to give this token in subsequent exchanges with participant A or any other participant.

These manipulations created a 2x3 between-participants factorial design. I had two between-participants independent variables: social information and token availability. The levels of the social information variables were: 1) no

social information, in which participants did not know who they were playing with in any round; 2) partner social information, in which participants can only see the ID of the participant they are currently playing with in any round; and 3) all social information, in which participants can see every participant's choice in every round, even if they were not playing with the participant themselves. The levels of the token availability variable were: tokens were available to use in the game and tokens were not available to use in the game. This created six conditions (Table 6-1). In three conditions, tokens were not included and the conditions varied in the extent of the social information provided. In the other three conditions, tokens were included and the social information was varied in the same way.

Following Camera et al (2010), in which participants played an average of 17 rounds, the game consisted of 20 rounds, meaning that participants were matched randomly 20 different times, and made 20 decisions. This allowed the experiment to be relatively short in total length even with matching delays (discussed later). Importantly, considerations of reputation become substantially weakened if one knows that they are playing in the final round after which they will not play again (Selten & Stoecker, 1986), so participants were informed only of an approximate number of rounds that they would be playing.

I collected demographic information for each participant (age, sex and prior experience of cooperative games) for the purpose of controlling for potentially important confounding variables in the analysis. I collected this information after the experiment using a short questionnaire. Another questionnaire given after the experiment also gave participants the opportunity to provide qualitative reports of their thoughts and approach during the experiment.

Table 6-1: *Combinations of social information and tokens variables that create 6 conditions*

	Conditions (N)					
	Control 1 (12)	Control 2 (12)	Control 3 (12)	Treatment 1 (20)	Treatment 2 (16)	Treatment 3 (20)
Social information						
None	X			X		
ID of partner		X			X	
Everyone's behaviour			X			X
Tokens						
Absent	X	X	X			
Present				X	X	X

Materials

The game was coded using oTree (Chen et al, 2016), which is an experimental software platform that enables the user to code custom experiments in Python and to set up servers for real-time multiplayer gameplay (see Appendix 4-5 for images of the screens participants saw in each condition). University networked computers were used for the experiment as they could all connect to the same local oTree server, allowing participants using different computers to play together simultaneously as long as they were connected to the university network.

Ethics statement

This experiment received ethical approval from the University of Exeter ethics committee, and was funded by a student grant from the European Human Behaviour and Evolution Association. Participants gave informed consent before they took part in the experiment and were fully briefed and debriefed. All data were fully anonymised and participants did not provide any

identifying information alongside their response data. Responses were kept strictly confidential with all data being stored on secure university databases. No participants sought to withdraw from the experiment but retained the right to do so.

Modelling

I first conduct a between-participants factorial ANOVA to detect any main effects and interactions involving the token and social information conditions in the absence of other influences. This is to examine whether there is any raw relationship between the conditions and cooperation before I introduce other predictor variables. I then conduct comparison of generalised linear models incorporating demographic control variables and multilevel adjustment for potential between-session differences in performance. This is followed by further model comparison examining how an individual's cooperation influences the extent to which tokens they issue go on to circulate in the population. This was achieved by including the frequency of cooperation by a given player and the number of times a token they issued was successfully transferred between any two parties in the population. Finally, the stability of cooperation across the rounds of the experiment in the different conditions was compared by including rounds as an interaction term in our multivariate models.

Results and discussion

Figure 6-3 illustrates that the inclusion of tokens shifts the distribution of cooperation, increasing the proportion of cooperative rounds. Social information does not seem to influence the distribution of cooperation to such a degree, although it appears to enable participants to reach 100% cooperation. Although

the token and social information conditions produce systematic patterns, it is important to note the level of variability in cooperation across the conditions. In every condition, scores range from 0% cooperation to over 80%. Analysis of the control variables showed that age, sex and prior experience have no significant influence on cooperation, and do not interact with the social information or token conditions (see Appendix 4-8 for bivariate tests using control variables).

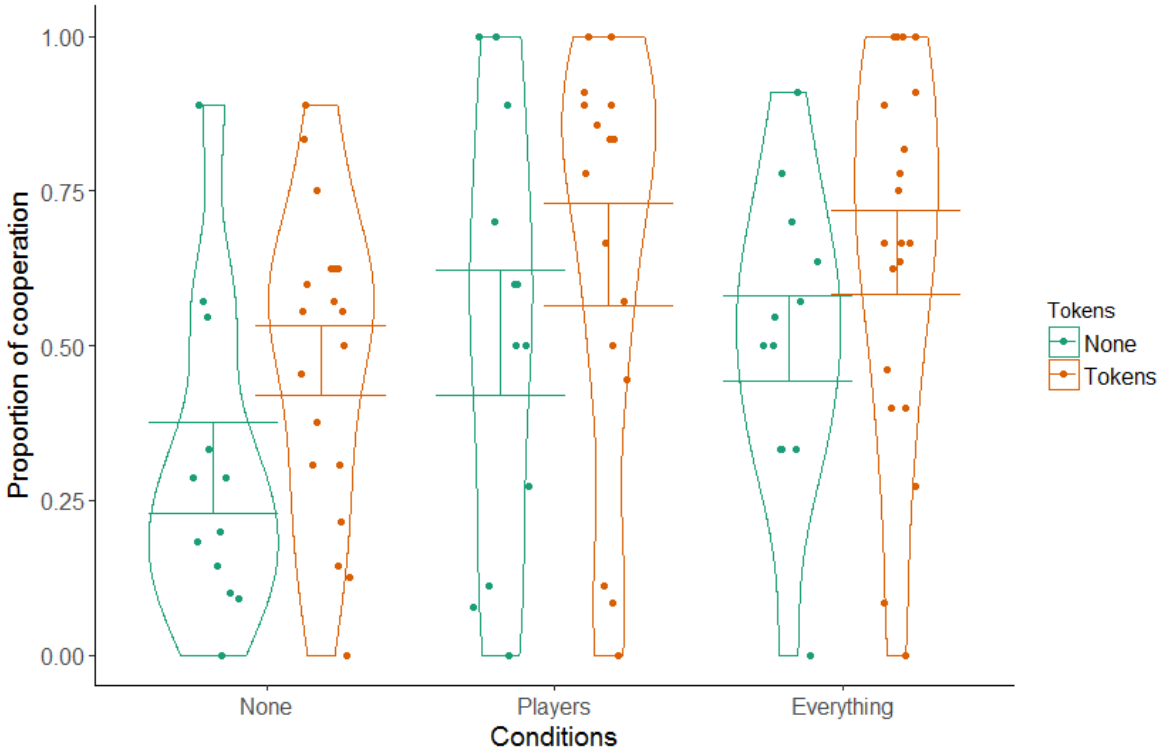


Figure 6-3: *Violin plot showing the proportion of cooperation across the experiment for each participant in each condition*

The initial factorial ANOVA (see Appendix 4-6 for homogeneity of variance and normality tests and Appendix 4-7 for confirmatory non-parametric tests) was significant overall ($F(5,86)=2.85$, $p=0.02$) and revealed that significantly more cooperative interactions occurred in the token condition (producers cooperated 59% of the time across all of the rounds) than the non-token condition (44%) ($F(1)=5.62$, $p=0.02$). It also showed that social information had a significant effect on cooperation ($F(2)=4.27$, $p=0.02$).

Specifically, giving participants information about who they are playing with increases cooperation (producers cooperated 59% of the time) relative to when players are anonymous (41%) (Tukey's p=0.04). Giving participants information about what everyone is doing every round also increases cooperation (producers cooperated 60% of the time) relative to when players are anonymous (41%) (Tukey's p=0.03). However, giving participants information about what everyone is doing each round does not increase cooperation (producers cooperated 59% of the time) relative to just providing participants with information about who they are currently playing with (producers cooperated 59% of the time) (Tukey's p=0.99). I also found that there was no interaction between tokens and social information (F(2)=0.05, p=0.95), meaning that social information did not affect the level of cooperation differently in the token and non-token conditions. This supports the idea that token use is a cooperative dilemma that is affected by social information in the same way as any other cooperative dilemma.

I conduct a model comparison to supplement the significance tests (Table 6-2). This first compared whether cooperation scores were more similar within groups than between groups regardless of the conditions to ensure that extraneous patterns of variation were not driving the results. I found little evidence of clustering as the ICCs reduce to 0 with the inclusion of the condition variables, and so I report a model comparison using only fixed effects. The comparison shows that the inclusion of both tokens and social information is important, as removing either one of these reduces model fit. The best-fitting model included tokens and social information, and the second-best model (although within 2 AIC of the best-fitting model) also included tokens and social information with the addition of the demographic control variables. The removal

of control variables marginally improves rather than damages model fit, which gives a simple best-fitting model with only tokens and social information included.

Table 6-2: *Model comparison examining predictors of cooperation*

	Random effect test				Fixed effects comparison				
Fixed effect									
Tokens (reference category: No)									
Yes	-	0.15**	-	0.15*	0.15**	-	0.15*	0.15*	-
Social information (reference category: None)									
Players	-	0.21**	-	0.19**	0.21**	-	0.19**	-	0.18*
Everything	-	0.19**	-	0.19**	0.19**	-	0.19**	-	0.19**
Age	-	-0.01	-0.01	-	-0.01	-0.01	-	-	-
Sex (reference category: Male)									
Female	-	-0.06	-0.10	-	-0.06	-0.07	-	-	-
Prior experience	-	0.08	0.07	-	0.08	0.07	-	-	-
Random effect									
Group	0.08	0.00	0.13	0.00	-	-	-	-	-
AIC	45.82	39.54	47.61	38.67	**37.54**	47.32	**36.67**	41.53	40.49

Numbers in cells represent standardised coefficients apart from those for the random effect which represent ICCs. p<0.05, p<0.01***

I conducted further analyses to gain more insights into the drivers of the difference in cooperation in the token conditions (N=60). It may be the case that the increase in cooperation associated with the inclusion of social information in the token conditions is due to increases in unconditional help-giving as opposed to successful exchanges that depend on the use of tokens. Two separate one-way ANOVAs showed that individual's attempts to use tokens (successful or unsuccessful) ($F(2)=0.14$, $p=0.87$) and the frequency of unconditional help-giving ($F(2)=0.67$, $p=0.52$) did not vary between the social information conditions. Figure 6-4 illustrates how social information had no effect on

attempted token use and help giving, although removing anonymity did cause a small number of participants to give unconditionally many times. The results shown in Figures 6-3 and 6-4 together show that there is no difference in attempts to use tokens between social information conditions, but an increase in the frequency of successful cooperation when social information is available. This increase is not explained by any changes in unconditional giving, which does not vary between conditions. Therefore, while people do try to use tokens when they are anonymous, they are rarely able to be used as a means of securing help during cooperative exchanges with others.

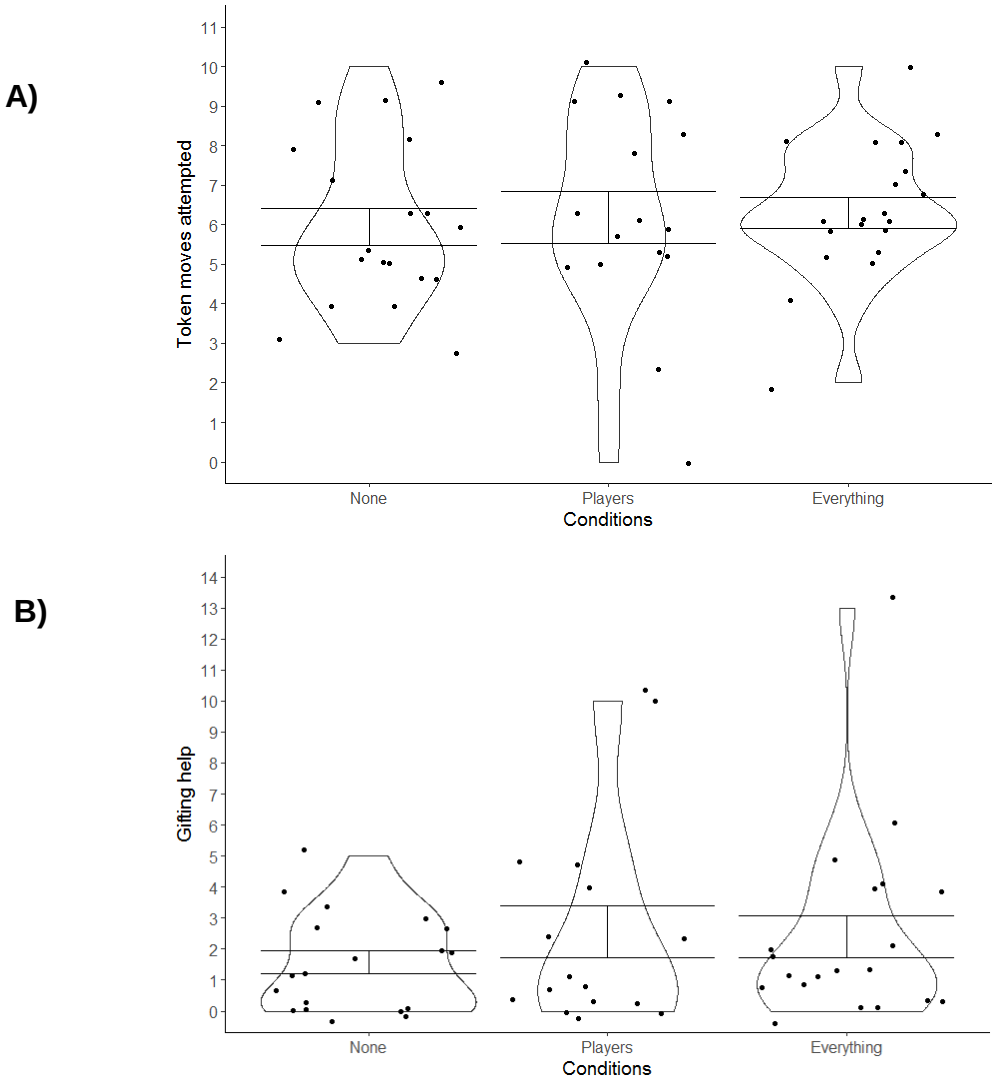


Figure 6-4: *Frequencies of attempted token use and altruism across social information conditions*

Panel A presents the frequencies of attempted token use across the social information conditions; panel B presents the frequencies of unconditional help giving.

I also examined whether tokens issued by individuals who show high levels of cooperation circulate in the population to a greater extent than tokens issued by individuals who do not cooperate as much. Contrary to my expectations, I found that there was no correlation (r=0.16, p=0.34). A high level of cooperation by a given player is not associated with an increase in the extent to which tokens they issued are used in exchanges in the population. For example, Figure 6-5 illustrates that in one instance, the tokens of a one participant circulated in numerous exchanges in the population despite this participant not cooperating at all throughout the experiment.

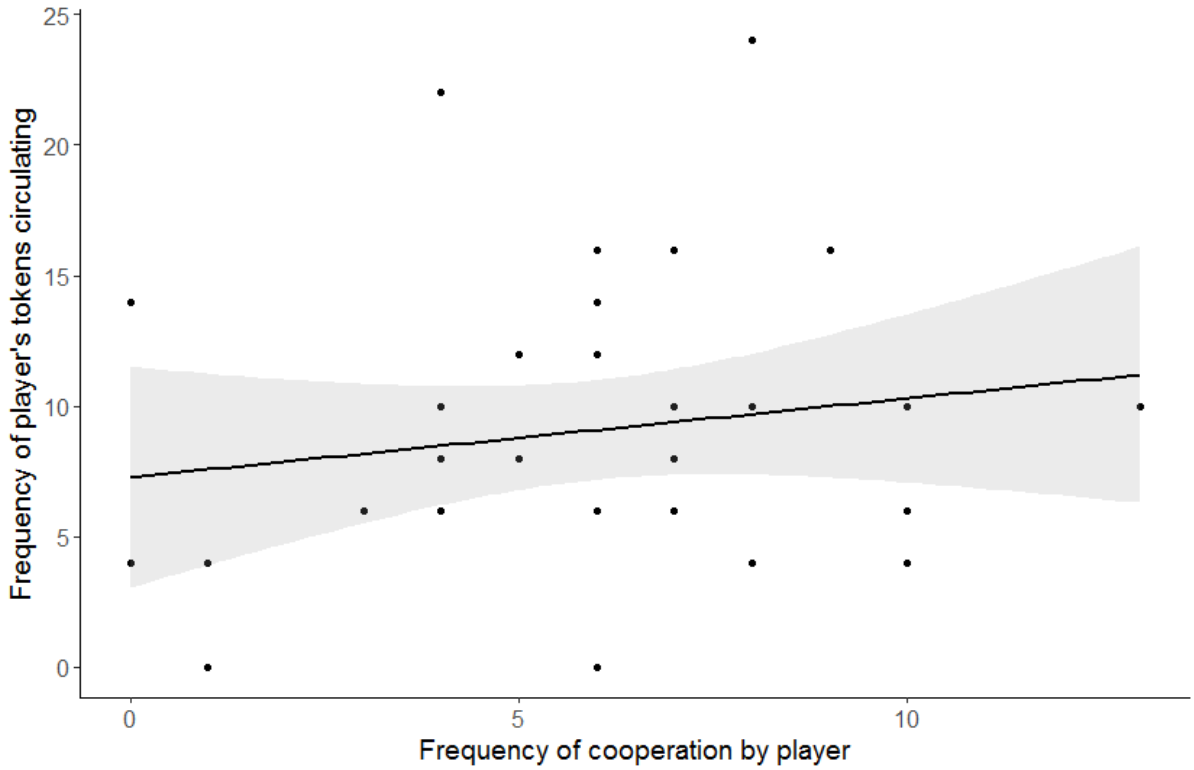


Figure 6-5: *Effect of players' levels of cooperation on the amount of times their token circulated among the players*

Finally, I evaluated how the conditions influenced the stability of cooperation across the rounds of the experiment. Figure 6-6 shows that when

no social information was available, cooperation generally decreased across rounds whether the participants were able to use tokens or not. Although cooperation fluctuates across the rounds, there is a relatively consistent pattern in which the peaks of cooperation reduce in size. The introduction of social information ameliorates this decrease to an extent. When participants had access to knowledge about whom they were playing with or the behaviours of everyone in every round, cooperation was more stable across rounds. This is emphasised when the non-token and token conditions are collapsed together, as cooperation falls when there is no social information but stays relatively constant when there is. However, model comparison showed that model fit is weakened by the inclusion of an interaction term that captures whether the conditions have any effect on the change of cooperation over rounds (Table 6-3). Therefore, the differences between the conditions indicated by Figure 6-6 are too slight for me to conclude that social information or token use have an effect on the stability of cooperation over time.

More generally, in the absence of a mechanism such as institutions, declining contributions over time are expected in most cooperative games because of slight self-serving biases resulting in self-serving responses by others, which causes cooperation to deteriorate (Fischbacher et al, 2001). This is particularly true in anonymous interactions. The slight downward trend of cooperation in my anonymous condition is consistent with this. However, the downward trend in the other social information condition appears to be driven by particularly large peaks in cooperation in the opening rounds. This initial cooperativeness may be an expected aspect of indirect reciprocity, as the maintenance of cooperation using this mechanism depends on the establishment of a reputation for cooperating. Indeed, the levels of cooperation

in the opening rounds between the social information conditions map onto the visibility of reputation information, with no ability to establish a good reputation resulting in low cooperation in the opening rounds of the anonymous condition, the opportunity to establish a good reputation with one player resulting in higher cooperation in the condition providing information about the person one is playing with currently, and the opportunity to establish a good reputation with the whole population producing even higher cooperation in the condition where all choices are visible. This may provide some insights into the workings of indirect reciprocity, as it appears that knowledge that one's actions are visible to others shapes propensities to cooperate and make oneself vulnerable to exploitation. While my study did not make any specific hypotheses regarding cooperation in the opening rounds of the game, these findings provide some guidance for future, more general experiments into cooperation, as digging down into the trade-off between how far a good reputation can reach (and therefore its benefits) and the costs of risking exploitation may offer insights into the conditions in which cooperation using indirect reciprocity can emerge.

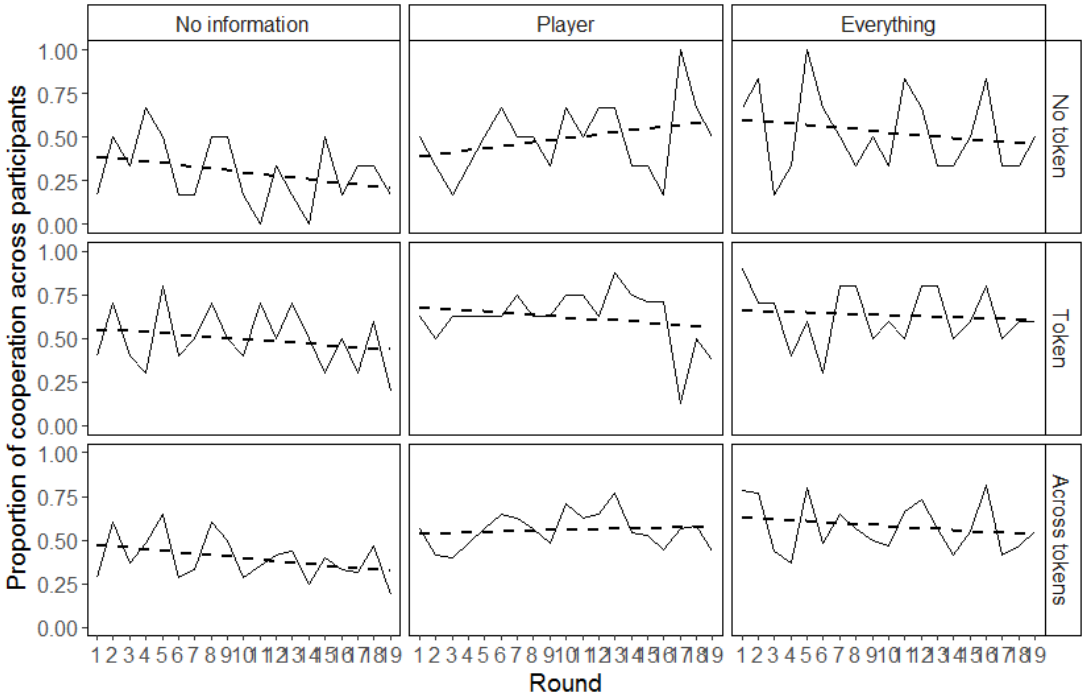


Figure 6-6: *Stability of cooperation across the rounds in each condition*

My analyses showed that access to social information allows people to form direct and indirect reciprocal relationships that enable valueless tokens of debt to be used as a medium of exchange. Introducing tokens into cooperative games and removing anonymity both increase the level of cooperation between individuals. Social information does not influence the extent to which individuals attempt to use tokens in exchanges, or the level of unconditional giving, but does increase the amount of successful exchanges of help for tokens.

Table 6-3: *Model comparison of the effect of conditions on the stability of cooperation over rounds of the game*

	No interaction model	Interaction model
Fixed effect		
Tokens		
No→Yes	0.14***	0.16
Social information		
None→Players	0.16***	-0.02
None→Everything	0.18***	0.21
Round	-0.01	-0.01
Tokens*Social information*Round		
No social information→Players: cooperation across rounds	-	0.02
No social information→Everything: cooperation across rounds		0.002
No tokens→Tokens: cooperation across rounds		0.004
AIC	**-52.36**	-44.95

*Numbers in cells represent standardised coefficients. Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

Qualitative themes

When participants had completed the experiment, they were given the opportunity to share what they thought was the best way to get the most points, how this strategy changed and any other detail they thought relevant. 71 out of

92 participants provided this feedback. 62 participants answered the question about the best way to get the most points, and 51 participants commented about their strategy. This feedback only ever referred to: being selfish, considering reputation and reciprocity, using tokens to protect against free-riding, using non-payoff-sensitive strategies, token value or token stocks (see below and Appendix 4-9 for more detailed breakdown of numbers of people who gave these comments).

A large proportion of the participants (37%) stated that they considered people's reputations as part of their strategy. Whether a participant decided to help another was highly contingent on their partner's previous behaviour. This was phrased as creating a "bond" in some cases, and as related to punishment for the "greed" of other players in other cases. When participants were given information about what every participant did in every round, they expanded their strategy to indirect reciprocity, looking for patterns of behaviour in every other player. Consistent with the expectations of reciprocity theory, participants withheld help when matched with a player who did not help them or others in previous rounds, and preferentially helped players who had helped others.

Over half (54%) of the participants who gave feedback reported that their initial strategy in the game was to never give other players help or tokens. This is consistent with rational choice theory, which predicts that individuals always seek to maximise their own personal payoff. However, only 6 (7%) of the participants pursued the strategy of never giving help, and only 1 participant (2%) in the token conditions never used tokens. The correspondence between what individuals say and how they behave has been the subject of much research in motivation and marketing, but not in cooperative games. The difference between the participants' reported strategy and their actual behaviour

most likely reflects a change in strategy in response to payoffs, emerging norms or other players' behaviours. This is consistent with reciprocity theory, as understanding of the cooperative tendencies of others is necessary for cooperation to emerge in such a small-scale economic game (Nowak, 2006). However it should be noted that the participants' written comments could simply reflect demand characteristics, as although most participants reported no experience with cooperative games (79%), they may have knowledge about how they would be expected to behave when participants in an experiment involving opportunism.

The participants' comments suggest that the most common change in strategy was from giving help to selling help. Participants who began giving help were sometimes matched with consumers who did not issue tokens, meaning that the participant did not receive any tokens in exchange for giving help. Despite the tokens having no value, participants were motivated to avoid giving help without receiving tokens in return by selling help instead of giving help. Selling help is a conditional decision, meaning that it only provides the other player with help if they choose to transfer a token, otherwise no help is given. The participants' decisions to move from giving help to selling help indicates that they preferred to acquire recognition of their helping behaviour in the form of a token of debt, even if this had the same payoff as if no such token was received.

A small minority of participants reported that they did not change their decisions in response to the behaviours of other players (4%). Of these, some reported alternating between cheating and helping or using tokens. In some cases this was due to indecision. But mostly, this was due to a desire to maintain 'balance' in their behaviour, where their decisions were equally

distributed between cooperation and non-cooperation regardless of payoff. This alternating strategy was most common in the conditions with no social information, suggesting that it may be an attempt to reap the benefits of cooperating with co-operators while protecting oneself against free-riders in the absence of any cues informing the participant about the tendencies of the other players.

Overall, I find that giving individuals access to information about the behaviours of the individuals with whom they are interacting increases cooperation in cooperative games in which individuals are allowed to exchange valueless tokens, as well as in games in which they are not. Allowing individuals to exchange tokens in games also increases cooperation. Cooperation is therefore at its highest when participants have access to social information and are able to exchange tokens. In general, these effects are modest in magnitude, with social information increasing cooperation when tokens are available by approximately 17%. Nevertheless, I show that enabling players to track the behaviours of others increases the successful use of tokens as a medium of exchange to a similar degree as it increases cooperation in the absence of tokens. This is in line with the hypothesis that token use is a cooperative dilemma, which suggests that the emergence of money is shaped by similar forces to those that affect cooperation within societies. Indeed, although the effects are modest in this controlled setting, such small benefits could lead to potentially larger effects in the real world where there are opportunities for communication and learning about the most beneficial strategies.

My findings build on a previous experiment that sought to explain money use. Camera et al's (2013) study claimed that valueless tokens of debt are used because people develop trust in the tokens. I indeed find that introducing tokens

does increase the number of cooperative interactions. Importantly however, I show that token use appears to increase when social information is available. This is consistent with the logic of the debt theory of money, which implies that the use of token money involves a cooperative dilemma. Individuals can receive goods they desire at no cost by issuing tokens with no intention of repaying the debts they signify. Therefore, for tokens of debt to circulate, a system is required to ensure that individuals do not default on their debts. Ethnographic and evolutionary study indicates that such a system may involve reputation or reciprocity, as these are important for the emergence and spread of credit arrangements and cooperation in small-scale societies because they allow individuals to channel their cooperation to those who will not cheat them (Graeber, 2011; Znoj, 1998). I find that this mechanism appears to apply to money use, as while people's *attempts* to offer tokens in exchange for real payoffs are not affected by the ability to track the behaviours of others, the acceptance of these tokens, and therefore the adoption of tokens as a medium of exchange, does appear to be dependent on people's access to social information.

One particular effect of the social information conditions is that providing information about the behaviours of every other player every round does not increase cooperation or successful token use relative to information about whom individuals are playing with. In other words, giving players information sufficient to allow them to reciprocate supports the same amount of cooperation as giving players information that enables the development of reputations. However, indirect reciprocity theory suggests that making all behaviours public would make it easier to channel cooperation to co-operators and give a greater incentive to avoid defecting. One potential explanation for this discrepancy

could be that the total population size was small. Therefore, the interactions any given other has with oneself represent a relatively large proportion of their total interactions. This may mean that how others behave towards oneself is fairly representative of how they behave towards others, causing their interactions with others to provide relatively little extra information. On the other hand, another potential explanation could be that whether people repay tokens they issued to some does not necessarily mean that they will do the same for others, particularly in the context of an experiment where decisions are rapid and no real cost is ever incurred on any participant. Therefore, the only important information may be how individuals behave towards the self, and how they behave towards others is not seen as indicative of this information.

Another aspect of the debt theory of money is that individuals give the tokens that they issue value through their own actions (Graeber, 2011; Mitchell-Innes, 1914). Individuals are responsible for repaying the debts that are signalled by the tokens they issue. If they do not do so, they receive benefits with no cost at the expense of others, which erodes the value of the tokens they issue as markers of a future repayment. However, I find little evidence for this process. The number of times a token issued by a specific individual circulates among others is an indicator of the value of the token as a medium of exchange, but I found that the degree of this circulation is not strongly correlated with the level of cooperation shown by the individual who issued the token. While there is a slight trend towards individuals preferring to use the tokens of co-operators as a medium of exchange, tokens issued by individuals who did not cooperate at all during the experiment also occasionally circulated among other players. One potential reason for this is that individuals were not interested in whom tokens were originally issued by, but this is inconsistent with

the qualitative reports of the participants (see above). Another explanation is that individuals may accumulate tokens from relatively non-cooperative others and not use them due to the behaviour of their issuer, but when they run out of other tokens, their remaining options are to refuse to exchange or use the tokens they have. In this case, individuals may attempt to use any token regardless of its issuer instead of refusing to exchange.

This emphasises a potential limitation of my methodology. I gave participants a fixed and finite number of tokens to use. While this was convenient for the experiment's mechanics and analysis, it may have been an unrealistic assumption that is potentially problematic for my interpretation. Theoretically, there is no reason why tokens of debt should be scarce. The objects themselves are immaterial and do not affect their ability to be used as money (Graber, 2011; Sahlins, 1974). Individuals should be able to issue anything in an exchange as long as it is attributable to them, which suggests that the number of tokens individuals can use may not be so limited in real life. Therefore, my experiment may have underestimated the extent to which tokens of debt are used in general, as the data suggest that 8% of participants ran out of tokens to use at some point during the experiment.

Prior experience, sex and age all have no effect on token money use. The findings of previous studies into the role of gender in cooperation have been mixed. Some found that males cooperate more than females (Brown-Kruse & Hummels, 1993; Kurzban & Houser, 2001; Rapoport & Chammah, 1965), others showed that females cooperate more than males (Frank et al, 1993; Nowell & Tinkler, 1994) and others still showed no evidence for a gender difference at all (Cadsby & Maynes, 1998). My findings are consistent with there being no systematic effect of gender on cooperation. While it may be the case

that gender captures systematic variation in how individuals are socialised to think about moral responsibilities (Gilligan, 1982), I show that this does not affect token use in experimental conditions.

In contrast, the absence of an age effect in my experiment is less conclusive. My sample does not permit me to make claims about the role of age in cooperation, as the variation in age was too low to allow meaningful comparison between ages. For future research, a less age-restricted sample should be collected to allow age comparison and also to enable questions to be asked about cooperative interactions between different age groups, which would increase the applicability of the findings to the real world.

The absence of an effect of prior experience stands in contrast to evidence that experience with cooperative games is associated with a decline in cooperation (Selten & Stoecker, 1986). However, it should be noted that this decline is commonly said to be due to individuals learning strategies that allow them to exploit others at little personal cost, which is accomplished mainly through defection towards the end of the game. In my experiment, I prevented participants from adopting such end-game strategies by presenting noisy information about the number of rounds in the game. That I did not find an effect of prior experience when end-game effects were impossible suggests that previously observed reductions of cooperation caused by prior experience may well be due to the learning of end-game strategies. On the other hand, it should be noted that prior experience was controlled for rather than systematically analysed, and had low variation with the vast majority of participants reporting no experience. Therefore, my sample does not permit any meaningful conclusions about systematic effects of prior experience on cooperation.

While my experiment offers insights into the conditions underpinning the emergence of money, my findings regarding the maintenance of money use over time are limited. Differences in token availability and social information both had little effect on the stability of cooperation across rounds. As mentioned, previous experiments have shown that over time, individuals in cooperation games tend to decrease their cooperation across rounds, often because they learn the benefits of free-riding over several rounds (Selten & Stoecker, 1986). In the experiment, cooperation was relatively stable across the rounds. Although there was more of a trend towards decreasing cooperation over time when participants were anonymous relative to when social information was available, a difference between the conditions in this trend was not supported statistically. Research on the stability of cooperation over time in various conditions is relatively limited, let alone cooperation involving token money. My findings do not permit me to make any strong conclusions about how stability of token use is affected by social information, and this represents an avenue for future research.

More generally, I offer support for the roles of direct and indirect reciprocity in cooperation, adding to the considerable evolutionary literature on the subject. I find that removing anonymity increases cooperation by shifting the distribution of cooperative behaviour from few persistent co-operators and many defectors to mostly co-operators and few persistent defectors. This pattern is consistent even when complexity is added to the cooperative interaction in the form of token money.

One limitation of my study is that while groups were randomised to ensure social relationships between participants were not introduced as a confounding variable, I used a student sample, so there is the potential for

individuals within groups to know one another and change their behaviour as a consequence. However, within the game participants were only referred to by randomly-allocated player IDs and no individual had any way of being able to discover which of the other players corresponded to which specific IDs. Therefore, in the unlikely event that some of the participants in a group knew one another, they could not change their behaviour to respond differently to those they knew. Moreover, there is no reason to assume that the extent to which participants knew one another would have varied systematically between the conditions, suggesting that it could not have realistically driven the findings.

Another limitation is the terminology used in the cooperation game. The participants were sampled from a single university in the UK, categorising them as a WEIRD sample (Western, Educated, Industrialised, Rich and Democratic) (Henrich et al, 2010). Not only does it make the sample unrepresentative, which severely limits the generalisability of my findings, it may be the case that the sample's experience with high economic development and effective institutions means that they associate the terms 'buying' and 'selling' with successful and productive behaviours that make them preferable to donating or doing nothing in an economic game. In the non-token condition, buying and selling were not available options. Therefore, the difference in cooperation between the token and non-token condition could be because participants were attracted to buying and selling as a response to demand characteristics, without engaging in how these options may allow them to solve the cooperative dilemma presented by the task. However the results show that there was a lot of variation in responses in the token conditions. Many participants donated tokens and helped, as well as choosing to do nothing. Perhaps more importantly, this potential bias cannot explain the differences in token use and cooperation between the social

information conditions, which was my main point of interest. Potential future experiments may benefit from changing the terminology used in the experiment. Removing cues that the game is an economic exchange may minimise any bias participants have towards engaging in buying and selling behaviours.

A similar limitation concerns how participants perceived the tokens. A small number of participants sought to collect as many tokens as they could because they believed the tokens would be revealed by the experimenter to have a value that would increase their payoff. The participants were extensively briefed and tested on their understanding of the game mechanics and this is reflected in qualitative feedback stating that they anticipated tokens may have value “even after being told they didn’t”. There are a number of reasons why participants behaved in a way that the instructions were designed to prevent. Pollution of the participant pool is being recognised as a growing problem is psychology, as experiments that use deception can cause participants to develop suspicions about experimenters’ intentions in subsequent experiments. More general suspicion may also be to blame as many of the participants reported having never taken part in a cooperative experiment before. Suspiciousness can lead to changes in behaviour (Adair, 1972; Hertwig & Ortmann, 2002) and in the case of my experiment, may have been the reason why some participants tried to collect tokens. Collecting tokens inherently reduces the extent to which the individual uses tokens in exchanges, but also impacts the ability of other participants to use tokens. Consequently, the belief that the tokens were not valueless may provide another reason to think that my experiment underestimates the extent to which individuals use token money.

In summary, I show that valueless tokens of debt are more likely to be used as money when relationships based on reciprocity can be formed, to a

modest degree. Until now, no study had shown that money systems could emerge in these conditions, and studies struggled to create a money system even when the money objects had intrinsic value. I show that the debt theory of money is a more likely candidate for explaining the origins of money than traditional commodity theories. Far from being a rational, economic decision, the use of money is a fundamentally social behaviour that is vulnerable to exploitation and only sustainable in a specific social environment where people are invested in long-term reciprocal relationships with others. My findings offer insights into how people might conduct their economic activity in cases of economic instability or change, when confidence in modern institutions that prevent defaulting may be lost, or in cases where economic relationships are burgeoning and the value of goods, currencies and social relationships is uncertain. By demonstrating how and why social relationships are important in money use, this chapter offers some guidance about where resources may be most efficiently used to maintain economic activity in such situations of economic uncertainty or instability.

Chapter 7: Discussion

In this thesis, I have attempted to contribute to our understanding of the diversity in economic development around the world by offering a perspective grounded in cultural evolutionary theory. I have used a cultural evolutionary framework to interrogate existing theories for variation in economic performance and money use between societies, and to devise new explanations based on shared history and cooperation. As well as making a theoretical contribution, I sought to demonstrate the value of a multi-methods approach, highlighting instances where traditional techniques may be inappropriate or biased.

In this concluding chapter I first summarise the findings from each of the individual analysis chapters. Then, I synthesise the findings across the chapters, exploring broader conclusions that emerge from taking the findings of chapters together. Following this I explore how the findings of this thesis have implications for studies of economic phenomena and cultural evolution, before offering recommendations for future research based on these findings.

In chapter 3, I found that the timing of statehood and agriculture both have primarily indirect effects on modern-day GDP. The timing of statehood strongly predicts the quality of modern-day institutions which in turn predict GDP, rather than having a direct effect on GDP as suggested in previous studies (Putterman & Weil, 2010). The timing of agriculture is associated more strongly with the earliness of statehood than GDP or other modern-day variables. These two indirect relationships are consistent with studies on societal evolution that suggest that 1) stable and effective institutions are the result of experimentation over many generations (Wright, 2006), with more time for experimentation with centralised governance leading to stronger institutions in future generations; and 2) the economic specialisation, sedentism and

growing population size associated with agriculture provide the conditions for centralised governance (Olsson & Paik, 2013; Putterman, 2008). I also evaluated other previously-identified direct relationships. On the one hand, I find support for various theories in institutional economics, showing that institutions are strongly predictive of economic development and that patterns of European settlement were related to ecological factors (Acemoglu & Robinson, 2012). On the other hand, I find no support for the ideas that in-group biases are predictive of GDP, or that in-group biases are responses to the disease environment (Fincher & Thornhill, 2012).

In chapter 4, I showed that patterns of shared history between modern societies play an important role in shaping the distribution of economic development around the world. Societies that share a relatively recent common ancestor are highly likely to be more similar in their modern-day economic performance than societies that are more distantly related. In contrast, societies grouped by other aspects of shared history such as similar environments and evidence of extensive communication do not seem to be as similar in their modern-day economic performance. This shows that the recency of shared history between societies is part of the explanation for variance in their economic outcomes. As this shared history cannot be captured by modern-day, nation-level factors, this suggests that it is being overlooked in existing cross-national research on economic development.

In chapter 5, I found that enforcement institutions are the strongest predictor of token money use in traditional societies. This relationship is consistent with the debt theory of money (Graeber, 2011), as the ability to formally sanction individuals for their behaviours resolves the cooperative dilemma inherent in tokens of debt that would normally restrict their use.

Another strong predictor of token money use was taxation, which provided further support for the debt theory of money as taxation is another way of resolving the same cooperative dilemma by giving all tokens that can be used to pay taxes inherent value. I also found some support for more traditional predictors of money use such as market engagement and settlement fixity, but to a lesser extent than the support found for institutions.

In chapter 6, I showed that information about how likely people are to repay their debts influences the extent to which valueless tokens of debt are used in a population as payment for beneficial services. Specifically, I compared rates of token money use and debt repayment when people have access to information about the frequency with which others issue tokens relative to when they do not have this information. I found that people cooperate more when they have this information about peoples' tendencies to default. I also found that tokens issued by individuals who do not often repay their debts actually appear to be able to circulate in the population, or at least are not necessarily avoided in transactions. The importance of this latter point requires further investigation, however, as this may be an artefact of a methodological decision to make tokens finite.

Across all the analysis chapters, I find support for the idea that cultural evolutionary mechanisms are important for explaining global variation in the development of economies. Cultural inheritance is the mechanism that drives the persistent effects of the timing of statehood and agriculture. Experience with centralised institutions and agricultural subsistence is passed down generations through social learning, which is necessary for this experience to accumulate within societies to the benefit of their modern-day institutions and economies (Bockstette et al, 2002; Spolaore & Wacziarg, 2009, 2013). Furthermore, the

effect of shared history also reflects the importance of cultural inheritance, as it is differences in the timing and degree of social learning between societies that create the patterns of cultural similarity and difference that appear to explain diversity in economies. Previous work has used ideas about how social learning shapes individual level behaviour to explain cultural inheritance of group-level traits such as social structures and institutions (Smaldino, 2014). My findings present the next step of this line of thinking, showing that patterns of cultural inheritance shape nation-level economic variables on a global scale.

As well as inheritance being an important cultural evolutionary mechanism, I have argued that selection underpins the relationship between state history and modern institutions. My findings are consistent with the idea that different ways of governing centrally are discovered or identified through experimentation (i.e. variation is generated) and successful innovations are retained and built upon over thousands of years (Wright, 2006). These innovations tend to be retained because they outcompete alternative strategies that are less effective. The importance of this selection process is further illustrated in the role of institutions play in driving the variation in economic performance and money use. Accepting debts as payment and facing vulnerability in contracts with distant or anonymous parties would both be quickly extinguished by free-riders in the absence of strong institutions (North, 1990). Therefore, societies with the strongest institutions provide the conditions in which economically beneficial behaviours such as large-scale mutually-profitable contracting as well as token money use can increase in frequency. This illustrates how a cultural evolutionary framework can be used to generate hypotheses about why certain behaviours may be adopted in some societies and not others, in contrast to more classical economic thinking which focuses

more on universal commonalities in how humans perceive and choose between different actions.

The findings of chapters 3 and 4 demand that we take seriously two statistical phenomena that have been overlooked in most previous cross-national economic studies: indirect relationships and the non-independence of modern-day nations. In chapter 3, I showed that accounting for indirect effects changes the conclusions drawn about long-run effects. In the case of state history the results indicate that previous studies may have misattributed the cause of the relationship between state history and GDP as a direct effect rather than an indirect effect mediated by the effect of state history on the evolution of institutions. I also showed that had I conducted a simple multiple regression without accounting for indirect relationships, this would have led me towards an erroneous conclusion that state history is not important in understanding the causes of modern day variation in economic performance. This illustrates the potential consequences of using OLS regression to test relationships that are explicitly indirect.

The difficulties of adjudicating between alternative explanations for human behaviour when one cannot easily specify mediators have been raised in previous work (Nettle, 2009) but so far not acted upon. Ultimately, I argue that as SEM can be used to explicitly model a detailed network of direct and indirect relationships, the approach can be used to address specific hypotheses more directly, and to isolate particular relationships to control for them or test them. One of the attractive features of this approach is that it encourages users to explicitly visualise the causal pathways assumed by different theories. In this way, it can provide an important conceptual tool for organising and synthesising alternative hypotheses. This makes it particularly useful for multivariate

analyses seeking to compare interrelated categories of variables such as ecological, historical and social factors. In particular, SEM makes the effects of far-reaching influences, such as ecological conditions that shape historical events and modern-day phenomena, much more statistically tractable. This makes it a valuable method that can be used to address a wide range of questions about cultural evolution and human behaviour, where there are often many competing ideas (Nettle, 2009).

In chapter 4, I found that there is sufficient non-independence between societies to produce meaningfully different results if this shared history is not accounted for. Most cross-national studies in economics and other social sciences do not account for these systematic patterns of similarity between modern nations. This suggests that many previous findings may be driven by clustering in the data instead of relationships between variables (for example, Currie & Mace, 2012). Work in the field of cultural phylogenetics has demonstrated the potential for this, finding that patterns of common ancestry can be used to explain the diversity in various cultural traits (Currie et al, 2010; Mace & Holden, 2005; Tehrani & Collard, 2002). However, this direct approach of reconstructing trees that reflect shared history and mapping them onto traits cannot easily be translated to nation-level data, as the methods used are designed for ethnically homogenous, relatively closely-related societies. Dealing with non-independence in nation-level data therefore presents a statistical and theoretical challenge. I present the use of language families as a random effect as a protocol to enable subsequent cross-national research to build models containing theoretically-motivated controls for global patterns of shared history. Language family data are readily available at the country level, and although they are relatively crude in the way that they downplay linguistic diversity in

many countries, I have shown that they can be incorporated into models to capture patterns of non-independence that threaten the accuracy of commonly-used statistical tests.

Chapters 3 and 4 also have broader implications for the field of cultural evolution. Many cultural evolutionary studies are small-scale, evaluating 1) signals of cultural adaptation in cross-sectional analyses of small populations (Henrich, 2004), 2) patterns of diversity in cultural traits in traditional societies in certain regions of the world (Mace & Jordan, 2011), and 3) biases of information transmission in laboratory samples to measure cultural inheritance (Caldwell & Millen, 2008). I show that the same cultural evolutionary mechanisms that inform these studies allow me to generate testable hypotheses for patterns of cultural diversity at a much larger, global scale that are well supported by the available data. Just as biological adaptation at the individual level is reflected in a broader pattern of relationships between species, cultural evolutionary processes have a measurable signature at the nation-level. This forms part of the explanation for why some economies perform differently to others, and must be accounted for theoretically and statistically.

In chapters 5 and 6, I further demonstrate the utility of a cultural evolutionary approach for generating new hypotheses. The relatively new debt theory about the origins of money framed the use of money as driven by trust, but overlooked the potential for trust to be exploited (Camera et al, 2013; Graber, 2011). This potential for exploitation should be obvious from a rational choice perspective that is based on individual utility. However, an evolutionary approach encourages further questions at different scales, such as what conditions can change this payoff dynamic, how different societies with different systems can reap the benefits of token money more effectively than others, and

how this shapes what groups outcompete others. The adoption of behavioural strategies in such cooperative dilemmas is evolutionary in nature, with strategies yielding high benefits being represented with greater frequency in the next generation. In most instances, cooperative or trusting strategies yield the greatest benefit in populations of other co-operators, but are otherwise vulnerable to exploitation by non-cooperators. I found that tendencies to engage in money use are low when systems that prevent defaulting on debts are not in place, showing that conceptualising money use as a cooperative dilemma and applying mechanisms from evolutionary theory to this dilemma enabled me to reveal previously-unknown complexities about the origins of money use. Namely, that social systems that maintain cooperation and govern actions appear to be important, rather than indiscriminate trust which is vulnerable to exploitation. This finding underlines broader arguments made in the literature about the value of highly proximate explanations for human behaviour (Ostrom, 2003). Trust is an explanation that is arguably more proximate than other factors like institutions or the ecology. Related to my earlier discussion of indirect effects, this means that using trust as an explanation can often only provide limited insights into the origin or maintenance of a behaviour, as it simply shifts the question a step backwards and requires us to address what explains diversity in trust.

These findings have considerable implications for existing theories of money. Currently, money is thought of as a means of maximising the efficiency of exchange (Jevons, 1897; Kiyotaki & Wright, 1989), the emergence of which is considered an economic decision driven by the benefit of making trade easier and quicker (Smith, 1776/1976). As an economic decision, the adoption of money is not affected by social context, and should occur anywhere where

exchange takes place. I instead find that the use of token money requires specific social conditions such as strong institutions to be able to emerge. Rather than the adoption of money only providing benefits through efficient and profitable exchange, the use of tokens of debt in the absence of mechanisms that support cooperation is likely vulnerable to exploitation by individuals who default on their debts, and cannot be maintained. Unlike previous theories, this provides an explanation that accounts for the many observed societies that engage in exchange but do not use token money.

Furthermore, the debt theory has been positioned as an alternative to the traditional theory of money use which is based on the inherent value of commodities (Graeber, 2011), but they have never been compared. In the first test of the logic of the debt theory of money, I find evidence more consistent with the debt theory than the commodity theory. This is particularly interesting given that aspects of the debt theory are more consistent with how modern economies operate, especially in developed countries. Globally, there is approximately $30 trillion of narrow money (coins, banknotes, checking deposits etc), which is eclipsed by the $80 trillion of broad money (including money deposits lent by banks) (The Money Project, 2015). Most banks hold a fraction of their total deposits in cash and are connected by networks of credit and debt (Pennachi, 2012). Like with these individual banks, the assumption of the global financial system is that contracts can be fulfilled and debts can be repaid. Banks and customers are confident that default cannot occur despite there not being enough money in the world to satisfy all debts and contracts. My findings suggest that to some extent, this may reflect the far-reaching effect of high confidence in underlying contract law and enforcement, which works to ensure that debts maintain value. Indeed, the Western liberal democracies with the

strongest institutions are also the countries with the most debt (Schultz & Weingast, 2003).

Further experimentation into token money use would help to confirm some of my conclusions about how people behave in circumstances that simulate the origins of money. One priority might be to make the tokens that people can use in these experiments infinite. In theory, tokens of debt can be anything provided they are attributable to the issuer in some way (Graeber, 2011; Mitchell-Innes, 1914). Testing people's behaviours when they can continually issue tokens accesses important questions such as: 1) do money systems emerge and stabilise through the actions of a single individual who issues lots of tokens that can be used in exchanges between others because the individual consistently repays their debts? And 2) does this cause money systems to be originally dependent on few strong co-operators whose behaviour can also potentially be the cause of the collapse of the money system? Another avenue for future experimental research would be to apply my token-based design to scenarios that are more explicitly based on exchange using goods. Whether variance in the value of different goods interacts with the ability to use tokens as payment is an as of yet unanswered question that would give valuable insights into the origins of money.

One particular feature of my analyses that enabled me to draw conclusions was the use of cross-cultural comparative methods. Although there are archaeological and historical records of tokens of debt (Earle, 2002; Einzig, 1966), previous evidence for the debt theory of money has largely been in the form of examples of when tokens have been used during specific historical events, such as IOU and bank crises in relatively small populations (Graeber, 2011; Wedeman, 1997). These natural experiments offer some insights into

when tokens tend to be used, but their very specific social and historical context makes it difficult to isolate what variables are driving the use and failure of tokens of debt. For example, during bank crises, token use may be perceived as only a temporary measure, which may give people confidence in others' abilities to repay their debts that would not normally be found. By examining a diverse sample of unrelated societies, I can access more general trends that repeatedly predict the use of token money and can make more representative conclusions about the mechanisms underpinning the evolution of money. Together, my systematic analysis and previous case-based analyses provide the beginnings of a convincing evidence base for the importance of debt in the emergence of token money.

On the other hand, the cross-cultural data I used is not without its limitations. In the case of the SCCS, I have discussed the potential issues with the validity of the variables, given that they were derived from observational data. The cross-national data used in chapters 3 and 4 suffer from a similar problem, as well as a particular risk of omitted variables given how interconnected historical, ecological, social and economic factors are. Going forward, the expansion of datasets that capture social norms concerning the boundaries of cooperation would be particularly useful. Currently, these norms are captured using proxies or composite variables constructed from separate but related studies, which risks the introduction of alternative explanations. For example, my in-group bias variable was partly comprised of a measure of family orientation, which only partially concerns the scale of cooperation (see chapter 3). This could mean that the variation in in-group bias I observed may be driven in part by differences in family systems, for instance.

More generally, future analyses would benefit from larger sample sizes both cross-nationally and from the SCCS. SEMs in particular estimate many parameters, and therefore often require the researcher to trade-off sample size against what relationships can be modelled without affecting the accuracy of the results. Data sources such as the World Bank are increasing in coverage year on year, and repositories such as D-Place are seeking to amalgamate currently disparate databases, which will maximise sample sizes by allowing different measures taken of the same societies to be easily accessible.

Across all the analysis chapters, I show that institutions are of key importance for the development of economies from their inception to the modern day. The movement of institutional economics over the last 30 years has primarily focused on explaining modern-day economic growth, revealing associations between institutions and market activity, contracting and effective enforcement (North, 1990). I find support for the association between institutions and economic growth in my analyses, showing that institutions are the component of economies that connect a society's history to its economic performance today. Institutions potentially embody thousands of years of historical experience (Nunn, 2012) and use this accumulated knowledge to drive economic behaviours.

However, I also demonstrate how to use an evolutionary approach to expand the institutional explanation to more foundational aspects of economies, namely money use. Fundamentally, institutions shape economies by resolving cooperative dilemmas. Much previous work has argued that the most important aspect of institutions is their inclusiveness, referring to the extent to which they provide the conditions for every member of the society to engage in cooperative behaviour with impunity (Acemoglu & Robinson, 2012). An important insight

made by this thesis is that cooperative dilemmas are central to many aspects of economies, including exchange and investment in centralised government. This builds upon previous research that has shown institutions to be primary driver of major human transitions, including the transition from small, kin-based groups to societies characterised by large-scale cooperation (Powers et al, 2016). Therefore, the recognition that money use cannot be sustained by trust and involves a cooperative dilemma invites the expectation that people's perceptions of the effectiveness of governance and sanctioning will affect their willingness to adopt money. This cultural evolutionary approach may be used to address future questions about the conditions underpinning the emergence of other major developments underpinning economic performance, such as effective contract-based law.

The importance of history and social conditions shown across the analysis chapters contrasts with classical economic assumptions. For example, many societies have highly effective institutions which have considerable societal benefits. However, despite clear instances in which societies have learned how to improve their institutions by borrowing ideas from other societies (Ferguson, 2012), many societies still have ineffective institutions. These are partly the result of their historical experiences, such as long histories of exploitation affecting social norms that shape trust and cooperation (Nunn, 2012). Such persistent effects of history are not well accounted for by rational choice models which focus more on how different people optimise their payoffs when choosing between the same options, rather than how the options themselves may vary due to context. That being said, I do find evidence for some level of optimisation, as individuals mostly only engage in behaviours like money use and large-scale cooperation when they are protected from the high

costs of exploitation by strong institutions. This demonstrates how the synthesis of evolutionary theory with economic ideas can generate accurate models of real-life behaviour. Recognising how history, ecology and social systems can shape the variation in what decisions are available for people to make provides the context necessary to understand how attempts to maximise payoffs can lead to different behaviours in different societies and individuals.

In this thesis I have shown how different methodological approaches can be used to interrogate theoretical claims from different angles. I have used different methodologies (secondary data analysis, experiments), employed different statistical techniques (SEM, multilevel modelling), conducted analyses at different scales (nation-, general factor-), and examined various samples (traditional societies, modern nations, real participants). In doing so, I have been able to drill down into the mechanisms underpinning my own findings. For example, having found that history is important for modern-day economic development, I examined other ways history could have an effect using a different method. Moreover, having showed that institutions were important for token money use, I asked further questions about how enforcement might work at a finer scale using an experiment. That there is a common conclusion about the role of institutions across all of these diverse approaches provides a strong case for the idea that institutions shape the development of economies from their inception to the modern day.

I also showed that approaches can be combined, such as in the combination of multilevel modelling and SEM. There is a great deal of scope for the insights of SEM to change the way we use multilevel modelling and vice versa. For instance, they both allow researchers to partition effects appropriately in different ways, and so when specifying a multilevel model, one

must consider that variation being captured at the level of the random effect may be related to the omission of a particular pathway at the lower level. Moreover, when specifying an SEM, one must recognise that parameter estimates will be shaped by the ability to adjust for non-independence using random effects. The ability to partition variation using multilevel modelling also allows me to scrutinise datasets such as the SCCS which claim to contain largely independent societies, as well as existing relationships, which may be artefacts of using OLS regression. In addition, multilevel modelling and the information-theoretic approach more generally have shaped the way I analyse experimental data. Traditionally, the statistical analysis of experiments involves comparing a treatment to a control, due to the way that manipulations or interventions are most commonly structured. However, this does not necessitate null hypothesis significance testing, as one can compare models containing different combinations of independent and extraneous variables, as well as grouping variables that may capture underlying similarities between particular participants that may drive their behaviours.

In this thesis, I aimed to use a cultural evolutionary approach to examine existing theories for variation in economic development and money use, and to devise new explanations using a cultural evolutionary framework. The broad findings of each of my chapters have met these aims. I have shown that 1) state history and the timing of agriculture have largely indirect, not direct effects on modern GDP; 2) shared history explains a portion of the diversity in socioeconomic development between modern nations that cannot be explained by nation-level predictors or measured using traditional methodologies; 3) the emergence of money is likely to be related to the resolution of the cooperative dilemma of debt; and 4) the emergence of money from valueless tokens of debt

is possible but not inevitable, and depends on the ability to form social relationships.

More generally, I show that despite the differences between economies at their inception in small-scale societies and globalised, digital economies in the modern age, economies are always underpinned by cooperation. This gives development at early and modern stages a common driver, namely the resolution of cooperative dilemmas which is most effectively achieved through institutions. Differences in institutions are responsible for both the ability of societies to adopt the money systems that are the foundations of economies, and the ability of economies to succeed in the modern day. I also show that a cultural evolutionary perspective is useful for guiding questions about what enables and what extinguishes various features of economies. This perspective forces researchers to ask under what circumstances could such a trait emerge, sustain and spread given the potential for exploitation and competition from alternative traits. It also demands that researchers address different scales of explanation, such as historical, population-level and environment-level as well as society-level. This comparative, multi-hypothesis approach stands as the most effective way to synthesise competing explanations across different literatures for phenomena in cultural evolution and human behaviour.

Chapter 8: Appendices to long-run historical and ecological determinants of economic development mediated by the cultural evolution of effective institutions

Supplementary methods

Appendix 1-1: Full table of hypotheses

Table 8-1 synthesises the main explanations for the global variation in economic development and its predictors found across the economic and evolutionary literature. The economic literature supplied most of the hypothesised direct effects, whether historical, ecological or proximate. The evolutionary literature, being more concerned with the role of endogenous and exogenous factors as conditions that shape the evolution of cultural traits, supplied the majority of the indirect effects.

No cross-national SEM could feasibly estimate each of these pathways due to a lack of data. To overcome this I first conducted numerous linear models to systematically reduce the full hypothesis table to a selection of realistically important hypotheses.

Table 8-1: *Documented Hypotheses Concerning Economic Development and Cultural, Historical and Ecological Attributes of Societies*

Variable	Hypothesis	Prediction	Number on Diagrams
Institutions	Adjudication of contracts and enforcement of law allows large-scale cooperation. Checks on the executive ensure incentives for labour and skill accumulation (Acemoglu & Robinson, 2012; Aoki, 2001; North, 1990; Rodrik et al, 2004).	Higher institution quality → higher GDP	1
	In the absence of formal laws, in-group members represent the best source of cooperation (Hruschka & Henrich, 2013).	Higher institution quality → lower in-group bias	2

In-group bias	Differences in standards used to treat in-group and outgroup members introduce risks of opportunism in transactions. Nepotistic aspect of these biases also contributes to political patronage and corruption (Kyriacou, 2016).	Higher in-group bias → lower GDP	3
	Formal laws are applied equally to all individuals, which is inconsistent with in-group preferences (Greif, 2006; Hruschka & Henrich, 2013).	Higher in-group bias → lower institution quality	2
State history	Historical experience with central organisation is heritable and predicts greater levels of economic development in the present day (Putterman & Weil, 2010; Spolaore & Wacziarg, 2013).	Longer state history → higher GDP	4
	Accumulation of refinements to governance by law takes time and shapes the effectiveness of the modern formal institutions that develop from them (Currie et al, 2016).	Longer state history → higher institution quality	5
	Centralised governance selects for cultures of trust and impersonal treatment (Hruschka & Henrich, 2013). Longer histories of statehood suggest more time for selection for impersonality.	Longer state history → lower in-group bias	6
	Europeans tended to settle in regions where there was little development and low population density (Acemoglu & Robinson, 2012).	Longer state history → lower European ancestry	7
Timing of agricultural transition	Earlier transitions provided a head-start to the development of important technologies associated with economic performance (Diamond, 1997).	Earlier agricultural transition → higher GDP	8
	Longer histories of features of agricultural subsistence (irrigation, large-scale coordination) suggest more experience with property rights (Baland & Platteau, 1998; Olsson & Paik, 2016), which may aid development of and engagement with centralised institutions.	Earlier agricultural transition → higher institution quality	9
	Agricultural production benefits from collectivist norms and increases pathogen pressure, implying	Earlier agricultural transition → higher in-group bias	10

	that agriculture selects for in-group biases (Olsson & Paik, 2016).		
	Growing population sizes associated with agriculture select for centralised governance to maintain cooperation and coordination (Diamond, 1997).	Earlier agricultural transition → longer state history	11
European descent	A body of knowledge and technologies associated with European populations aids economic activity (Easterly & Levine, 2012).	Higher European ancestry → higher GDP	12
	Europeans transplanted relatively inclusive institutions when they settled in large numbers. Where they did not settle in large numbers, they established authoritarian systems designed to exploit populations and extract natural resources (Acemoglu & Robinson, 2012).	Higher European ancestry → higher institution quality	13
	European culture is relatively individualist and impersonal (Schwartz, 2006).	Higher European ancestry → lower in-group bias	14
Disease	Disease stunts productivity and investment in long-term goals like education (Sachs & Malaney, 2002).	Higher disease → lower GDP	15
	Disease stimulates the behavioural immune system owing to the fitness costs of contracting novel diseases (Fincher & Thornhill, 2012).	Higher disease → higher in-group bias	16
	The disease environment influenced the extent of European settlement (Acemoglu & Robinson, 2012).	Higher disease → lower European ancestry	17
Latitude	Latitude covaries with climate and natural resources (Bonds et al, 2012).	Higher latitude → higher GDP	18
	Latitude covaries with natural endowments which predict the extent of bias of resources towards elites (Easterly & Levine, 2003; Engerman & Sokoloff, 2012).	Higher latitude → lower institution quality	19
	Latitude covaries with the suitability of regions for agriculture (Olsson & Paik, 2013).	Higher latitude → earlier agricultural transition	20
	Latitude covaries with patterns of human migration	Higher latitude → shorter state history	21

	(Olsson & Paik, 2013).	Higher latitude → higher European ancestry Higher latitude → lower in-group bias	22 23
	Latitude covaries with environmental variables that predict extents of infectious disease (Bonds et al, 2012).	Higher latitude → lower disease	24

Appendix 1-2: Pathways tested in the model comparison

Figure 8-1 below shows the pathways I included following the linear models and those I manipulated for hypothesis testing. The pathways in black represent those that were supported by the linear models, and therefore appeared in every single SEM I conducted. The pathways in red were those relating to the main hypotheses about whether the effects of state history and the timing of agriculture are direct or indirect. The model comparison was a comparison of SEMs that always included the black pathways, and had every different combination of the red pathways.

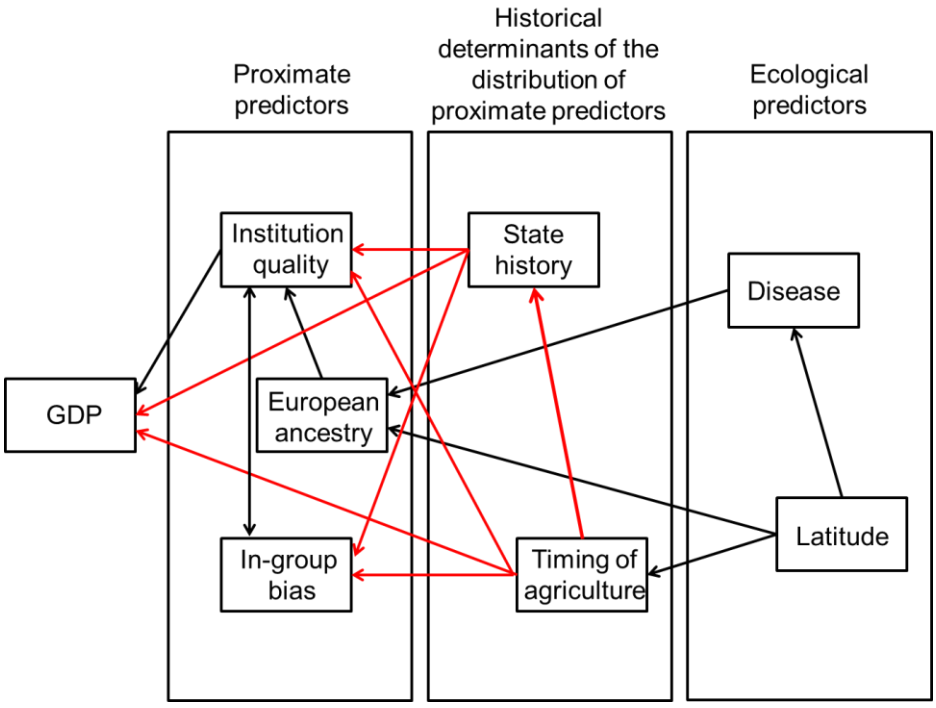


Figure 8-1: *Path diagram highlighting the pathways manipulated*
This diagram does not present the results of any SEM: the thickness of the arrows is constant.

Appendix 1-3 Multicollinearity checks

Table 8-2 below shows that the variance inflation factor (VIF) values for the variables are all <3; generally, VIF values of 5 are seen as a cause for concern, while VIF values of 10 or more suggest serious multicollinearity (see O'Brien (2007) for discussion of various rules of thumb).

Table 8-2: *Variance inflation factor values for predictor variables*

Predictor variable	VIF
Institution quality	2.89
In-group bias	2.63
European ancestry	2.29
State history	1.73
Timing of agriculture	1.93
Disease	2.84
Latitude	1.83

Supplementary results

Appendix 1-4: Pairwise correlation matrix

Table 8-3 presents a matrix of the pairwise correlations between the variables in the analysis.

Table 8-3: *Pairwise correlation matrix*

	GDP	Institution quality	In-group bias	European descent	State history	Timing of agri.	Disease	Latitude
GDP	1							
Institution quality	0.82	1						
In-group bias	-0.63	-0.76	1					
European descent	0.64	0.49	-0.45	1				
State history	0.36	0.30	-0.12	0.12	1			
Timing of agriculture	0.34	0.15	0.05	0.26	0.59	1		
Disease	-0.66	-0.55	0.51	-0.73	-0.15	-0.24	1	
Latitude	0.41	0.25	-0.18	0.47	0.32	0.48	-0.56	1

Appendix 1-5: Linear model tables and diagrams with reference to the full hypothesis table

Table 8-4 presents the results of the initial linear models. Pathway numbers that correspond to the pathway numbers specified in the full hypothesis table are shown (Table 8-1).

Table 8-4: *Results of the linear models testing individual stages of hypothesised pathways*

Outcome variable	Predictor variable	Path number	Coefficient	p
GDP	Institution quality	1	0.56	<0.001**
	In-group bias	3	-0.09	0.23
	European descent	12	0.14	0.09
	State history	4	0.04	0.52
	Agriculture timing	8	0.11	0.09
	Disease	15	-0.09	0.26
	Latitude	18	0.03	0.60
Institution quality	In-group bias	2	-0.54	<0.001**
	European descent	13	0.25	0.02*
	State history	5	0.15	0.04*
	Agriculture timing	9	0.06	0.45
	Latitude	19	-0.05	0.49
In-group bias	Institution quality	2	-0.56	<0.001**
	European descent	14	-0.17	0.13
	State history	6	-0.02	0.84
	Agriculture timing	10	0.12	0.17
	Disease	16	0.09	0.34
	Latitude	23	0.01	0.93
European descent	State history	7	0.06	0.24
	Disease	17	-0.17	0.03*
	Latitude	22	0.17	0.002**
State history	Agriculture timing	11	0.55	<0.001**
	Latitude	21	0.07	0.47
Agriculture timing	Latitude	20	0.38	<0.001**

*p<0.01**; p<0.05**

Despite several variables showing correlations with GDP, the only significant direct predictor of GDP when including all variables in a linear model is institutional quality. This result provides evidence against many of the hypotheses that propose a direct effect of certain factors on economic development. There is no support from these analyses for direct effects on GDP

of in-group bias, European ancestry, state history, agriculture timing, disease and latitude. The strong relationship between institution quality and GDP leaves little variation that can be explained by these other variables. This guides me towards potential indirect relationships, as I can turn my attention to which variables explain the variation in institution quality, and in turn, step further back to examine what factors explain variation in those variables.

Higher quality institutions are predicted by lower levels of in-group bias, higher proportions of European descent, and longer state histories. This offers support for 1) the suggestion that strong institutions and in-group biases reduce the benefits of one another and 2) the hypothesis that institutions are among the cultural traits that European populations transmit. It also supports the theory that longer histories of statehood provide more time for the development of effective institutions. State history, in turn, is strongly related to the timing of agriculture but not latitude. This is consistent with the idea that sedentism and increased population density historically led to changes in political organisation. The timing of agriculture is related to latitude, in line with the suitability of agricultural subsistence being dependent on climatic and other ecological factors. I find no support for a relationship between disease and in-group bias, suggesting that disease does not influence GDP by creating avoidant norms. However, disease is associated with European ancestry, in line with the hypothesis that the extent of settlement by colonists was dependent on the disease environment.

Figure 8-2 recreates the diagram presenting the pathways with the most statistical support with the inclusion of the pathway numbers specified in the full hypothesis table (Table 8-1).

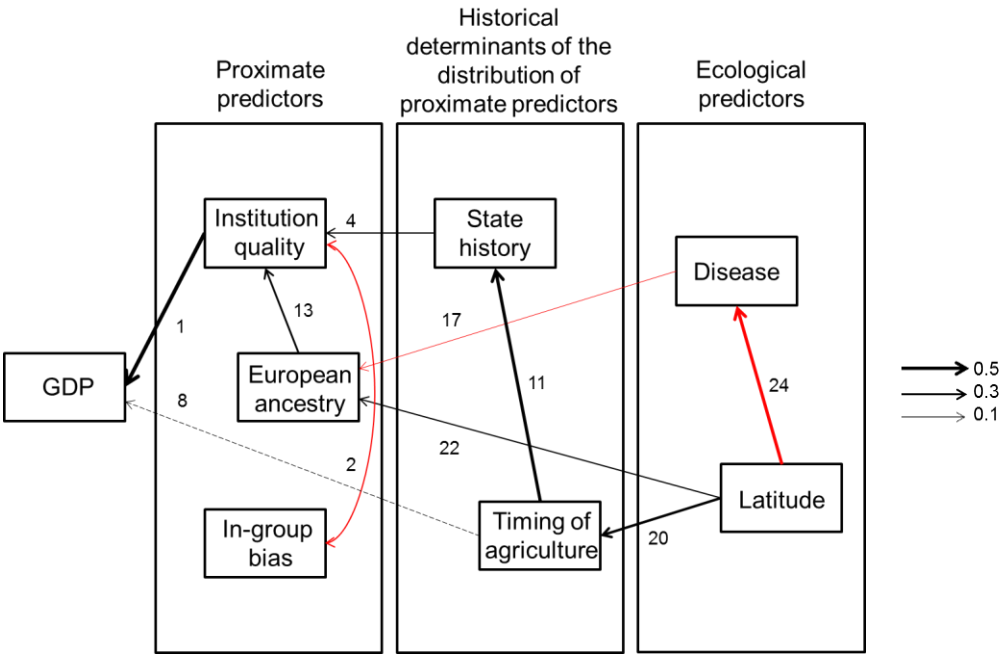


Figure 8-2: *The pathways for which SEM comparison provided the most statistical support*

Red paths represent negative correlations and black paths positive correlations; line widths are proportional to the Akaike weighted coefficients of the pathways, specified by the key above; the dotted pathway was rejected from the linear models but was strongly supported in the model comparison.

Appendix 1-6: Scatterplot matrix of the indirect effect of state history through institutions

Figure 8-3 below shows each stage of the indirect effect of state history on GDP through modern institution quality. State history is positively correlated with both institution quality and GDP, and institution quality strongly positively correlates with GDP. State history, however, does not correlate strongly with the variation in GDP left unexplained by institution quality, suggesting that state history is correlated with GDP because it explains institution quality.

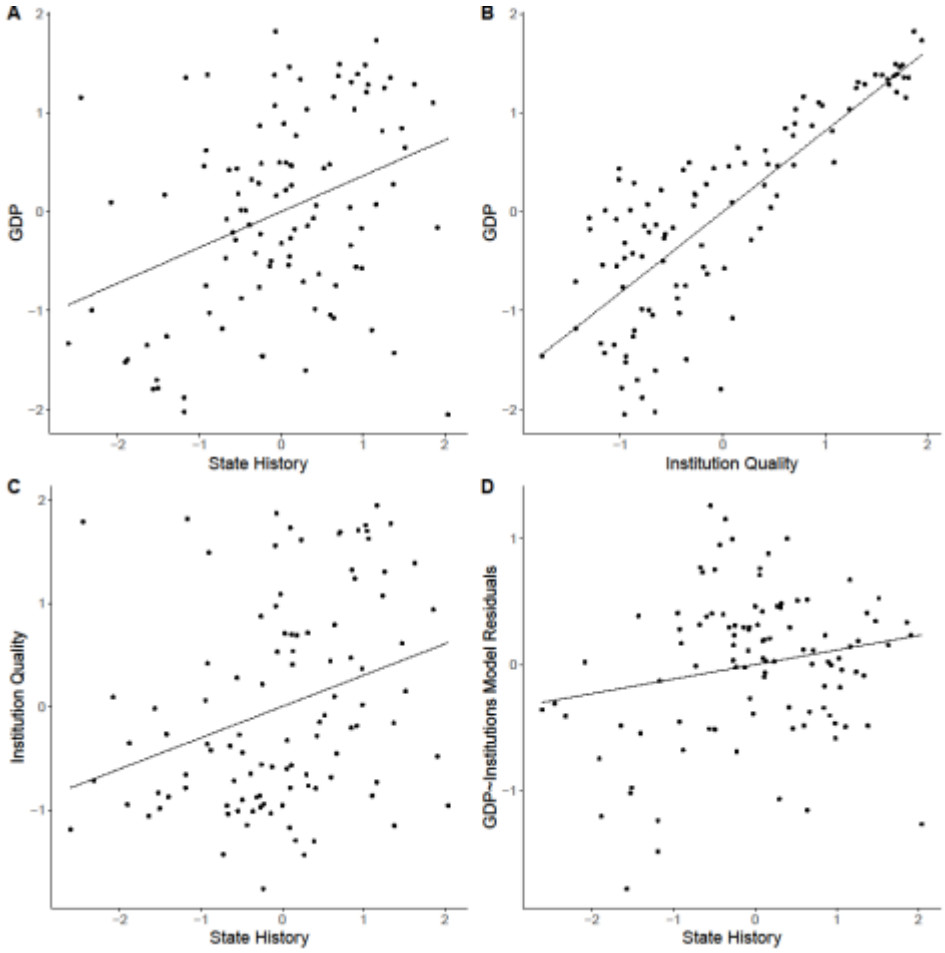


Figure 8-3: *Stages of the indirect relationship between state history and GDP through the quality of modern institutions*

A) state history is moderately positively correlated with GDP (r=0.36); B) institution quality is strongly positively correlated with GDP (r=0.82); C) state history is moderately positively correlated with institution quality (r=0.30); D) state history is weakly positively correlated with the variation in GDP left unexplained by variation in institution quality (r=0.06).

Appendix 1-7: Comparison of the Indo-European subfamilies and family data

Below I present the full SEM comparison from the dataset that used Indo-European sub-families (Table 8-5) and from the dataset that used the Indo-European family (Table 8-6). This comparison was undertaken to ensure the findings were not sensitive to my own decisions regarding how best to account for shared history in the data.

The decision to use sub-families was driven by the large number of Indo-European countries in the dataset and the diversity between these countries. The use of language families as a random intercept aims to account for systematic cultural similarities between countries that are the result of how recently they shared a common cultural ancestor. However, using the Indo-European language family as a whole collapses together, for example, South Asian and Scandinavian countries. This suggests that use of the whole family does not capture patterns of shared history in as much detail as is possible. By contrast, using sub-families allows me to account for a greater number of more closely-related groups of countries and therefore better control for statistical non-independence.

Table 8-5: *Results from the 95% confidence set for the original SEM using subfamilies*

AIC	wi	STATE HIST->GDP	STATE HIST->INST	STATE HIST->INGR	AG TRAN->GDP	AG TRAN->INST	AG TRAN->INGR	AG TRAN->STATE HIST
1511.15	0.13		X	X	X			X
1511.31	0.12		X		X			X
1512.76	0.06		X		X		X	X
1512.93	0.05		X	X	X	X		X
1513.07	0.05		X		X	X		X
1513.09	0.05	X	X	X	X			X

1513.15	0.05		X	X	X		X	X
1513.25	0.04	X	X		X			X
1514.08	0.03		X		X	X	X	X
1514.39	0.03				X	X		X
1514.65	0.02		X	X				X
1514.70	0.02	X	X		X		X	X
1514.76	0.02	X	X	X				X
1514.82	0.02		X					X
1514.86	0.02		X	X	X	X	X	X
1514.86	0.02	X	X	X	X	X		X
1514.93	0.02	X	X					X
1515.00	0.02	X	X		X	X		X
1515.09	0.02	X	X	X	X		X	X
1515.40	0.02				X			X
1515.40	0.02				X	X	X	X
1516.02	0.01	X	X		X	X	X	X
1516.02	0.01			X	X	X		X
1516.26	0.01		X				X	X
1516.32	0.01	X			X	X		X
1516.37	0.01	X	X				X	X
1516.43	0.01		X	X		X		X
1516.54	0.01	X	X	X		X		X
1516.57	0.01		X			X		X
1516.65	0.01		X	X			X	X
1516.68	0.01	X	X			X		X
1516.76	0.01	X	X	X			X	X
1516.80	0.01	X	X	X	X	X	X	X
1517.33	0.01	X			X			X
1517.34	0.01	X			X	X	X	X
1517.37	0.01			X	X			X
1517.38	0.01				X		X	X
1517.38	0.01			X	X	X	X	X
1517.59	0.01		X			X	X	X
1517.70	0.01	X	X			X	X	X

Table 8-6: *Results from the 95% confidence set for the SEM with the Indo-European family instead of subfamilies*

AIC	wi	STATE HIST->GDP	STATE HIST->INST	STATE HIST->INGR	AG TRAN->GDP	AG TRAN->INST	AG TRAN->INGR	AG TRAN->STATE HIST
1616.27	0.08		X	X	X		X	X
1616.42	0.07		X		X			X
1616.47	0.07		X	X	X			X
1616.81	0.06		X	X			X	X
1616.96	0.06		X					X

1617.01	0.05		X	X				X
1617.06	0.05		X	X	X	X	X	X
1617.60	0.04		X	X		X	X	X
1617.84	0.04		X		X		X	X
1618.22	0.03	X	X	X			X	X
1618.27	0.03	X	X	X	X		X	X
1618.31	0.03		X		X	X		X
1618.37	0.03	X	X					X
1618.38	0.03		X				X	X
1618.40	0.03		X	X	X	X		X
1618.42	0.03	X	X		X			X
1618.43	0.03	X	X	X				X
1618.47	0.03	X	X	X	X			X
1618.86	0.02		X			X		X
1618.94	0.02		X	X		X		X
1619.01	0.02	X	X	X		X	X	X
1619.06	0.02	X	X	X	X	X	X	X
1619.79	0.01	X	X				X	X
1619.80	0.01		X		X	X	X	X
1619.84	0.01	X	X		X		X	X
1620.27	0.01	X	X			X		X
1620.31	0.01	X	X		X	X		X
1620.34	0.01		X			X	X	X
1620.35	0.01	X	X	X		X		X
1620.40	0.01	X	X	X	X	X		X
1621.61	0.01				X	X		X
1621.75	0.01	X	X			X	X	X

Comparing tables 8-5 and 8-6 shows that using Indo-European subfamilies drastically improves model fit (by over 100 AIC). It also gives greater certainty as to the best-fitting model. Using subfamilies gives the model with the lowest AIC a 13% chance of being the best model, and also produces 2 models that are at least twice as likely as any other model to be the best fitting model. In contrast, using the family instead of subfamilies gives the model with the lowest AIC an 8% chance of being the best model.

Table 8-7 below summarises the results of the SEM comparison using the Indo-European family instead of subfamilies. This shows that my results are robust, as the direct and indirect pathways supported in the original SEM receive support in this model.

Table 8-7: *Direct and indirect effects of state history and timing of agriculture in the SEMs within 2 AIC units of the best-fitting model using Indo-European language family data*

		Variables							
	Predictor	Institution quality	State history			Timing of agriculture			
	Outcome	GDP	GDP	Institution quality	In-group bias	GDP	Institution quality	In-group bias	State history
AIC	Akaike weight								
1616.27	0.08	0.72	-	0.28	-0.21	0.09	-	0.13	0.53
1616.42	0.07	0.72	-	0.19	-	0.09	-	-	0.53
1616.47	0.07	0.72	-	0.27	-0.14	0.09	-	-	0.53
1616.81	0.06	0.72	-	0.28	-0.21	-	-	0.13	0.53
1616.96	0.06	0.72	-	0.19	-	-	-	-	0.53
1617.01	0.05	0.72	-	0.27	-0.14	-	-	-	0.53
1617.05	0.05	0.72	-	0.34	-0.26	0.09	-0.12	0.22	0.53
1617.59	0.04	0.72	-	0.34	-0.26	-	-0.12	0.22	0.53
1617.84	0.04	0.72	-	0.17	-	0.09	-	0.06	0.53
1618.22	0.03	0.71	0.04	0.27	-0.21	-	-	0.13	0.53
Akaike Importance		0.95	0.28	0.95	0.58	0.52	0.31	0.45	0.95
Weighted Parameter Estimate		0.69	0.01	0.24	-0.11	0.05	-0.01	0.06	0.51

Table 8-8 below presents the Akaike statistics (importance of each pathway and weighted coefficients) for the pathways from the timing of agriculture and state history to GDP both directly and indirectly through institution quality and in-group bias, for both language family classifications. In the models using the Indo-European family, three minor differences are apparent: 1) the pathway from state history to in-group bias increases in importance; 2) the pathway from the timing of agriculture to GDP decreases in importance; 3) the pathway from the timing of agriculture to in-group bias increases in importance.

The most important aspect of this comparison is that the three minor changes mentioned above do not change my conclusions. The important pathway from state history is still through institutions and not directly to GDP. Similarly, the most important pathways from the timing of agriculture are still to

GDP and to state history. This consistency in the findings suggests that the decisions regarding language families did not influence the results.

Table 8-8: *Comparison of the Akaike statistics for the direct and indirect effects of state history and the timing of agriculture between the Indo-European subfamilies and family data*

		Akaike Statistics			
Predictor Variable	Outcome Variable	Indo-European Sub-family		Indo-European Family	
		Akaike Importance	Weighted parameter estimate	Akaike Importance	Weighted parameter estimate
State history	GDP	0.29	0.01	0.28	0.01
	Institution quality	0.85	0.15	0.95	0.24
	In-group bias	0.44	-0.05	0.58	-0.11
Timing of agriculture	GDP	0.79	0.11	0.52	0.05
	Institution quality	0.32	0.02	0.31	-0.01
	In-group bias	0.29	-0.01	0.45	0.06
	State history	0.95	0.52	0.95	0.51

Supplementary discussion

Appendix 1-8: Region-specific relationships between the timing of agriculture and GDP

Previous research has suggested that the relationship between the timing of agriculture and GDP is negative within regions while being positive between them (Olsson & Paik, 2013). This makes it difficult to glean whether the direct relationship between the timing of agriculture and GDP that I found support for in the model comparison is supportive of the head-start hypothesis. Table 8-9 below presents the correlation coefficients between the timing of agriculture and GDP calculated within the language families/subfamilies. The relationships are mostly positive, although there is a slightly negative relationship in the Balto-Slavic family. This provides some support for the direct relationship identified between the timing of agriculture and GDP in the original comparison.

Table 8-9: *Relationships between timing of agriculture and GDP within language (sub)families*

Language family/subfamily*	Coefficient of timing of agriculture and GDP
Afro-Asiatic (N=8)	0.45
Balto-Slavic (N=14)	-0.09
Germanic (N=15)	0.23
Indo-Iranian (N=6)	0.21
Italic (N=23)	0.54
Niger-Congo (N=13)	0.28

**Only those with >5 cases to ensure the coefficients are relatively meaningful.*

However, Table 8-10 shows the relationships within different continents, and supports previous findings of a negative relationship within Europe. As the relationship is persistently negative in some regions, this suggests that the direct relationship between the timing of agriculture and GDP I identified does not provide strong support for the head-start hypothesis. The alternative

mechanism that is underpinning this direct relationship is unclear, suggesting that future research drilling down into the reasons for a relationship between the timing of agriculture and GDP would be valuable.

Table 8-10: *Relationships between timing of agriculture and GDP within continents*

Continents	Coefficient of timing of agriculture and GDP
Africa (N=21)	0.29
Americas (N=19)	0.57
Asia (N=26)	0.05
Europe (N=35)	-0.31

Appendix 1-9: Instrumental variable analysis using settler mortality data

A central claim of the chapter is that state history shapes institution quality which shapes GDP in turn. But I recognise the potential for reverse causality between institution quality and GDP. My analysis deals with this somewhat: in the model comparison, state history only predicts institution quality and not other proximate factors, and correlates positively with GDP. As there is no obvious way in which modern GDP can influence state history, this provides evidence for an important pathway from institution quality to GDP.

One way of establishing whether there is evidence to support a proposed causal relationship is to employ instrumental variable analysis. Below I present my own instrumental variable analysis following the well-known work of Acemoglu, Johnson and Robinson (2001), who used historical data on the mortality rates of European settlers in different countries as an instrumental variable to capture variation in the inclusiveness of their modern institutions (Table 8-11). I replicated the analysis of Acemoglu et al (2001) by replacing the institution quality variable with their measure of settler mortality and a more recent measure of settler mortality compiled by Auer (2013). When included in a model with the predictor variables I used in my analysis, the instrument for institution quality has a significant correlation with GDP in the same (negative) direction as found by Acemoglu et al (2001). Unsurprisingly, the coefficients of the other proximate predictors change but the ecological and deep historical factors remain non-significant. This suggests that the claim regarding the importance of a pathway from institution quality to GDP is robust.

Table 8-11: *Results of the linear models including every predictor variable with settler mortality replacing institution quality*

Outcome variable	Predictor variables	Coefficient	p
GDP	Settler mortality (AJR)	-0.19	0.03*
	In-group bias	-0.28	0.03*
	European descent	0.35	0.03*
	State history	0.08	0.54
	Agriculture timing	0.06	0.69
	Disease	-0.13	0.42
	Latitude	-0.03	0.78
GDP	Settler mortality (Auer)	-0.39	<0.001**
	In-group bias	-0.36	<0.001**
	European descent	0.41	0.01*
	State history	0.07	0.41
	Agriculture timing	0.11	0.27
	Disease	0.01	0.97
	Latitude	0.05	0.65

*Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

Chapter 9: Appendices to assessing the importance of shared history in shaping patterns of modern day socioeconomic development

Supplementary Results

Appendix 2-1: Pairwise correlation matrix

Table 9-1 presents a pairwise correlation matrix of the factors used in the models. This suggests no multicollinearity between the factors.

Table 9-1: *Correlation matrix of the fixed effects and outcome variable*

	Development	European descent	History	Ecology
Development	1			
European descent	0.61	1		
History	0.25	0.23	1	
Ecology	-0.46	-0.57	-0.41	1

Appendix 2-2: Comparison using a different language family definition

In chapter three's analysis I selected the largest language family in terms of population size within a country as the country's language family. One potential outcome of this is that large-scale migration of populations conceals important historical differences between populations. This is particularly apparent in South America, where large European populations cause many South American countries to be members of the same language family as some European countries. This obscures important differences both between European and South American populations and between populations within South America. Indigenous language families are rarely the largest in South American countries, but often exceed a third of the population. Therefore, in chapter four I recategorised countries as their indigenous language family if members of this language family comprised over a third of the country's population. Below I repeat the analysis of chapter four using chapter three's language family categorisation to ensure that my decisions about how to categorise language families were not driving my results (Table 9-2).

Table 9-2: *Comparison of models using two different language family specifications*

	Language family (chapter four categories)		Language family (chapter three categories)	
Predictor of development				
European descent	-	0.54***	-	0.53**
History	-	0.18*	-	0.17
Ecology	-	-0.13	-	-0.15
ICC	0.63	0.52	0.62	0.53
AIC	302.54	290.06	305.58	289.85

*Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

The similarities in the ICCs of models using these different categories suggest that my conclusion regarding the variation in socio-economic development attributable to language families is robust. While not the focus of this analysis, it should be noted that the parameter estimates also remain largely similar, although the effect of history does drop out of significance. This analysis suggests that my findings were not driven by the way I defined language families, and that variation in development is consistently attributable to language families despite changes in how some countries are categorised.

Appendix 2-3: Comparison of different continent definitions

In my analysis, I assume a particular definition of continents, Below I relax this assumption to ensure that it is not driving the results. Table 9-3 presents the results of a model comparison with two alternative categorisations of continents. In the first of these alternatives, I collapse together Europe and Asia into Eurasia. In the second, I split the Americas into South America and North/Central America. I also present the findings from the original analysis for comparison.

Table 9-3: *Model comparison with different continent definitions*

	Continent (original)		Continent (with Eurasia)		Continent (split Americas)	
Predictor of development						
European descent	-	0.81***	-	0.82***	-	0.82***
History	-	0.09	-	0.09	-	0.09
Ecology	-	-0.13	-	-0.13	-	-0.13
ICC	0.48	0.00	0.41	0.00	0.41	0.00
AIC	352.11	338.69	369.71	338.69	353.67	338.69

*Cells contain parameter estimates. Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

Changing how I define continents does not meaningfully alter the parameter estimates or ICCs. The parameter estimates remain constant across each of the models. The largest change is between the ICCs of the different null models, which suggests that continents defined by a combined Europe and Asia or split Americas are marginally less able to explain the variation in socio-economic development compared to my original continent definition. This analysis suggests that the results were not driven by the way I defined continents, and that even if categorised in several different ways, continents do not explain any variation in socio-economic development after country-level predictors are accounted for.

Appendix 2-4: Comparison using variables not factors

In the original analysis I conducted PCA to create factors for history and ecology that I used as the predictor variables. This is because I was only interested in broadly controlling for country-level variation in these factors, not testing specific relationships between socio-economic development and different historical and ecological predictors. Although the variables loaded highly on the factors in the PCA, there was some missing variation. Table 9-4 presents another model comparison with raw variables as predictors, rather than factors, to test whether this omitted variation had any effect on the results.

Table 9-4: *Model comparison using the raw variables (not factors) as fixed effects to check whether missing variance using factors has any effect on results*

	Grouping Variable						
	None	Language family		Continent		Religion	
Predictor of development							
European descent	0.51**	-	0.41*	-	0.51**	-	0.46**
State history	0.43**	-	0.27*	-	0.43**	-	0.31*
Timing of agriculture	-0.28	-	0.003	-	-0.28	-	0.02
Disease	-0.59**		-0.39*		-0.59**		-0.32*
Tropicality	-0.32		-0.29		-0.32		-0.41*
Precipitation	0.22		0.21		0.22		0.31
Latitude	-0.15		-0.07		-0.15		-0.03
ICC	-	0.63	0.50	0.48	0.00	0.39	0.41
AIC	320.22	302.54	286.71	352.11	322.22	349.90	298.86

*Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

The results of the model comparison in Table 9-4 are not different to the results of the original comparison. Parameter estimates for historical variables change substantially with different grouping variables, while ecological variables are relatively unaffected. Most importantly, the proportion of variation in socio-economic development attributable to language families, continents and religions is unchanged. When country-level predictors are accounted for,

language families account for the most variation, followed by religions, then continents which explain no variation. This suggests that the use of factors as predictor variables is not driving the results.

Appendix 2-5: Comparison without European descent

Different language families, continents and religions are likely to vary considerably in the number of people with European ancestry they have. Excluding this variable from the analysis gives more insight into to what extent the findings are driven by the variation in European ancestry. Table 9-5 replicates the original model without the European descent variable.

Table 9-5: *Model comparison without European descent*

	Grouping Variable						
	None	Language family		Continent		Religion	
Predictor of development							
History	0.09	-	0.18	-	0.05	-	0.29**
Ecology	-0.42***	-	-0.20*	-	-0.24*	-	-0.33***
ICC	-	0.63	0.60	0.48	0.43	0.39	0.41
AIC	361.25	302.54	294.59	352.11	350.57	349.90	316.85

*Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

Table 9-5 shows that excluding European ancestry causes some change in the parameter estimates for history and ecology, likely due to the introduction of omitted variable bias. More importantly for my purposes though, the ICC values remain stable. This is in line with the theoretical expectation that the grouping variables are ultimately accounting for variation in socio-economic development that is at a different scale, and so cannot be heavily influenced by the manipulation of variables at the country-level.

Appendix 2-6: Grouping variables as fixed effects and multiple grouping variables

Table 9-6 explores how the results change if I use grouping variables as fixed effects instead of random effects, and shows the effects of combining multiple grouping variables into one model using fixed and random effects. As I have strong theoretical and statistical reasons to use random effects (see chapter 4), this supplementary analysis is exploratory, and seeks to examine what (if any) effects using fixed effects would have on the results. In this analysis I only include religions and language families as continents did not account for any variation in socio-economic development when country-level variables are controlled for.

Table 9-6: *Model comparison with language families and religions in the same model*

	Grouping variable			
	Null: language family as fixed effect	Null: religion as fixed effect	Language family	Religion
Predictor of development				
European descent	0.34	0.65***	0.56**	0.32
History	0.22*	0.24*	0.09	0.13
Ecology	-0.07	-0.14	-0.22**	-0.22**
Language family	◊	-	RANDOM	◊
Religion	-	◊	◊	RANDOM
ICC	-	-	0.67	0.77
AIC	272.81	299.12	257.77	241.61

*◊: coefficients not recorded here because each factor has so many levels. RANDOM means the variable was included as a random intercept. Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

The first two columns of Table 9-6 largely mirror the results of the original analysis. Compared to models using religions, models including language families reduce the role of European ancestry and marginally decrease the

effects of history and ecology. Additionally, models that include language families fit the data better than those with religions. The second two columns present my more exploratory analysis. These models indicate that including religions and language families together improves model fit. This is consistent with the idea that they capture different sources of variation, namely idea borrowing and common ancestry respectively. This is also reinforced by the increases in their ICCs, which indicate that language families (religions) can explain more variation in socio-economic development once religions (language families) have been accounted for. Specifying the models in this way also causes some slight changes in parameter estimates, with history reducing in its effect and the ecology increasing in its effect. However, I note that caution should be exercised with the interpretation of these two models, as using categorical variables with imbalanced levels as a fixed effect can create biases in parameter estimates.

Appendix 2-7: Modelling using the non-transformed religion variable

I constructed the religion variable used in the chapter by separating the largely African (excluding North African) religions collapsed together as "other" religions into distinct groups. Therefore, rather than treating African religions as one single religion, I treat African religions as distinct. Obviously, neither of these alternatives is representative of the real world. The former demands that African countries share one religion, while the latter demands that African countries have unrelated religions. Consequently, below I present the results of analyses using both definitions to ensure that this decision is not driving the results (Table 9-7).

Table 9-7: *Model comparison using both definitions of African religions*

	Religion (used in chapter)		Religion (non-transformed)	
Predictor of development				
European descent	-	0.65***	-	0.64***
History	-	0.25**	-	0.25*
Ecology	-	-0.14	-	-0.14
ICC	0.39	0.40	0.41	0.46
AIC	349.90	304.02	347.14	303.15

*Coefficients represent standardised coefficients. p<0.001***; p<0.01**; p<0.05**

This analysis shows that changing the definition of African religions does not meaningfully affect model fit or parameter estimates. This indicates that the results in the chapter are not the result of how I chose to categorise African religions. One thing to note however is that defining African religions as a single religion (the non-transformed version) allows the religion factor to explain marginally more of the variance in development than when African religions are separated. The reason for this is unclear, but is potentially related to how the original 'other' category largely captures Sub-Saharan Africa. Therefore, it may

be proxying for patterns of shared history or shared ecology at a finer scale than those captured by my general factors.

Chapter 10: Appendices to the cultural evolution of token money

Supplementary results

Appendix 3-1: Frequency tables

Table 10-1 presents the frequencies of societies that are members of the various measured categories to show their raw covariance. For every level of each predictor variable, I show how many societies use money and how many do not.

Table 10-1: *Frequency tables for each of the predictor variables and money use*

Predictor	**Money use**	
Level	**Absent**	**Present**
Sanctions		
None	22	8
Restricted	3	7
All	3	18
Gossip		
0	2	1
1	4	6
2	8	9
3	6	9
4	8	8
Hierarchy		
Zero	20	7
≤2	7	17
≥3	1	9
Markets		
Regional and below	15	10
Supra-regional	13	23
Fixity		
Nomadic	9	4
Semi-nomadic	8	3
Permanent	11	26
Famine		
Low	11	7
Moderate	6	11
High	11	15

Table 10-1 shows some notable covariances that align with the results of the original modelling. Approximately 73% of societies that have no sanctioning power do not use money. By contrast, 86% of societies that have the ability to sanction all decisions use money. 74% of societies that have zero levels of

hierarchy do not use money, while 90% of those that have three or more levels use money. 60% of societies that have regional or smaller markets do not use money, but 64% of societies with supra-regional markets use money. Moreover, 69% of nomadic societies do not use money while 70% of permanent societies do use money. These covariances are all consistent with the theoretical expectations presented in the chapter. However, famine and gossip present less clear pictures, with less systematic patterns of category sharing.

Appendix 3-2: Accounting for foreign influence in money systems

To aid interpretation and ensure that the results were not affected by the inclusion of categorical variables with imbalanced levels, I collapsed money use into no money and money in the original analysis. However, in the SCCS, some societies were categorised as using tokens that had been introduced by other societies, rather than those that emerged endogenously. This introduces the potential for foreign influence to drive the results. For example, foreign powers may have systematically introduced money into societies that had stronger sanctions. Consequently, I conduct further analysis to separate foreign money systems from indigenous money systems. First, in Table 10-2 I use multinomial logistic regressions to replicate the original bivariate logistic regressions of the relationships between individual predictors and money use, but split the outcome variable into three levels: no money, indigenous money and foreign money.

Table 10-2: *Multinomial logistic regressions for each predictor variable and money use split into none, foreign and indigenous*

Variable	r		odds		d.f.	p	
	None->Indigenous	None->Foreign	None->Indigenous	None->Foreign		None->Indigenous	None->Foreign
Enforcement (reference category: none)					60		
Restricted	1.99	1.71	7.33	5.49		0.03	0.08
All	3.09	2.39	21.99	11.00		<0.001	0.007
Gossip	<-0.01	0.03	0.99	1.03	60	0.99	0.92
Hierarchy (reference category: 0)					60		
≤Two	1.86	2.03	6.43	7.62		0.01	0.01
≥Three	3.56	2.59	34.99	13.33		0.003	0.06
Market activity (reference category: local-regional)	0.99	0.95	2.69	2.59	60	0.11	0.18
Settlement fixity (reference					60		

category: nomadic)							
Semi-Nomadic	0.12	-0.58	1.13	0.56		0.92	0.66
Permanent	1.88	1.41	6.55	4.09		0.03	0.12
Famine					60		
(reference category: low)							
Moderate	0.79	1.52	2.20	4.58		0.32	0.12
High	0.59	1.09	1.80	2.99		0.40	0.23
Latitude	0.04	0.03	0.02	0.02	60	0.01	0.06

Table 10-2 shows that the findings are not changed by recategorisation of the outcome variable to account for foreign influence. The predictor variables have similar effects on the probability of indigenous or foreign money use. This is consistent with the theory concerning the role of sanctions in money use. Due to the cooperative dilemma underpinning tokens of debt, sanctions should be important in the maintenance of imported money systems as well as their endogenous emergence. The introduction of tokens of debt by foreign powers would likely be quickly exploited by defectors, meaning that sanctions are just as important in these conditions as they are when money emerges endogenously. One exception to the stability of the findings is that Table 10-2 shows that the shift from nomadic to semi-nomadic is associated with a small increase in the likelihood of indigenous money use, but a decrease in the likelihood of foreign money use. It is unclear why the likelihood of foreign money use would be higher in nomadic societies than in semi-nomadic societies, suggesting that this finding may be an artefact of the limited sample size and the relatively small numbers of semi-nomadic societies available in the data.

Table 10-3 below continues this analysis by replicating the full model comparison using the three-level outcome variable. Importantly, this also shows that the results are not affected by the collapsing together of foreign and indigenous money. Sanctions are still the most important influence, followed by taxation (hierarchy). The Akaike weight scores also show that I have few

models that are comparatively highly likely to be the best model, and many that are very unlikely to be the best model. This gives a 95% confidence set that contains only the top four models, which means that there is high dispersion across the Akaike importance scores, with gossip, fixity, famine and latitude all having minimal importance as they do not feature in the confidence set.

Table 10-3: *Model comparison for different combinations of predictor variables and money use split into none, foreign and indigenous*

AIC	Enforcement		Gossip	Levels of hierarchy		Market	Fixity		Famine		Latitude	Akaike weight
	None → Restricted	None → All		Zero → One	Zero → Three		Nomadic → Semi-nomadic	Nomadic → Permanent	Low→ Moderate	Low→ High		
119.80	**X**	**X**										**0.43**
120.98				**X**	**X**							**0.24**
121.71	**X**	**X**		**X**	**X**							**0.17**
123.51	X	X				X						0.07
123.74	X	X	X									0.06
126.84	X	X	X	X	X	X	X	X			X	0.01
127.71											X	0.008
128.67	X	X	X			X	X	X	X	X	X	0.005
129.98							X	X				0.003
130.45			X	X	X	X	X	X	X	X	X	0.002
130.55	X	X	X	X	X		X	X	X	X	X	0.002
130.56	X	X		X	X	X	X	X	X	X	X	0.002
132.99						X						<0.001
133.68									X	X	X	<0.001
134.03	X	X	X	X	X	X	X	X	X	X	X	<0.001
135.48	X	X	X	X	X	X			X	X	X	<0.001
135.78							X	X	X	X		<0.001
136.39			X									<0.001
137.28									X	X		<0.001
142.56	X	X	X	X	X	X	X	X	X	X	X	<0.001
Akaike importance	0.66		0.00	0.41		0.07	0.00		0.00		0.00	

Appendix 3-3: Distinguishing commodity money and tokens

In the chapter, I explain the results of the models with reference to the debt theory of money. This theory specifically concerns the mechanisms underpinning the use of token money. However, due to data limitations, the money variable also contains a limited number of societies that use commodity money instead of tokens. To ensure that these cases are not driving the results, Table 10-4 explores the relationships between the individual predictor variables and money use having excluded cases in which societies use commodity money instead of tokens.

Table 10-4: *Bivariate logistic regressions for each predictor variable and money use excluding commodity money cases*

Variable	r	odds	d.f.	p
Enforcement (reference category: none)			57	
Restricted	1.52	4.58		0.06
All	2.75	15.58		<0.001
Gossip	0.05	1.05	57	0.83
Hierarchy (reference category: 0)			57	
≤Two	1.96	7.14		0.003
Three	3.40	29.99		0.003
Market activity (reference category: local-regional)	1.16	3.17	57	0.04
Settlement fixity (reference category: nomadic)			57	
Semi-Nomadic	0.52	1.69		0.61
Permanent	2.33	10.23		0.007
Famine (reference category: low)			57	
Moderate	1.01	2.75		0.17
High	0.92	2.5		0.16
Latitude	0.04	1.04	57	0.005

Table 10-4 shows that the results are not changed when I use a sample in which the only money systems are token-based or absent by excluding commodity money cases. Sanctions and taxes are associated with the highest

probability of money use and differences in famine conditions are associated with the least change in the probability of money use. This is consistent with the proposal that the original findings are driven by differences in how societies solve the cooperative dilemma at the heart of the debt theory of money, which is a theory concerned specifically with token use.

Appendix 3-4: Dividing gossip into categories

In the original analysis, I treated gossip as a categorical variable. This was to aid with interpretability, but does require the assumption that the spacings between the levels of the gossip variables were equal in size. Therefore, to ensure that this treatment of the gossip variable is not driving my results, I repeated the full model comparison with gossip defined as a categorical variable (Table 10-5).

Table 10-5 shows that treating gossip as a categorical variable made little qualitative difference to the findings. Sanctions and hierarchy are still the most important predictors and famine is the least important. However there is more uncertainty regarding the best-fitting model with the highest Akaike weight being 0.28. Fixity also has less importance than in the original model comparison, although it still appears in two of the three best-fitting models. The gossip variable itself does appear to have some influence on money use, but not in any systematic or linear pattern, particularly because societies with the highest gossip score seem to have a lower probability of using money when compared to those that scored 1, 2 or 3 on the gossip scale, but not those that scored 1. This is in line with the discussion in chapter 5 about the potential limitations and ambiguities of the gossip variable itself.

Table 10-5: *Model comparison for different combinations of predictor variables and gossip divided into categories*

AIC	Enforcement		Gossip				Levels of hierarchy		Market	Fixity		Famine		Latitude	Akaike weight
	None → Restricted	None → All	0→1	0→2	0→3	0→4	Zero → One	Zero → Three		Nomadic → Semi-nomadic	Nomadic → Permanent	Low→ Moderate	Low→ High		
67.64	**4.61**	**3.89**	**2.16**	**12.27**	**9.98**	**1.26**	**8.63**	**18.61**	**1.06**	**0.25**	**1.45**			**1.04**	**0.28**
68.33	**4.12**	**3.22**					**1.97**	**7.96**	**1.30**	**0.12**	**1.69**	**1.46**	**0.98**	**1.04**	**0.19**
69.47	**3.76**	**6.69**					**3.90**	**4.04**							**0.11**
69.74	4.28	3.64	2.39	12.95	9.11	1.45	8.06	19.33		0.27	1.39	1.29	0.87	1.04	0.09
70.30	5.67	13.99													0.07
70.35	4.31	4.69	5.82	46.04	47.27	3.71	22.43	29.41	0.87			1.38	0.79	1.02	0.07
71.22			0.79	5.69	3.53	0.51	13.05	41.81	1.63	0.34	1.87	1.37	0.78	1.04	0.05
72.04	4.16	3.50	2.39	11.96	8.52	1.44	7.47	17.55	1.01	0.28	1.39	1.29	0.89	1.03	0.03
72.09	5.25	12.06							1.37						0.03
72.52							6.38	17.31							0.02
72.88	5.80	7.79	1.66	1.97	1.11	0.58			1.12	0.11	2.04	1.09	0.90	1.05	0.02
73.95	8.42	16.71	8.24	7.33	9.85	3.73									0.01
76.30	3.69	3.01	2.32	20.23	23.14	2.33	12.66	43.13	1.28	0.09 INT	0.59 INT	0.08 INT	1.28 INT		0.004
79.65														1.03	<0.001
80.01										0.87	4.87				<0.001
82.23												2.25	1.36	1.03	<0.001
82.36										0.94	4.59	2.39	1.76		<0.001
84.75									2.57						<0.001
87.57												2.71	2.07		<0.001
93.19			2.41	1.86	2.44	1.67									<0.001
Akaike importance	0.89		0.53				0.83		0.66	0.65		0.44		0.72	

Cells contain odds ratios. INT=interaction between fixity and famine included in model

Appendix 3-5: Accounting for language families

Although the SCCS was created to contain independent societies to reduce the effects of Galton's problem, some research has suggested that non-independence is still an issue in this sample (see chapter 5). Therefore, I conduct further analysis with various controls for non-independence to ensure that the results were not impacted in any way by relationships between the sampled societies. As we have seen in previous chapters, multilevel models can control for patterns of non-independence using proxies for shared history such as language families. However, owing to the relatively small sample size, and the large number of language families in the sampled societies due to their relative independence, multivariate models containing all of the predictor variables and a random effect for language family face convergence issues. Consequently, I use other available tools to evaluate the impact of potential non-independence on the results. First, I replicate the bivariate logistic regressions with language families as a random effect to see whether this changes the nature of any relationships. Then, I explore the proportion of variation in money use that is attributable to language families in various models, specifically combinations of the strongest predictors: sanctions and hierarchy. Finally, I replicate the full model comparison with the inclusion of language families as a fixed effect. While including language families as a fixed effect may result in slightly biased estimates because of imbalances in the number of members of different language families, I present this analysis as an exploration into how sensitive the findings are to variables that attempt to capture relationships between societies.

Table 10-6 below presents the replicated bivariate logistic regressions with language families as a random effect. Crucially, this shows that the

relationships between the predictor variables and money use are not changed when I account for language families. None of the relationships change direction; in fact, the findings seem to be exaggerated as coefficients that were high in the initial analysis increase in size, and coefficients that were originally relatively weak reduce in their strength.

Table 10-6: *Multilevel logistic regressions for each predictor variable and money use including language families as a random effect*

Variable	r	odds	d.f.	p
Enforcement (reference category: none)			57	
Restricted	2.15	8.62		0.04
All	3.23	25.23		0.001
Gossip	0.19	1.22	57	0.49
Hierarchy (reference category: 0)			57	
≤Two	1.93	6.94		0.002
≥Three	3.25	25.71		0.004
Market activity (reference category: local-regional)	1.65	5.19	57	0.05
Settlement fixity (reference category: nomadic)			57	
Semi-Nomadic	0.25	1.28		0.85
Permanent	2.81	16.66		0.03
Famine (reference category: low)			57	
Moderate	1.08	2.95		0.19
High	0.96	2.61		0.21
Latitude	0.05	1.06	57	0.03

Table 10-7 below uses ICCs of multilevel models to explore the proportion of variation in money use attributable to language families. When no predictor variables are included in a model other than language family as a random effect, 30% of the variation in money use can be attributed to differences in language families. This suggests that shared history may have a limited effect on the results. The variation in money use accounted for by shared history is relatively modest even when there are no other predictor

variables in the model, which is when one would expect the variation explained by shared history to be at its maximum as there are no other variables present that may take some of the variation currently attributed to shared history. Table 10-7 also presents an exploratory exercise in which I include the variables that feature in the best fitting models: sanctions and hierarchy. It shows that the inclusion of the hierarchy variable removes any variation attributable to language families. This implies that the best-fitting models are robust to any effect of non-independence, as they capture all the variation that language families appear to account for.

Table 10-7: *Multilevel logistic regressions for each combination of the predictor variables sanctions and hierarchy, with language families as a random effect*

Variables		**Random effect**
Sanctions	**Hierarchy**	**ICC (language family)**
		0.3
X		0.28
	X	0.00
X	X	0.00

Table 10-8 below presents a replication of the full model comparison, with language families included as a fixed effect in every model. This shows that the main finding is unchanged: the odds ratios and Akaike importance scores both suggest that sanctions are the most important predictor variable. However, the effect of one variable does appear to change. In the original analysis, hierarchy is one of the stronger predictors. If language families are included as a fixed effect, the influence of hierarchy drops substantially, making it one of the weaker predictors of money use according to odds ratios and Akaike importance scores. Taken together with Table 10-7 above, this suggests that there is some covariation between levels of hierarchy and language families in the SCCS. Consequently, we must exercise caution with the interpretation of

the strength of the role of taxation in the evolution of money from the model comparison. It is worth noting however that including language family as a random effect did not decrease the strength of the relationship between hierarchy and money use in a bivariate model (see Table 10-6). Moreover, including categorical variables that have imbalanced levels such as the language family variable is known to produce biased estimates in fixed effects models, which makes it difficult to establish whether this apparent change in the effect of hierarchy is a result of non-independence in the data or bias in the model. Ultimately, it must be stressed that the analyses in these last three tables are seeking to replace a full model comparison that explicitly accounts for any hierarchical structure using multilevel modelling, as the sample and variables restrict the ability to conduct such a comparison. Therefore, I encourage further study that specifies a range of variables that are more appropriate for multilevel modelling and that will enable us to understand what (if any) effect non-independence in the SCCS has on the results.

Table 10-8: *Model comparison for different combinations of predictor variables with language family included as a fixed effect in each model*

AIC	Enforcement		Gossip	Levels of hierarchy		Market	Fixity		Famine		Latitude	Akaike weight
	None → Restricted	None → All		Zero → One	Zero → Three		Nomadic → Semi-nomadic	Nomadic → Permanent	Low→ Moderate	Low→ High		
88.75	**11.54**	**28.99**	**1.74**									**0.38**
90.79	**6.62**	**18.22**										**0.14**
91.08							0.52	11.74				0.12
91.47	4.50	10.76				3.29						0.10
92.98	7.93	12.67	1.49			2.42	0.06	2.83	0.39	0.45	1.00	0.05
93.00	7.57	41.32		0.66	0.09							0.05
93.06											1.08	0.04
93.49	15.95	16.35	1.70	0.78	0.24	1.82	0.06	2.35			0.99	0.04
94.74						6.94						0.02
94.99			0.86	2.36	8.80	8.16	0.07	6.66	0.20	0.09	1.06	0.02
95.07							0.49	12.46	0.63	0.78		0.02
95.70									1.23	2.89	1.08	0.01
96.10	9.87	39.54	1.44	0.59	0.07	1.60			0.95	2.96	1.04	0.009
96.34	10.76	19.29	1.48	0.59	0.19		0.14	3.09	0.43	0.78	1.00	0.009
97.08	4.21	11.99		0.64	0.21	1.96	0.16	3.46	0.33	0.43	1.02	0.006
98.83	7.39	14.06	1.38	0.68	0.22	1.65	0.13	2.92	0.41	0.62	1.00	0.003
100.09			1.38									0.001
101.02									1.88	3.69		<0.001
107.42	6.66	9.97	1.43	1.03	0.60	0.79	0.09	4.12	0.36	0.87	1.01	<0.001
Akaike importance	0.74		0.48	0.10		0.22	0.22		0.06		0.14	

Note: model with interaction between fixity and famine could not converge due to large numbers of categorical variables with many levels

Chapter 11: Appendices to an experimental test of the tokens-as-debt theory for the evolution of money

Supplementary methods

Appendix 4-1: Participant information form

PARTICIPANT INFORMATION FORM

What is this study about?
This project is being conducted by the University of Exeter's Human Biological and Cultural Evolution research group. This research is interested in the evolution of money and how people use IOUs in cooperative situations.

What will I have to do?
You will take part in a computer-based game that is comprised of several rounds. Each round, you will be randomly matched with a different partner with whom you will play. Each round you will also be randomly allocated to one of two player types that can make different decisions. 'Producers' choose whether or not they want to increase the score of their partner at a cost to their own score. 'Consumers' can choose to give an IOU, signed by themselves, to their partner. Some participants will be able to see the choices made by other players throughout the game.

Do I have to take part?
No. Participation is entirely voluntary. If you decide you do not want to take part you will be free to leave the study at any time without giving a reason.

What will happen to my data?
Your data are entirely anonymous. The choices you make will be stored with an identification number, so we are unable to link your data with your name or any other personally identifying information. Your data will be stored and analysed by Adam Flitton at the University of Exeter. Any findings will be written in a thesis.

Are there any risks to taking part?
There are no risks to taking part in this study. This study has been granted ethical approval through the university's ethics committee, which abides by the guidelines of the British Psychological Society. If you have any concerns about this study, please contact the lead researcher at: af395@exeter.ac.uk

Questions?
Please ask any questions you have about this information or the study before signing the consent form overleaf.

Appendix 4-2: Consent form

PARTICIPANT CONSENT FORM

Researcher's name: Adam Flitton (af395@exeter.ac.uk).
Project title: Cultural evolution of money.

	YES	NO
I understand what is on the participant information form.		
I understand that I can withdraw from the experiment at any time without providing a reason.		
I understand that my data will be kept strictly confidential.		
I understand that anonymity will be maintained in the data and the written report.		
I agree to take part in the study.		

Signed:

…….....

Appendix 4-3: Demographic and feedback questionnaires

UNIVERSITY OF EXETER

Demographic Information and Qualitative Feedback

Thank you for participating in this study.

Please provide us with the following information:

Age: …….

Sex: …….

How many public goods/cooperation experiments have you played before (approx.)? ……

At the beginning, what did you think was the best way to gain the most points?

Did your strategy change as the rounds progressed? Why did it change and in what way?

Appendix 4-4: Debrief form

PARTICIPANT DEBRIEF

What was this about?

This study was conducted to investigate the evolution of money systems. We wanted to see if the ability to see other people's behaviours would affect the extent to which people give help in exchange for different people's IOUs. This experiment is part of a wider research project investigating the role of institutions and reputation in the evolution of cooperative and economic behaviours.

Ethical reminder:

Your data are entirely anonymous. Any choices and payoffs are stored with an identification number, making it impossible to link data to personal information. The data you have provided will also remain strictly confidential.

Who can I contact if I am worried about this study?

If you have concerns about this study, please contact the lead researcher: af395@exeter.ac.uk

Appendix 4-5: Images of the screens for different conditions

Below I present screenshots that show what the computer screens showed the participants in different conditions and highlight the differences between them. The screens in every condition have some commonalities. The participants can always see the round number, what role they have been assigned to be, a reminder of the payoff matrix, their available choices, and a table that reminds them of what they chose to do and what the outcome of this decision was. This table updates every round.

Figure 11-1 presents the parts of the screen that varied between the control social information conditions. First, the no social information condition does not provide information about who the participant is playing with, while the other two conditions do. Second, the social information conditions track partner information in the updating table, as a reminder of how different players acted previously. Thirdly, the all social information condition includes a separate table which also updates every round and shows what every other player chose to do in the last round.

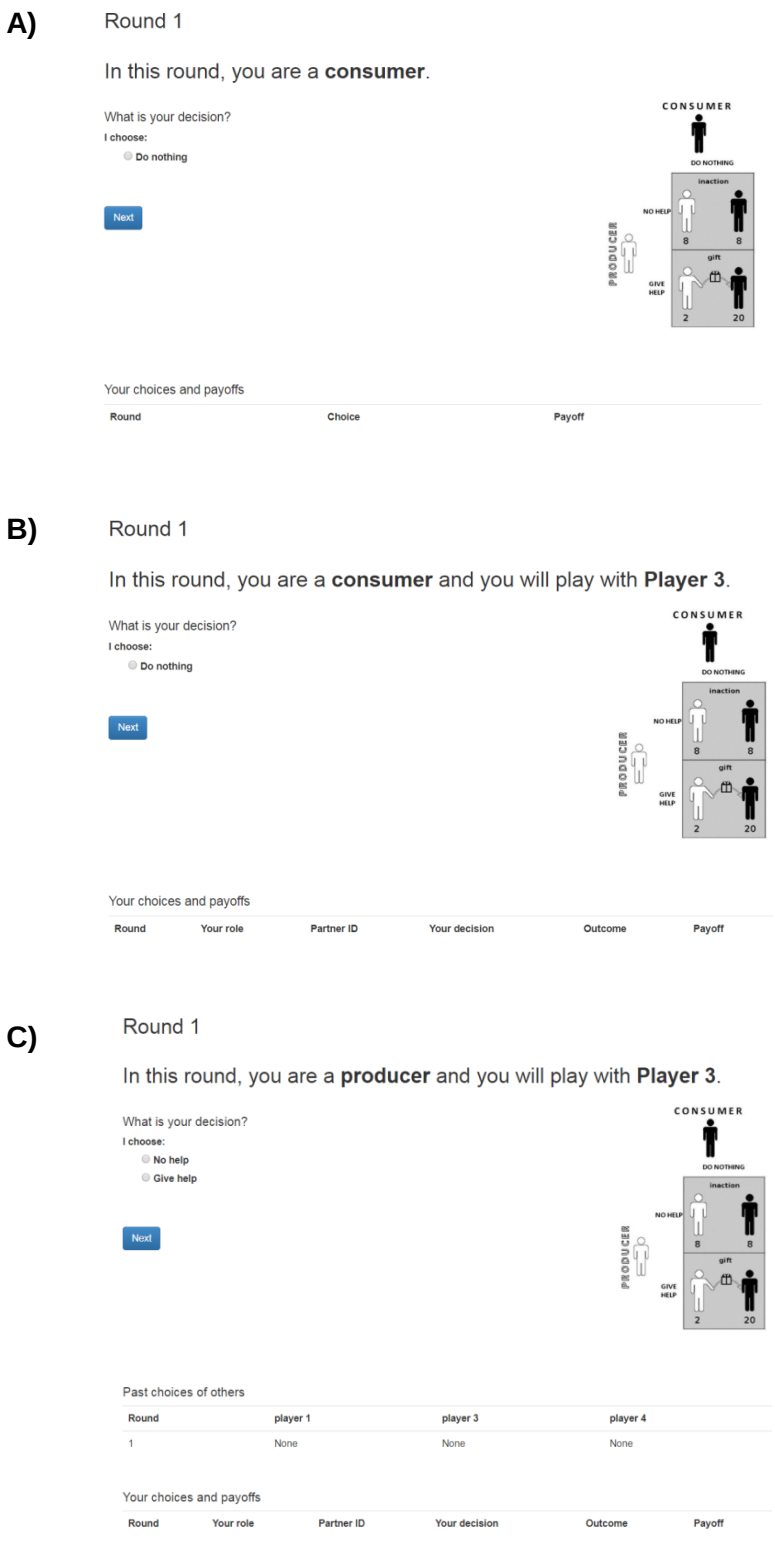
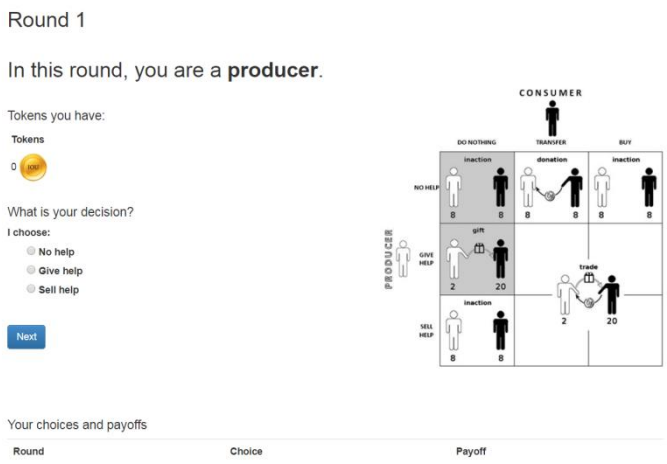


Figure 11-1: *Screenshots of what the participants in the different control conditions saw on the screen*

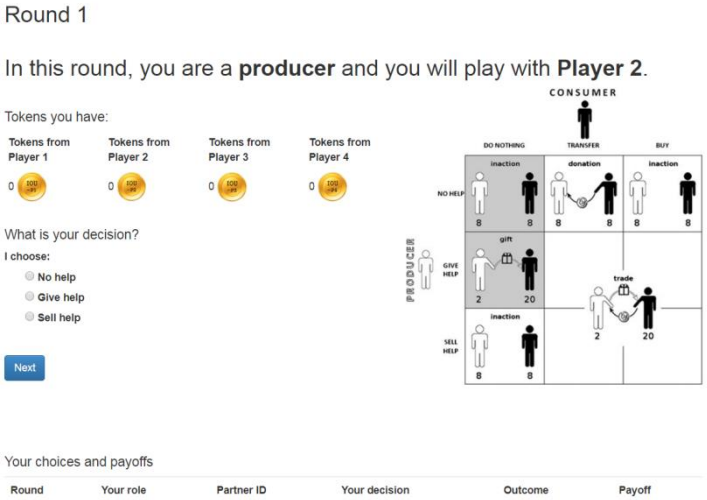
Panel A shows the control condition with no social information; Panel B shows the control condition with partner information; Panel C shows the control condition with all social information.

For the token conditions, an extra piece of information is displayed on the screen for all participants. A count of the number of tokens in the participant's possession is presented on the screen. In addition, as tokens are attributable to different players in the token condition, counts of how many tokens the participant has received from specific other players is also presented. In terms of the social information manipulations, these are the same as in the control conditions, with the social information conditions presenting the ID of the person the participant is currently playing with and the all social information condition having an extra table showing everyone's behaviours every round (Figure 11-2).

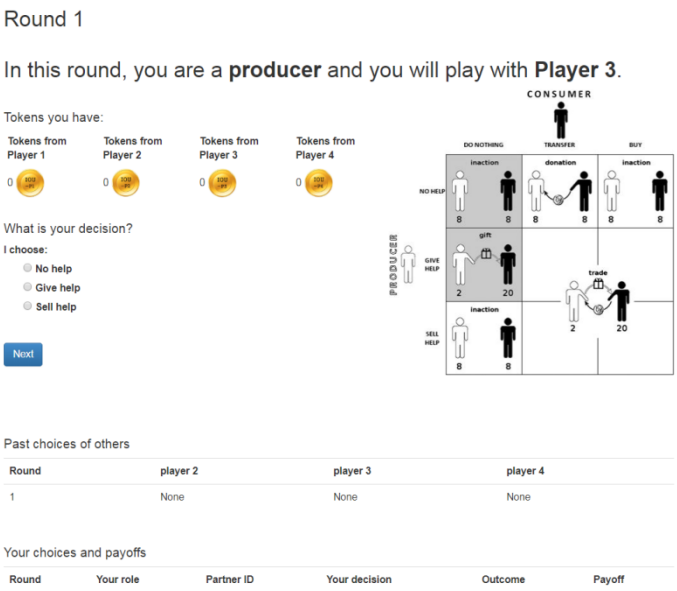
A)



B)



C)



Past choices of others

Round	player 2	player 3	player 4
1	None	None	None

Your choices and payoffs

Round	Your role	Partner ID	Your decision	Outcome	Payoff

Figure 11-2: *Screenshots of what the participants in the different token conditions saw on the screen*

Panel A shows the token condition with no social information; Panel B shows the token condition with partner information; Panel C shows the token condition with all social information.

Appendix 4-6: Tests of normality and homogeneity of variance

The importance of homogeneity of variance and normality is increased when using a proportional outcome variable (Ferrari & Cribari-Neto, 2004). A Bartlett's test of homogeneity of variances revealed no evidence for differences in variance across the social information (K^2=2.17(2), p=0.34) and token (K^2=0.01(1), p=0.94) conditions. A Shapiro-Wilk test of the normality of the residuals of the factorial ANOVA also suggested no evidence for non-normality (W=0.98, p=0.09).

Supplementary results

Appendix 4-7: Non-parametric analysis of the conditions

Although the data did not violate the assumptions regarding normality and homogeneity of variance, the sample size and distribution suggest that confirmation of the effect of the conditions using non-parametric tests would be informative. Unfortunately, at the time of writing there is no non-parametric equivalent of a factorial ANOVA. Therefore, I conduct two separate bivariate non-parametric tests, one on the effect of social information on cooperation and one on the effect of tokens on social information. A Mann Whitney U test showed that the token condition had a significant effect on cooperation ($W=711.5$, $p=0.02$). A Kruskal-Wallis test showed that social information also had a significant effect on cooperation ($H=8.19$, $p=0.02$). Post-hoc pairwise Wilcoxon tests showed significant differences in cooperation between the conditions in which participants had no social information and when they had information about with whom they were playing ($p=0.05$). There was also a significant difference between when participants had no social information and when they had information about everyone's behaviours every round ($p=0.02$). No significant difference was found between the condition in which participants had information about with who they were playing and the condition in which participants had information about everyone's behaviours every round ($p=0.86$).

Appendix 4-8: Analysis of control variables

In Table 11-1 I present analyses of the control variables. First I explore their effects on the outcome variable (cooperation), and then I test their association with the different conditions to ensure that there is no systematic variation in the control variables that may be driving the effects of the conditions.

Table 11-1: *Tests of the relationships between the control variables and the outcome variable, and between the control variables themselves*

Relationship **Outcome variable** **~Predictor**	**Statistical test**	**Result**
Cooperation		
~Sex	Linear regression	F→M r=0.07, p=0.27
~Age	Linear regression	r=-0.01, p=0.42
~Prior experience	Linear regression	0→1 r=0.09, p=0.31 0→2 r=0.11, p=0.39
Token conditions		
~Sex	χ^2 test of independence	χ^2=0.09, p=0.77
~Age	Binomial logistic regression	r=0.01, p=0.81
~Prior experience	χ^2 test of independence	χ^2=3.34, p=0.19
Social information conditions		
~Sex	χ^2 test of independence	χ^2=0.03, p=0.98
~Age	Multinomial logistic regression	None→Players r=0.05, p=0.45 None→Everything r=0.05, p=0.33
~Prior experience	χ^2 test of independence	χ^2=3.76, p=0.44

Table 11-1 shows that none of the control variables had any relationships with the outcome variable. Cooperation does not vary as a result of sex, age or prior experience with cooperative games. Importantly, Table 11-1 also shows that the distributions of age, sex and prior experience in the sample were not systematically different in any given condition. Age, sex and prior experience

did not vary across the levels of both of the between-participants independent variables (tokens and social information). Therefore, I can be confident that it was the manipulations as opposed to the control variables that drove the results.

Appendix 4-9: Qualitative feedback

At the end of the experiment, each participant was given a form on which they were encouraged to voluntarily record their thoughts about what they were doing, the best way to get the highest payoff and their strategies. 71 participants completed at least part of this form. Table 11-2 below presents a breakdown of the comments made by the participants.

Table 11-2: *Comments given by participants on qualitative feedback forms*

Question	Best way to high payoff (N=62)		Strategy (N=51)
Never help/be selfish/do nothing	38	Defect	37
		Reputation	19
Cooperate/help	14	Reciprocate	18
Buy	7	Random	2
Reciprocate	3	Ran out of tokens	4

The first section of Table 11-2 shows that most participants believed the best way to get the highest payoff would be to never help others. Far fewer believed that cooperation or reciprocation were the most successful strategies. This is in line with the expectations of rational choice theory, as defection is the optimal strategy for any one individual, in contrast to cooperation which requires every group member to cooperate to ensure the maximum payoff for everyone. This is reiterated in the second section of Table 11-2, which shows that the most commonly reported strategy was defection. However, it should be noted that despite the fact that over half of the participants who completed the form claimed that defection was both the best way to get a high payoff and the strategy they used, the behavioural data show that very few participants consistently defected (this is explored further in the chapter).

The second section of Table 11-2 also shows that several participants explicitly stated that their strategies involved reciprocation and management of

their reputation, lending credence to the interpretation that direct and indirect reciprocity are important underlying mechanisms of token money use. Finally, a very small amount of participants reported making choices at random and reported running out of tokens (also as examined in the discussion section).

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