Title
Culture, Institutional Performance, and Path Dependence

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Abstract

In this paper, we develop a model of institutional and cultural path dependence. Our model captures institutional externalities, transmitted through culture. Institutions create behavioral regularities which in turn form part of culture. These behavioral regularities then influence future choice between institutions because the culture affects institutional fit, as measured by utility. The resulting interplay between cultural forces and institutional choices creates cultural and institutional path dependence. This model shows that not only does the set of past institutional choices matter, but so does the order in which institutions arose.

1 Introduction

The performance of an institution depends upon how a community will react to it. Community traits affect institutional performance whether we take a broad view—economic growth depends upon property rights, levels of trust, and institutional stability (North 1990, Easterly, Ikenberry, etc.)—or whether we look at smaller scales: voluntary contribution mechanisms for public good provision perform effectively in close-knit, high-trust, homogeneous communities but fail in loosely-connected, low-trust, diverse communities (Ostrom 2005). These facts produce tension among scholars and policy makers. Generally speaking, social

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scientists agree that culture matters, although some believe that it matters more than others. And undoubtedly, culture's sway depends upon context. Cultural forces would rarely be so strong as to compel a producer to turn down a higher price for an exported good. However, culture may exert substantial influence on the method—the institution—that a community uses to divide the profits from that trade. The question for political science and economics is how to include culture in our analyses. We could follow the common approach of treating culture as an exogenous feature, where each culture is a separate petri dish within which we drop an institution and see what grows.

Treating culture as exogenous excludes feedbacks between institutions and culture. These feedbacks clearly exist. Institutions shape culture: they influence—and in some cases determine—beliefs, behaviors, world views, and connectedness. Therefore institutions generate externalities that affect other institutions because they alter the way that a community will respond. Culture is the medium for transmission of these institutional externalities.

In this paper, we describe a dynamic model of institutional selection that includes cultural effects as core features of the model. We view culture not as something appended but as something intrinsic to the processes analyzed within formal models of institutions. These cultural effects create bidirectional causalities: culture affects institutions and institutions affect culture. Rather than think of a particular institution as generating some number of outcomes, say six, two of which are country specific and four of which arise with regularity around the globe, we think of institutions as generating multiple equilibria or paths and as culture as influencing which of those equilibria or paths result. Put more specifically, each potential equilibria or path can be thought of as having a basin of attraction. The basin in which a particular country finds itself as well as the size of that basin are functions of culture, since culture determines the initial conditions and the learning dynamic. Thus, the cultural context influences the resulting equilibrium or dynamics that result. In some domains, there may be few regularities in outcomes we see. Diverse cultures may generate diverse outcomes. This lack of regularity does not deny the usefulness of formal models. To the contrary, now the formal models—with the aid of thick descriptions of initial points

and adjustment dynamics—may present even greater attachment to reality. Our approach complements descriptive accounts by providing a precise, formal, logically consistent model of how contextual effects might operate. Yet, as will be clear, our model is firmly rooted in the logic of game theory.

Our model builds from Bednar and Page (2006): agents play ensembles of games simultaneously, playing distinct strategies in each game but optimizing utility over the whole set of games. Explicit consideration of ensembles highlights the current context, what we might call the *horizontal* context, the full set of strategic situations that an individual encounters at any one time. In this paper, we add a historical or *vertical* context, where institutions and behaviors build upon one another over time. Culture has both horizontal and vertical components. How we behave in one context depends upon other current contexts. It also depends upon how we've acted in the past—what behaviors and norms have been established and passed on. This vertical component to culture creates the possibility of *path dependence* of culture generally and of institutional choices in particular.

We use this model to produce five phenomena. We show how the *set* of existing institutions influences culture. We also show how the *order* in which the institutions were added makes a difference in the culture that emerges. Using the terminology introduced by Page (2006), we show both *phat* (set) and *path* (order) dependence to cultural patterns of behavior. We also show that the choice over institutions is both *phat* and *path dependent*. The optimal institutional choice depends on the set of existing institutions and on the order in which those institutions arose. In other words, the externalities between institutions conveyed by cultural are both horizontal and vertical. This should come as no surprise to area studies scholars. Institutions shape culture. In doing so, they necessarily affect the performance of other institutions and the choices among them.[1] Finally, we show how institutional choices differentially limit paths. Some institutional choices may leave more future options open

[1]Terri Karl finds evidence of this in her analysis of oil rich states. The benefits that accrue from oil hinders the efficacy of markets to create incentives to innovate or diversify: this behavior is dampened. As a result, markets don't work as well as they work in other places (Karl 1997).

than others. Although culture matters, it may matter more in some cases than in others.[2]

Before proceeding with the remainder of the paper, three comments are in order. First, cultures cannot borrow ideas from other more successful cultures, although we accept that this effect exists. For example, Gerschenkron has shown that "backward" countries benefit from adopting an institution or technology later because they can learn from their predecessors and skip several stages in the linear progression of technology. We do not dispute his hypothesis, but merely mention that we ignore it for reasons of tractability. Our cultures will muddle through. They won't take great leaps forward.

Second, our discussion and examples have been at the level of society, but the logic extends to the organizational context as well. There are many examples of this sort of path dependence in the corporate culture literature (Cohen and Sastry 2000). Organizational theorists refer to the importance of early stages in corporate culture formation as imprinting. Empirical evidence of imprinting has been found in craft unions, department stores, banks, newspapers, and high-tech firms (Stinchcombe 1965, Swaminathan 1996, and Boeker, 1989). Cohen and Bacdayan (1994) have found evidence of cultural imprinting, where early learning influence later strategies. For example, if subjects are sufficiently imprinted with a right-turn heuristic, they may take left turns by executing three successive right turns. While this is inefficient, it is simpler given the cognitive tools at their disposal. Imprinting may occur at the societal level as well. For example, Ebays method of auctioning off goods has become prevalent because so many people have evolved strategies for playing in that game. It is even used in settings where other types of auctions could (at least in theory) work better because people are less comfortable with the other auctions.

Third, and finally, why focus on behavior? Most social scientists talk about beliefs when

[2]Our embrace of culture should not be read as a denial that formal models can reveal empirical regularities about institutional performance. They can and they have (Morton 2004). But these regularities have not proven sufficiently powerful to guide policies in the areas of economic development and political stability. To the contrary, the history of development efforts reveals that a one-size-fits-all theory of institutions fails, often miserably (Easterly 2001). This does not imply that we should abandon formal models or the search for regularities. If we could understand what holds generally—free labor markets and central bank independence leads to stable growth—and what depends upon country level factors, then we can reach deeper understandings and can design better institutions and policies.

discussing culture.[3] We believe that this underemphasizes the importance of behavior, both physical and cognitive. Behavior sheds light on our physicality. We move. We dance. We shake hands. We bow. These behaviors become part of who we are and we cannot change them. Nor can we quickly learn new ones or abandon those we've acquired over our lives. Culture may more resemble tacit knowledge—it may inaccessible to our conscious mind (Polanyi 1974). The ability to be German, just like the ability to play water polo, may defy explication. Our focus on behavior allows us to imagine people as bundles of linked behaviors. Each behavior can create external effects with others. A core insight from this behavioral bundling will be that consistency and complementarities prove advantageous. Acquiring a new behavior that builds from existing behaviors is much simpler than starting from scratch. Having said all this, behavior in strategic contexts depends crucially on beliefs. But just as beliefs can drive behaviors, so too can behaviors influence beliefs. People can expect others to behave consistently. Our behavioral models links behavior to cognition. We rely on an automaton model to capture the encoding of behaviors inside peoples heads. These automaton adapt to incentives.

Our behavioral focus also allows us to see how institutional changes can create fear. When we think about an intervention "threatening a way of life" we do not mean that it will

[3]The study of culture suffers from an abundance of definitions across a dozen fields. We have identified six components used to define culture: *representations and focality* (see Hong and Page 2001, Johnson and Calvert), *belief systems* (Ensminger, Greif), *networks and social capital* (Putnam and Kranton), *mental models* (Nisbett, Atran and Medin), *semiotics* (Weeden), and *behavioral repertoires* (Bednar and Page 2006). Some cultural attributes like trust (Zak) and individualism (Ingelhart) cut across these factors. Trust depends upon belief systems and across social network and individualism is partly captured by representations as well as by belief systems.

One approach to modeling culture would be to condense these many features into a single variable, as Greif and Laitin (2005) model *quasi parameters.* Their quasi parameters can be thought of as state variables in a dynamical system. Just as current investments alter the level of capital in a macro model of the economy, current institutions effect levels of trust, demographic variables, and so on. These state variables in turn influence future payoffs and perforce choices. For example, a policy that creates incentives to have fewer children shifts demographics and alters the incentives to save. It also shifts the size of kinship networks and may influence levels of social capital and trust.

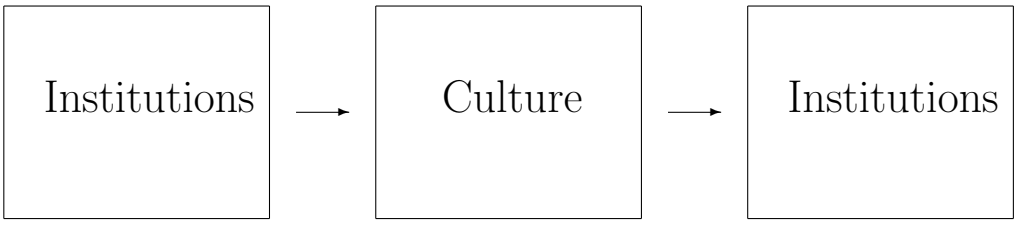
Our approach differs. Rather than try to bundle together multiple cultural attributes, we pick a single cultural dimension—behavioral repertoires—and work through the logic based on a model that equates culture as behavior. The baseline model may be extended in future research. Our framework only requires that institutions influence the cultural dimension (in our case behavior) and the cultural dimension influences institutional performance. We believe that by splitting culture into some of its components and exploring the interplay each has with institutions that we can gain insights into the larger problem.

merely change beliefs, but that it will fundamentally change the the ways in which people behave toward one another, and how, through institutional externalities, it might undermine existing institutions. Finally, the behavioral approach naturally captures stickiness. People change behavior slowly because those behaviors are so ingrained. The French may be slow to respond to the incentives to innovate (Suroweicki) and immigrants may choose to reduce their number of offspring but not so far as to match that of the new society within which they now live (Fernandez).

2 Institutionally Relevant Culture

Institutions not only generate outcomes, which can be good or bad, but they also influence behaviors, beliefs, networks, and meanings. They influence culture. Culture—be it in the form of beliefs, social connectedness, perspectives, mental models, or, as in this paper, behaviors—then can be understood as shaped by institutional choices. In turn, culture helps to explain the success of institutional choices. Therefore we have a two-way causality: institutions shape culture and culture influences the choice over institutions. This dual causality can result in culturally contingent equilibrium selection and, where a community is also selecting new institutions, in path dependent choices over institutions.

The Causal Chain



This causal chain points to five possible phenomena.

Cultural Phat Dependence: The set of existing institutions may affect the culture.

Cultural Path Dependence: The order in which institutions are created may affect the culture.

Institutional Phat Dependence: Rational choices over institutions may depend on the set of existing institutions

Institutional Path Dependence: Rational choices over institutions may depend upon the order in which institutions arose.

Differential Path Limitation Some paths of institutional choices may limit the set of possible path continuations more than others.

The distinction between the first two phenomena is subtle. Both say that to understand how new institutions perform, whether it be capitalism in Russia or democracy in Iraq, we must look at the past. Its constraints are much more current than the girdles of nostalgia or the comfort of routine. The distinction centers on the *order* in which the past played out, start to finish. Clearly, a detailed, ordered history tells us more than a broad-stroke characterization. For this reason, we borrow from Page (2006) and distinguish between cases in which only the set of past choices matter, *phat dependent processes*, and those cases where the order also matters, *path dependent processes.* The third and fourth phenomena refer to institutional choices rather than culture, again distinguishing between set and order dependence. The final phenomena that we might expect such a model to produce relates to the extent to which institutional choices limit paths.

A Simple Version

We can construct a boilerplate version of these phenomena as follows: suppose that we are interested in the performance of an institution C, which seems to work well in one society but not so well in another. Or, suppose we are surprised to find that Community 2 prefers

institution D to institution C, when C has performed so well in Community 1. There are three ways this problem might present itself:

Case 1: Ensemble Composition affects Institutional Performance

	Community 1	Community 2
Period 1	A	A
Period 2	B	B'
Period 3: either	C (good performance)	C (poor performance)
or	C preferred to C'	C' preferred to C

In Case 1, the ensemble—the incentive environment, structured by multiple institutions—differs between Communities 1 and 2. In both communities, the populations face Institution A, but their second institution differs. Bednar & Page 2006 argued that culture—a behavioral pattern—depended upon the ensemble. Because of the differences in their ensembles, the culture that emerges in Community 2 may be different from Community 1. When we introduce a new strategic environment, Institution C, to the two communities, the reaction to it may differ due to the different cultures, and when reactions differ, performance may vary. Alternatively, if the two communities have a choice over a way to structure a new problem area—for example, how to structure elections in a new democracy—the choice that one community makes may differ from the second because it has evolved a culture, due to its existing ensemble composition, that performs better under one institution than the other.

The many failed attempts to help developing countries are examples of Case 1. What were thought would be successful interventions have often proved failures because institutions do not perform as expected, and sometimes cultural differences are identified. This framework backs the analytical blame-identification one step, to the root of the cultural difference: varying strategic contexts in apparently unrelated social transactions.[4]

[4]This intuition is supported by the experimental evidence in the Henrich et al 2004. COMPLETE DESCRIPTION.

Case 2: The Effect of Simultaneous vs Delayed Introduction of an Existing Institution on Institutional Performance

	Community 1	Community 2
Period 1	A and B	A
Period 2		B
Period 3: either	C (good performance)	C (poor performance)
or	C preferred to C'	C' preferred to C

In Case 2, Community 1 introduces two institutions simultaneously, while in Community 2, a second institution isn't introduced until the first is well established. In this second community, behavioral routines and other artifacts of culture are shaped by Institution A. When Institution B is added, individual reaction to the incentives introduced by it will be conditioned by the existing culture, itself a product of Institution A. In Community 1, the two institutions were introduced simultaneously, and so the culture that evolved did so in a multi-institutional context.

Case 2 differs from Case 1 because ensemble composition is not sufficient to explain the differences in reaction to Institution C. In Case 2, the communities have identical ensembles at the start of Period 3. This example highlights the importance of sequential versus simultaneous introduction of institutions. Examples of this case abound in emerging markets. In some cases, a stock market is introduced with a regulatory regime, such as an SEC, in place for dispute resolution, while in other developing markets, the stock market is introduced and the regulatory or legal institution is introduced after the fact.[5]

In our last example, the two communities have the same institutions but they adopt those institutions in a different order.

[5]In new work, Anna Grzymala-Busse has identified significant variation in performance of the stock markets in Eastern Europe based upon the timing of the introduction of the regulatory institution. When market behavior was allowed to develop in the absence of regulation, regulation was much less effective once introduced than if behavior had developed with regulatory oversight from the start.

Case 3: Path Dependent Ensemble Effects on Institutional Performance

	Community 1	Community 2
Period 1	A	B
Period 2	B	A
Period 3: either	C (good performance)	C (poor performance)
or	C preferred to C'	C' preferred to C

In this third case, the two communities have identical ensemble compositions and in each community, preexisting institutions were introduced sequentially. The difference is the *order* of introduction. [6]

In each of these three cases, our dependent variable is the institutional choice (or performance) in Period 3, and we argue that it can be best understood by considering how the order of adoption of earlier institutions affected the culture, which in turn affected the community's reaction to the third institution. If we analyze single institutions in isolation, we miss the effect of a full strategic environment. People respond to incentives not on an institution-by-institution basis, but with an eye on the broader context. Therefore, they develop patterns of behavior that cope with—or, rather, optimize their return over—a range of strategic situations, taking into account the cognitive costs of those behaviors. Thus, behavior in any one context may appear suboptimal, or cultural, but is in fact rational in light of the full ensemble of contexts that people confront.[7] Recognizable patterns of behavior that differ across societies may therefore be partly explained by a close examination of the full ensemble of institutions that influence behavior in those societies. The set, or ensemble, of institutions affects the performance of a new institution by priming the culture.

In explicitly considering how culture shapes behavior and creates institutional interactions and externalities, our theory goes one level deeper than existing theories about institutional complementarities that seek interactions among institutional effects. Evidence that the value of central bank independence interacts with size of the unionized share of labor

[6] See Shefter and literacy work from Darden.

[7] We are not saying that these actions are nested, that one action has implications in many games (Tsebelis). We are saying that a behavioral response that takes into account the cost of additional cognitive structures and behavioral rules may result in the consistent, slowly changing, sometimes suboptimal behavior that is described as cultural.

demonstrates that institutions interact, but it does not show how those interactions are mediated by culture—by behavioral patterns, beliefs structures, and levels of social capital (Franzese 2001).

Our simple cases imply that early institutional choices can influence the long term economic success of a society. Greif (1994) makes this point in his formal analysis of the 11th century Maghribi and the 12th century Genovese. Greif shows how economic outcomes and institutional performance depend on characteristics of the societies: the trust-based, segregated economic relations of the Maghribi worked well as long as the trading circle was small, but the individualistic Genovese had institutions in place to enforce contracts, giving them the advantage in long-distance trading. In our framework, the societies choose different economic and political institutions as a function of previous decisions. So like Greif, we can explain why an institution might perform differently in two societies. In addition, we provide a framework to explain the emergence of the cultural consistencies that drive these differences.

Outlining a Formal Model

We proceed from an assumption that institutions define a set of actors and possible actions. They structure information and incentives, and they delimit or expand the set of achievable outcomes. Therefore, it is natural to model them as game forms. The characterization of institutions as game forms has consequences. The central concept in game theory is equilibrium. Even models that contain agents who learn are assumed to attain equilibria. The presumption of equilibrium is a strong one. Equilibrium considers purposeful actions by individuals but not by groups or coalitions. Much of politics occurs at the level of groups. Groups coalesce around regional, party, and ethnic identities. A more appropriate solution concept might then be the core, but as core rarely exists, the system may produce complexity.

An institution describes the set of possible actions A for each of N agents who are identified by the index i which ranges from 1 to N. The payoff to agent i, $\pi_i(a)$ depends upon the vector of actions a. As many institutions create repeated interactions, we can

think of strategies S as sequences of actions that depend in some way on past actions. The standard approach to evaluating an institution as we have mentioned considers the equilibria it generates. Given an institution I, we can define the set $NE(I)$ as the Nash equilibrium outcome of that institution.[8]

The advantage of assuming that equilibria arise from individual agents responding to their institutionally created incentives is that it allows us to compare institutions by the equilibria they generate. Good institutions generate good equilibria. Bad institutions generate bad equilibria. But, the institutions as equilibria approach leaves insufficient space for the complexity that we see in the real world. Nevertheless, we choose that approach here, though not as strongly as we might. We will allow the equilibrium implemented by an institution to change over time.

If each of two institutions generates unique equilibria, then we can say that the first institution is better than the second if the payoffs to every agent are better under the first institution than under the second (Pareto Dominance), if the average payoff are better (utilitarianism), or if the lowest payoff are better (Rawls' minmax criterion). When institutions generate multiple equilibria these comparisons become problematic. We could average over the equilibria somehow. We might do this based upon on the sizes of the basins of attraction for the various equilibria. Let us show how that is done as it allows us to introduce culture. An institution can be thought as operating in a cultural context, C. We can think of the players in this institutional game as beginning from some point and as adapting through time. This adaptation creates a dynamic in the space of possible strategies which can be usefully modeled as a dynamic system. A dynamic system has three parts (i) a representation of strategies (ii) an initial strategy (or possibly a distribution over them) and (iii) a learning rule – a rule for creating new strategies. A *stable attractor* is a equilibrium strategy to which the learning rule converges and remains at once it is attained.

With this framework, we can see how theorists and empiricists come to differ in their

[8]We are ignoring for the moment whether Nash is the appropriate solution concept or whether some refinement should be applied, and again, we are ruling out coalitional deviations as well.

appraisal of institutions. Theorist put a prior over the set of possible cultural contexts or assume that the cultural context does not prevent the best equilibrium from being chosen. Their evaluation of the institution then either equals the institution's average performance or its best possible performance. Empiricists care less about the average performance of an institution than about how it performs in a given cultural context. They would take C as given and compare the institutions given that C. What we propose lies between and complements those two approaches. We proposing that we should explore how institutional choices change C. That may not be deterministic. Therefore, we cannot average over all C nor can we take C as fixed; we have to think of C as something that evolves in response to changes in institutions.

In an appendix, we provide an outline of a more general theoretical model that allows us to show how path dependence arises. Here, in the main body of the paper, we choose to make many of the same points by considering a specific example.

An Example: Reciprocal Exchange

To clarify our theoretical argument, we present the example of reciprocal exchange. Kranton (1996) shows that both free trade and reciprocal exchange can be self sustaining. Both institutions have equilibria. Which institution performs better depends upon the heterogeneity of the goods being traded or sold. The more heterogeneity in goods and preferences, the better the market performs relative to reciprocal exchange. We could assume that the better institution is always selected. If so, we could solve for that level of heterogeneity for which the two institutions perform equally well, and if a society has a level of heterogeneity above that, then they should choose a market. If they have a level below that, they should choose to have reciprocal exchange.

Let's now consider an expanded version of Kranton's model in which the agents have existing social networks as well as various skills at trading and bartering. Depending upon the nature of these networks and the skill distribution, the market outcomes and the reciprocal exchange outcomes may differ from that assumed in the simple stark model. Variation in

bartering skill could create unequal distributions in the reciprocal exchange setting. Relatedly, well connected social networks would benefit reciprocal exchange as trades would be easier to locate. So, the threshold between where markets outperform barter depends on culture, as does the choice over institutions. And as those institutional choices will further shape and define the culture, future institutional choices will also be affected.

In this example, we can also see how the order in which institutions were put in place could have effected the culture in ways that shift the threshold. Suppose that a society first implemented a democratic form of government and then later on an informal institution of dowries emerged. It might well be that marriages would not be political in nature. They could be freely chosen. Alternatively, had the dowries emerged first, marriages might have been used for strategically, to create networks.[9] If we assume that blood relations have higher levels of trust with one another, then intermarriage can increase trust across groups. Restricted marriage between groups can create a social hierarchy. Thus, even with a democracy in place, the social hierarchy created by the politicization of marriage might remain. Our two societies, though they have the same institutions in place, one formal and one informal, would have very different social structures. And, it follows that the heterogeneity threshold above which markets outperform barter would differ in the two societies. We also see evidence of the third phenomena. What would be a good institutional choice depends upon the existing institutions and the cultures they help to create. One society might choose to barter. Another might choose to set up a market. Those choices would be rational. They would also be culturally contingent.

3 A Model of Cultural and Institutional Path Dependence

We now construct a a specific model of cultural and institutional path dependence. This model builds from the game(s) theory model of Bednar and Page (2006). In that model, agents play an ensemble of games. Agents evolve strategies using modified finite state au-

[9] Padgett

tomata that allow agents to play multiple games simultaneously. These automata strategies share states and cognitive subroutines across games.

In what follows,we consider the same set of six games as in our earlier paper. Each game has two actions, one that is more selfish (S) and one that is more cooperative (C). In the first four games, cooperation lowers an agent's own payoff and raises the payoff of the other agent. Being selfish has the opposite effects on payoffs. In the other two games, these conditions hold only when both agents play C. Each game has two pure strategy equilibria in which one player cooperates and one is selfish. This collection of games has many nice properties as discussed in Bednar and Page (2004).

A Table of Games appears at the end of the Paper

The particulars of the automata are not important for this analysis but they are as follows. We assume 100 agents, divided into fifty column agents and fifty row agents. The row and column players are each numbered from 1 to 50. Each agent plays five other agents in twenty five rounds in each game. For example, column agent 24 plays row agents 22,23,24,25, and 26. These agents evolve strategies using hill climbing algorithms as well as by copying agents who perform better. The algorithms are sufficiently sophisticated to locate efficient outcomes for each game when played individually. In the results that we show, each agent adapted its strategy 2000 times.

Our use of automata to encode strategies should be noncontroversial. Automata can be analyzed mathematically, and they have proven capable of generating outcomes not much different from what people produce in real experiments (Rubinstein 1986, Kalai and Stanford 1988, Miller 1996). Crucial for our analysis is that the current configuration of the agents' automata can be seen as C_t, the cultural context. It is the starting point in the dynamical system. The introduction of another institution, another game, creates a dynamic in that space. The culture can then influence the outcome produced by the institution, and the institution in turn influences the culture. At the moment, this might all seem a bit abstract. Fortunately, the use of the automaton allows us to take snapshots of the cognitive structures

inside the agents' heads. We can examine the automata directly and see how institutional choices shape them.

Our agents begin with randomly created automata. These automata encode the agents' strategies. We can represent these automata in two dimensional space. In each of the two states, the agent takes an action (either C or S). In each state, there are also four possible outcomes of the play of the game.

CC	CS
SC	SS

Under each of the four possible pairs of plays (CC, CS, SC, or SS), the agent must decide to either stay or go. Note of course, that whatever action the agent takes in that state limits the possible outcomes to only two of these four outcomes. The other transitions remain latent. These latent transmission can be the residue of previous game forms. These latent transitions become important if the agent changes its action in that state. Given this setup, we can write each state as follows:

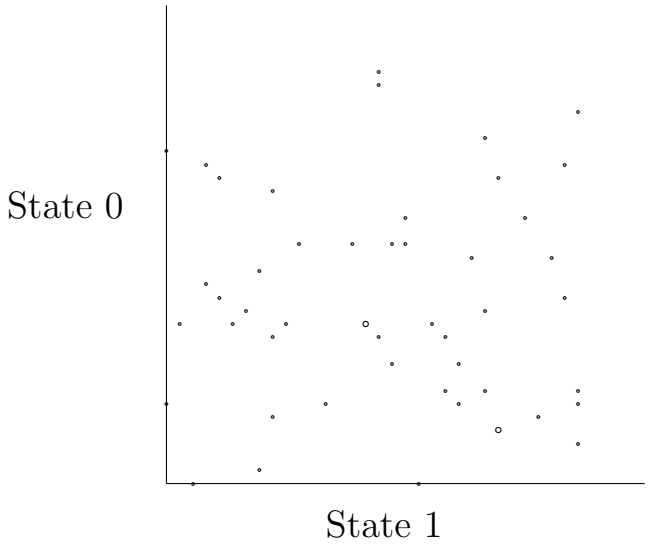
A State: State i = (Action, transition if CC, transition if CS, transition if SC, transition if SS)

An example: State 1 = (C, remain in 1 , go to state 0, remain in 1, remain in 1)

If we convert, C's to 0's and S's to 1's, then we can write each state as a string of five binary digits. The state above would be written as (0,1,0,1,1). We can then use the inverse of the standard binary encoding mapping to translate those digits into the integers ranging from 0 to 31 with 00000 encoded as 0 and 11111 as 31.[10] We can then graph the initial automata for the fifty row agents.

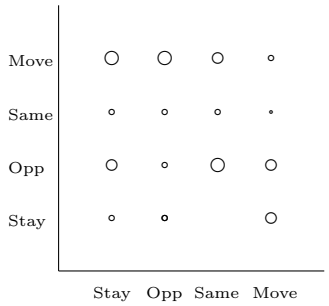
[10]The method is simple: each element in the string is encoded according to its position and its value, so 11111 is $1 * 2^0 + 1 * 2^1 + 1 * 2^2 + 1 * 2^3 + 1 * 2^4 = 31$.

Initial Distribution of Automata



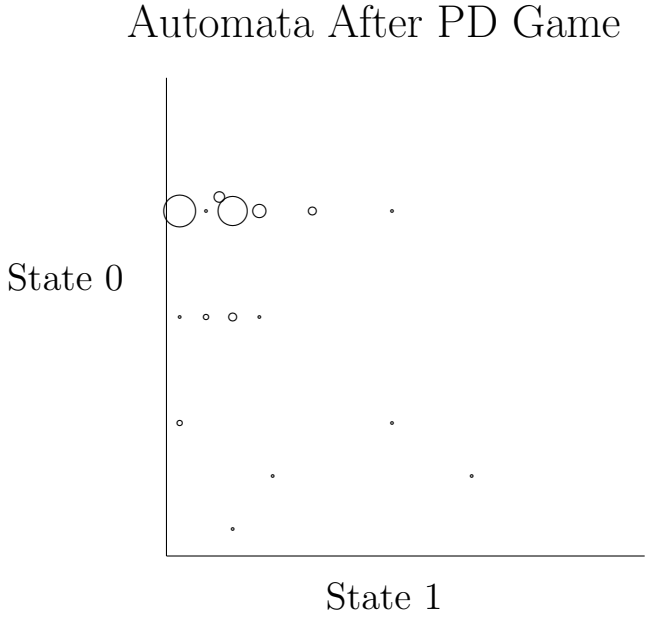
This picture shows that initially, the automata are spread evenly throughout the space of alternatives. There is no structure to the automata. However, this map does not tell us much about the behavior of the automata. We can crudely classify the automata in each state as to whether *stay* in that state regardless of what the other agent does. Strategies that are always selfish or cooperative fall into this category. Other strategies tell agents to change states only if the other agent takes the *opposite* action. Thus, those agents whose states get classified as (opposite, opposite) are most likely playing tit for tat. And, those strategies classified as (stay, opposite) or (opposite, stay) are most likely grip trigger. Other strategies always *move* to the other state. This would be true of strategies that alternate. Finally, some strategies move if the other agent takes the same action as the agent. We can replot the graph above using this classification of states. As before, the size of the circles denotes the propensity of the strategy. Note again the even spread.

Initial Distribution of Automata: Classified by Strategy



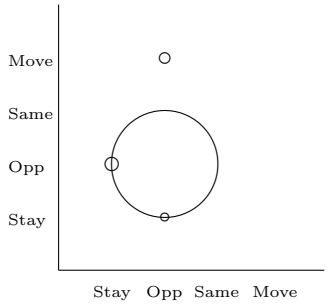
Cultural Phat Dependence

If we have these agents learn how to play a game, they create structure in the space of automata and we see evidence of cultural phat dependence. The next figure show the distribution of the automata of fifty agents after the agents have evolved strategies in the PD game.



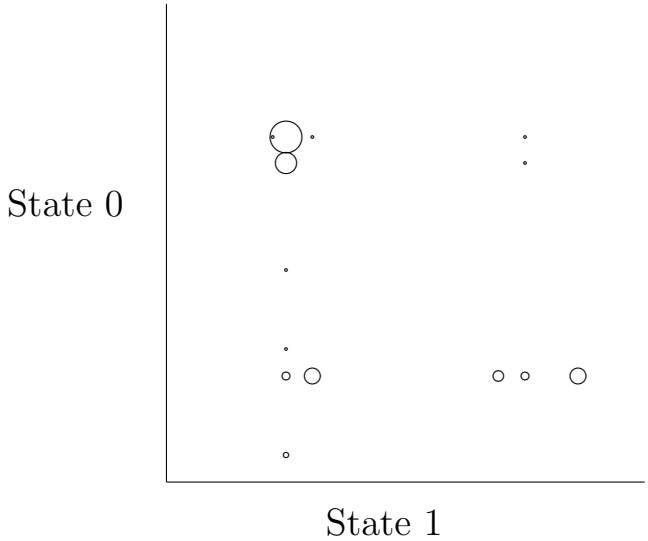
Automata After PD Game

Classified by Strategy

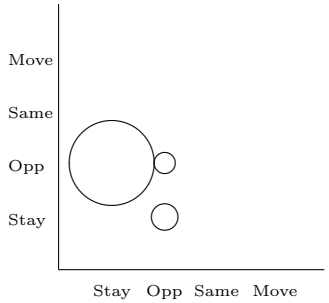


The strategies embeded in these automata are such that most of the agents cooperate in every period. The huge circle represents tit for tat – an agent switches states only if the other agent takes the opposite action. The smaller circles represent grim trigger – an agent stays fixed in one of the states, the selfish state. The next figure shows the automa that evolved for agents playing only the Knife Edge game. The strategies embedded in these automata resulted in a large majority of the outcome in (S,C) and (C,S) and the remaining in (S,S).

Automata After Knife Edge Game



Automata After KE Game
Classified by Strategy

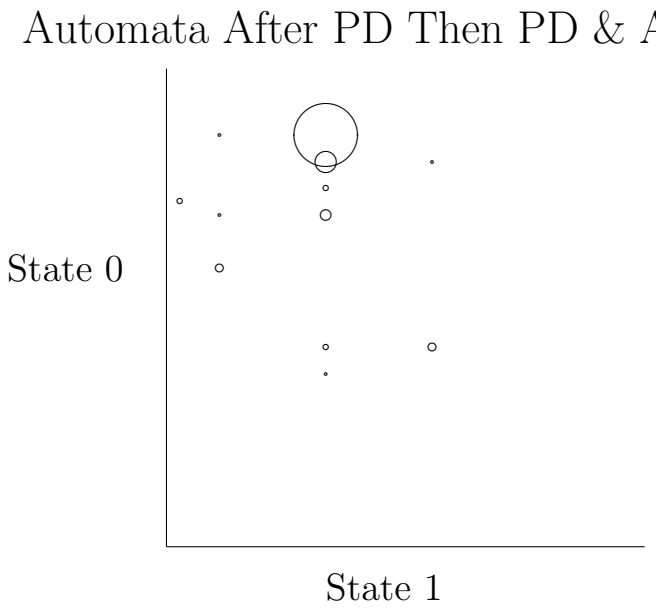


These again are only the automata for the row agents. In this game, we happen to see a lot more grim trigger. Also, though we cannot see this in the graph, some of the agents are alternating. Notice that in both in this game and in the PD game, the automata do not converge globally. This occurs because the agents only play games with neighboring agents. The main point that we're trying to make with the graphs is that the distribution of strategies differs after the two games. The cultural context C depends upon which game was played. Thus, we see evidence of *cultural phat dependence*. We will show even more evidence for this shortly. Before showing that evidence, we must describe the outcomes from the single game ensembles. The table below shows the distribution of outcomes and strategies across the six games. These can be thought of as the outcomes that would occur with an assumption that there is no cultural context. The agents start from blank slates when evolving strategies.

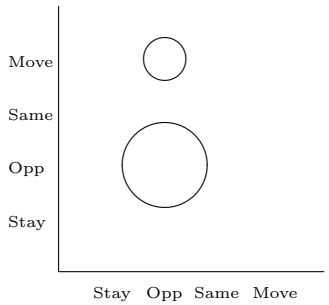
Individual Game Outcomes

Game	Strategy Distribution
PD	(C,C)
SI	(S,S)
KE	10% (C,C), 10% (S,S) 80% (S,C) (C,S)
ALT	85% (S,C) (C,S)
BL	(S,C)
TR	(C,S)t

The outcome data help explain the previous graphs. The outcome in PD, (C,C), differs from the outcome in KE, most of the time (S,C) or (C,S). Therefore, we should not be surprised that the automata look different. They have to. The next two graphs show the distribution of automata after the game ALT is added to each of these PD and to KE. These graphs show how the initial game effects the distribution over automata after the second game has been has been added. This is further support for our first hypothesis, that the set of institutions effects the cultural context. The agents face different ensembles of games and the strategies they evolve differ. The first figure shows what happens when ALT is added to PD. The strategies embedded in these automata result in alternation in ALT. All outcomes are either (S,C) or (C,S). In the PD game the agents play (C,C).

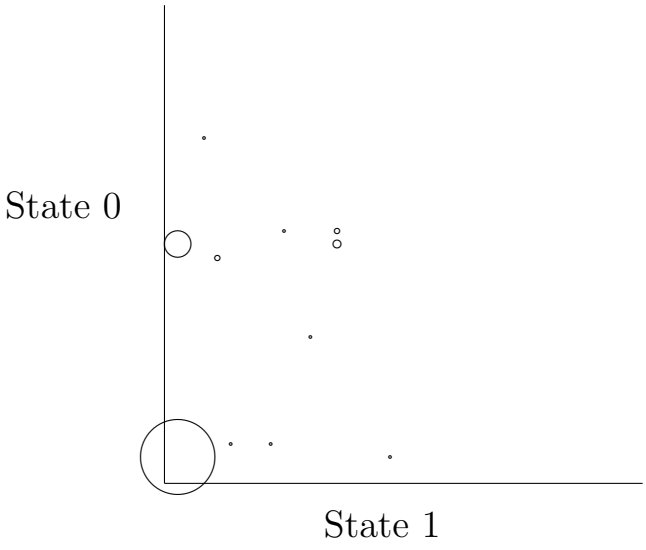


Automata After PD then PD & ALT
Classified by Strategy

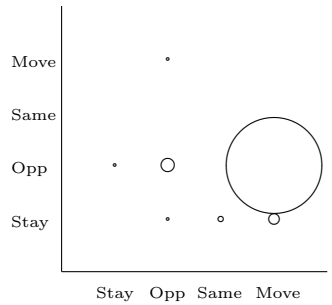


The large circle shows agents who play tit for tat in the PD game and who alternate between the (C,S) and (S,C) in the alternation game. The smaller circle also represents agents who alternate in the ALT game and who cooperate in the PD, but these agents switch to (C,C) after playing (S,S). The next graph shows the automata after ALT is added to KE. The strategies represented by these automata result in the agents alternating in both games.

Automata After KE Then KE & ALT



Automata After KE Then KE & ALT
Classified by Strategy

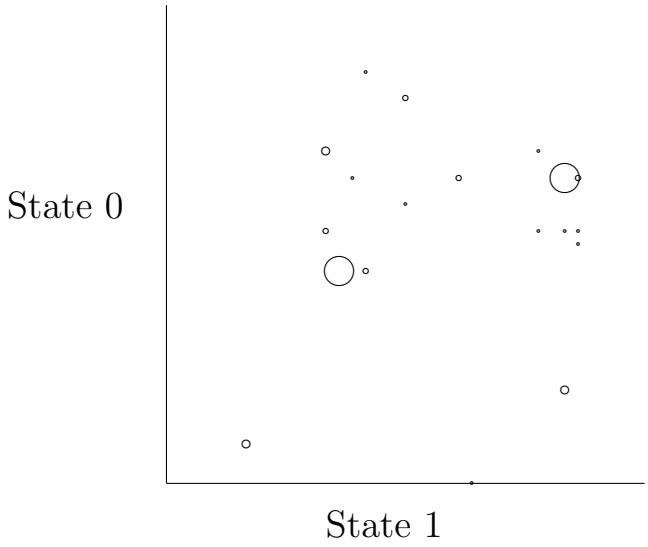


As the second graph makes clear by the number of agents who move regardless of the outcome, most of the agents alternate between the two actions. Here again, we see evidence of cultural phat dependence. The set of institutions influences the culture.

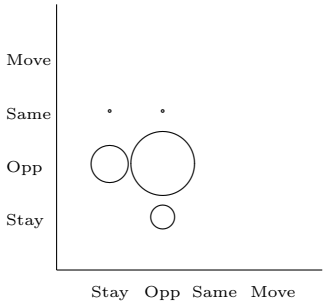
Cultural Path Dependence

We now test whether our model produces *cultural path dependence* The next two graphs demonstrate that the cultural context can depend upon the order in which we add the institutions. The first graph shows the automata when the PD is played first and then KE is added. The second graph shows the automata when KE is played first and PD is added.

Automata After PD Then PD & KE

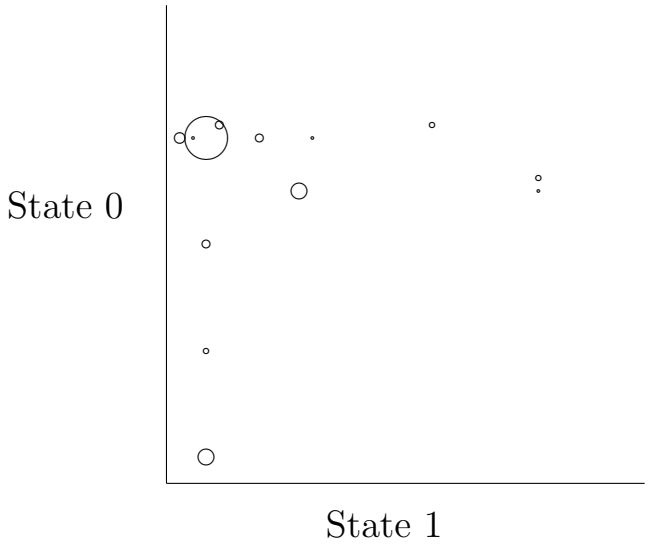


Automata After PD Then PD & KE
Classified by Strategy

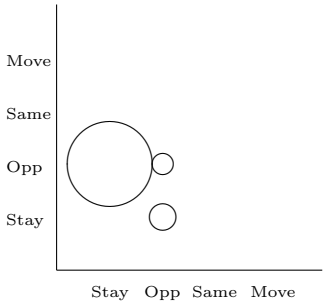


The second graph shows lots of agents playing tit for tat as well as many agents playing grim trigger. This is consistent with what we see when the agents play only the PD game. We now switch the order in which the two games are played.

Automata After KE Then KE & PD



Automata After KE Then KE & PD
Classified by Strategy



Here, we see that many more of the agents play grim trigger. They move if the other agent takes a selfish action, but they stay in the selfish state. For this particular pair of games, the outcomes do not differ. The agents play (C,C) in both games regardless of the order. However, the two cases differ in how they support this cooperation.

Institutional Phat Dependence

To test whether the model produces *institutional phat dependence* we perform the following experiment. For each of the six games, we evolve automata strategies for the agents and then

add each of the six games as a second institution to see what outcomes emerge. The next two tables show the outcomes for those same six games when they are the second institution. In each case, we have previously allowed the agents to evolve strategies in another game. The first table shows the outcomes when that game was the Prisoner's Dillema Game. It can be thought of as creating a cooperative culture since the agents learn to cooperate in the PD game. So, here again, we see evidence of cultural phat dependence, but that is not our focus.

Individual Game Outcomes
In a Cooperative Culture

Game	**Strategy Distribution**
PD	(C,C)
SI	(S,S)
KE	(C,C)
ALT	83% (S,C) (C,S)
BL	(S,C)*
TR	(C,S)*

The (*) denotes that cooperation was destroyed in the PD game. The next table shows what happens when the first game is BL. We call this a male dominated culture because the row players (males) get their preferred outcome in the game. Playing this game first prevents cooperation in the other games when they are added.

Individual Game Outcomes
In a Male Dominated Culture

Game	**Strategy Distribution**
PD	100%(S,S)
SI	(S,S)
KE	(S,S)
ALT	(S,S)
BL	(S,C)
TR	(C,S)

Comparing across these tables, we see that a rational choice among institutions could be institutional phat dependent. If the first institution creates a BL game, then that makes institutions that create KE, ALT, or PD games poor choices. Alternatively, if the first institutions creates a PD game, then an institution that creates any of those three games would be a good choice. Thus, the set of institutions could determine which institutional choices perform well.

Institutional Path Dependence

We next show how the order that institutions are chosen can effect the performance of, and, therefore, the choice over other institutions. In the first table we show the outcomes for the six games when we first create a selfish culture with the SI Game and then add the PD game. In the second table, we show outcomes for the six games when we introduce the games in the opposite order.

Individual Game Outcomes

SI then PD

Game	**Strategy Distribution**
PD	(C,C)
SI	(S,S)
KE	(C,C)
ALT	100% (S,C) (C,S)
BL	95%(C,C)
TR	100%(C,C)

Individual Game Outcomes

PD then SI

Game	Strategy Distribution
PD	(C,C)
SI	(S,S)
KE	(C,C)
ALT	100% (S,C) (C,S)
BL	(S,C)* or (C,C)
TR	(C,S)* or (C,C)

As before (*) denotes that cooperation in lost in the PD game. The two tables differ in their final two rows. When PD is introduced first, then approximately half of the time, the agents cooperate in the BL and TR games. This happens because the cultural contexts differ. When PD is played first and then SI, the agents are more likely to support cooperation in PD with TFT. When SI is played first, cooperation in the PD game is more likely to be imposed through grim trigger. The mutation to (S,C) or (C,S) from Grim Trigger is easier than from TFT. So, the cultures clearly differ. The cooperative culture in the first case is more robust. And these cultures create externalities between the institutions. In the first case, the addition of a TR game or a BL game results in a cooperative outcome in that game and does not destroy cooperation in the PD game. However, in the second case, introducing the BL or TR game does destroy cooperation. Thus, it could well be that the first society might add an institution that creates a BL or TR game, whereas the second one would not owing to its disruption of cooperation.

Institutional Constraints on Paths

Finally, we show how institutional choices, and the cultural contexts they produce, limits the possible set of paths. Consider a world with three distinct communities. Within each community, agents play only one game, but they can choose which game to play. Next, assume that over time, population growth, changes in technology, or shocks to the environment result in new types of interactions, such as the need to trade an additional good, to create a primitive legal system, or to manage a common resource. Suppose as well that different institutional approaches can structure these interactions, defining a game form. We define the addition of a new institution—a new game—as the start of an period.

We first show through an example how institutional choices can depend upon past choices. To do this, we consider D temporal domains added sequentially, one per period. A domain can be thought of as either a problem or an opportunity. Gathering food would be a domain, as would allocating resources or fighting an enemy. Domains are contexts in which some institutional solution, formal or informal, arises and crates a game form. For each domain, we assume that one of two institutions may be chosen as a way to organize the new strategic interaction, so that in each period a new institution is added. This creates 2^D possible paths that could emerge.

We assume that these two institutions compete. The institution that generates higher aggregate utility is chosen. Of course, this wouldn't always be the case, but we'll assume that this happens, otherwise, we're stuck saying that institutional choices differ because of randomness. Therefore, we assume that somehow, a society can make the better choice in each case. In this toy example, we suppose that institutional choices appear in the following ordering:

Domain-Eras and Choices

period 1	**period 2**	**period 3**	**period 4**	**period 5**
PD or TR	PD or SI	TR or AL	TR or AL	Al or SI

Agents make optimal choices over institutions in each period but that they do not take into account future choices over institutions. If we were assuming fully rational behavior, we would have to make explicit assumptions about distributions of game pairs to substantiate this assumption, but even that may strain credulity. The founding fathers did not contemplate social security, medicare, or the income tax.

Given this setup, there would appear to be 32 possible institutional paths, but some of these would never occur if agents choose institutions that maximize payoffs at the start of each period, if they were rational. Suppose that a community chose a PD in period 1. In period 2, they might choose either PD or SI and still play both games optimally. If another community chose TR in period 1, it must choose SI in period 2. Using similar logic, it

can be shown that if agents are restricted to using two-state automata and at the start of each period choose the game that gives the higher total payoff, then that there are only five possible institutional paths, as follows:

All Possible Paths given Cultural Constraints

	period 1	**period 2**	**period 3**	**period 4**	**period 5**
Community 1	PD	PD	AL	AL	AL or SI
Community 2	PD	SI	AL	AL	AL or SI
Community 3	TR	SI	TR	TR	SI

The "meta game" of choosing which games to play has multiple equilibria. We also see that feedback develops between rational institutional choice and culture. Community 3, by making a choice to structure its first interactions using the TR game—a hierarchical ordering of payoffs that favors one segment of the society over another—constrains its future choices; while Communities 1 & 2 remain flexible in the final period, Community 3 prefers SI because it has already developed a behavioral routine that makes this game easier for it to play optimally.

This phenomenon is not restricted to this particular initial ensemble. To show this, we consider two ensembles. The first consits of a PD game followed by an ALT game and then another PD game, We call this the PAP initial ensemble. We also consider a ensemble that begins with the SI game and then sequentially adds two TR games. We call this the STT ensemble. For each of these ensembles we ran 500 histories in which we added three new games to the ensembles. These new games were each selected from a pair of randomly selected games. Whichever game, when added to the ensemble, generated the higher average payoff was chosen. To determine the added value, we allowed the agents to evolve strategies in each of the enlarged ensembles and then chose the game whose addition led to the higher payoff for the entire ensemble of games. We then added a second game and a third game. At the end of each run of the model, we had a ensemble with six games.

We first present some aggregate data on the differences in the ensembles. We can count the number of times that each game was contained somewhere in the five hundred ensembles

extensions.

Games Chosen in Extended Ensembles

Ensemble	PD	ALT	SI	KE	TR	BL
PAP	305	182	366	73	244	98
STT	115	154	231	77	384	0

Two features jump out immediately. First, no BL games are chose in the STT ensemble Second, almost three times as many PD games are chosen in the PAP initial ensemble than under the STT ensemble. This is overwhelming evidence of path dependence.

The data on the distribution across ensembles is even more suggestive of the cognitive weight of the initial ensemble. There are two hundred and sixteen possible three game ensemble continuations. Yet, only a small percentage of those are realized given the two intitial three game ensembles as shown in the table below. The table also gives the number of three game ensembles realized if there is no initial ensemble.

Number of Three Game Ensembles Chosen

Ensemble	Number
PAP	36
STT	12
None	33

Notice that the number of three game ensembles is larger given the PAP initial ensemble than if there were no initial ensemble. This implies that the initial ensemble need not decrease the set of possible paths. It could increase them. In this case, that increase can be explained by the strong cooperative culture that emerges. The cooperative culture is able to respond to many possible games forms effectively. By way of contrast, the initial ensemble STT severely restricts what might happen. This is because the society is strongly male dominated.

Interestingly, the paths created by PAT and STT differ substantially. The next table shows the intersections between the three game ensembles chosen given the two initial ensembles and with no initial ensemble.

Common Three Game Ensembles Chosen

Ensemble	Number
PAP & STT	2
PAP & None	7
STT & None	8

Only two ensemble extensions arise under PAP and STT: (SI,SI,TR) and (SI,PD,PD). Both of these ensembles occur approximately forty times given the STT initial ensemble, but they only appear one time and twelve times given the PAP initial ensemble. Thus it is fair to say, that they process of adding game forms is extremely dependent on the initial ensemble.[11]

4 Conclusions & Extensions

This paper demonstrates proof in concept. We have shown that institutions create a cultural context within which institutions operate. Thus, institutions shape culture and culture influences institutional performance. We needn't throw up our hands in disgust, writing this off as an irresolvable circularity in reasoning: instead, culture—which previously was most often abandoned in logic analysis as predetermined or extra-rational—is a product of the primitive strategic environment. Rational, purposeful agents will make the most of these interactions, given their cognitive abilities. Their strategic adaptation evolves into culture, a behavioral shorthand. Culture, whether seen as belief systems, behavioral patterns, cognitive structures, trust relations, social networks, or representations of reality, can then be thought of as the state of a dynamical system. Institutions shape the incentive environment within that

[11]To check that this was not an artifact of noise, a second run of the model using the PAP initial ensemble create 37 ensemble extensions. These 37 ensemble extensions contained all 36 of the extensions found in the intiial run.

system. The result of the incentives—the performance of an institution—depends upon the state of the system and how the agents responds. How they respond is culturally influenced; the community's mode of behaving, including each one's expectations of the other, will affect how individuals within it react to a new institution.

Culture need not, though it does here, prevent agents from maximizing utility in each game. The way we have modeled culture assumes agents are purposeful, but also cognitively constrained. It has become standard practice to assume that agents optimize relative to their information; in this model, our agents have a finite capacity to handle information. At some point, those constraints bite, and the agents fail to optimize within a particular game, although they do continue to optimize over the whole ensemble of institutions.[12]

The specific model that we have implemented with that framework provides support for our three hypotheses: that the set of institutions effect culture, that the order that institutions are implemented can matter, and that the choice over institutions may be depend upon the path, on the set of institutions already chosen and their order.

This path dependence is not caused by increasing returns per se (Page 2006). It is caused by what we might characterize as culturally mediated institutional externalities. Culture influences institutional performance and institutions influence cultures; therefore, existing institutions influence the performance of a new institution. Further, the order that institutions are implemented matters, not just the set of existing institutions. This means that there is true *path dependence*, not just *phat dependence*.

Most important is not the specific model that we have introduced but the more general framework. Our framework allows us the implementation of *any logically consistent model of culture*, whether it be based on networks, belief systems, trust, or representations of reality. We chose to model it based upon the cognitive subroutines of agents as it seemed the least technically demanding. Ideally, a model would include several of the features of real world culture that experts believe important.[13] For instance, we could allow the agents to change

[12]For those who do not want to abandon optimality that assumption could be changed.

[13]An especially valuable extension would be to move beyond these six games, toward something more realistic, such as property rights, democracy, and markets. Much easier said than done! For that reason, we

their networks depending upon the success of their interactions. The agents could choose not to play with some agents and to play with others. Some institutions will result in richer network structures than others. This evolved structure of interaction will affect how future institutions perform and how they are chosen.

Our focus on the micro-level features of a society—how people are connected, how they categorize the world, what they believe, how the interpret signs, and how they behave—contrasts with current empirical approaches of categorizing cultures. Survey reasearch methods emphasize salient features that distinguish cultures. We should not confuse salience with relevance. Institutional performance may be more affected by subtle differences in connections, behavior, belief systems and the like than by those differences that are most pronounced to an observer.

have chosen first to show how the framework provides traction in a much simpler set of environments.

Appendix: An Abstract Model of Institutional Path Dependence

To gain some understanding of how culture can create institutional path dependence, in this appendix, we construct an abstract model and state some claims, which we do not prove, but which easily can be proved. We assume discrete periods indexed by t. In each period, there exists a cultural context C_t and a choice from among two institutions, which we call I_t^0 and I_t^1. The 0 and 1 are accounting devices. The institution given the label 0 or 1 in one period need not be related in any way to similarly labeled institutions in later periods. We assume that the society makes a *rationally based* but *myopic* choice over these two institutions. By myopic we mean that they choose the institution that generates the greater aggregate utility without taking into account the effect of that choice on future institutional choices and on the culture. Those effects are tranmitted through culture. Because institutions can influence the culture C_{t+1} need not be the same as C_t. For the purposed of this paper, we assume that all societies begin in the same initial cultural context C_0.

To describe what we mean by rational, we need to make this model more complete. Define the outcome given an institution I and a cultural context C as $I(C)$ For the moment, we're allowing outcomes to be points, cycles, or even paths. Given I, we let $E(I)$ equal the set of all outcomes such that there exists a cultural context C that produces that outcome if the institution is chosen in that cultural context. Formally, $y \in E(I)$ if and only if $y = I(C)$ for some C.

The process we describe need not be deterministic. And in our specific model it will not be. So we think of the cultural context C_t as generating a probability distribution over the set of possible outcomes, $E(I)$. A choice is *rationally based* if either it maximizes the expected value over $E(I)$ given C or if it maximal in expected value based upon samples, say such as when a federal systems uses states as laboratories for institutional choices (Bednar). These samples can be thought of as trial runs of the institutions.

An institution I **culturally dominates** *another institution $\hat{I}$ given culture C, if any outcome*

in $I(C)$ is better than the best outcome in $\hat{I}(C)$.

We can then state the following claim.

Claim 1 *A rationally based decision rule never chooses a culturally dominated institution.*

An *institutional path* is an institutional choice in each period. We denote an institutional path as a sequence of 0's and 1's. The path of first choosing institution 0 in period 1, then choosing institution 1 in period 2, and choosing institution 0 in period three can be written as follows: $\{0, 1, 0\}$.

This construction is not sufficient to get at the possibility of path dependence. For that, we need to also alternate the order in which the choices between institutions arise. To do this, we can replace the word period with the word domain. If we assume T domains, we can imagine them arising in any order. Our second hypothesis is that the ordering of the institutions affects culture. With this framework, we can state that hypothesis formally.

Institutionally Path Dependent Culture (IPDC) *exists if given some set of $\hat{T}$ domains, there exists two orderings such that the resulting culture $C_{\hat{T}}$ differs under the two orderings.*

We can also state the third hypothesis formally.

Institutional Path Dependence (IPD) *exists if given some set of $\hat{T}$ domains, there exists two orderings of the same domains such that the choice over institutions differs in the two orderings.*

Note that the second claim is stronger than the first.

Claim 2 *IPDC does not imply IPD, but IPD does imply IPDC.*

The path notation allows us to consider the possibility of *path dependence*. If the agents had perfect foresight, and if they discounted the future sufficiently little, then they would never choose anything but an optimal path. We therefore assume that they lack this foresight,

that they have no idea what domains will arrive next. We implement this assumption by restricting attention to *path optimal* institutions. An institution is path optimal if it is the optimal institution given the existing set of choices. Hereafter, we refer to the set of existing institutional choices as the *ensemble* of institutions. We further assume that past choices cannot be undone. We can then define a ensemble as *path attainable* if there exists a path of path optimal institutions. In other words, a ensemble is path attainable if there exists an ordering of the domains such that each institution was optimal in its domain given the previous set of institutions chosen. It is now possible to state some general claims. The proofs of these claims contained in an appendix.[14]

The first claim states that the institutional ensembles attained need not be optimal. This means that the society might benefit by switching some earlier choices after the fact.

Claim 3 *Path attainable ensembles need not be locally optimal*

The next claim states that the optimal ensemble may not be reachable. At some stage, it may require choosing a suboptimal institution.

Claim 4 *The globally optimal ensemble may not be path attainable*

A corollary to this claim is that there may exist many locally optimal ensembles that can never be attained. These are often called Garden of Eden equilibria (Epstein and Hammond).

Corollary 1 *There exist locally optimal ensembles which are not path attainable*

The next claim states that the cultural context C_t can depend upon the history of institutional choices.

Claim 5 *Institutionally Path Dependent Cultures can exist.*

The final claim states that the choice over institutions can depend upon previous institutional choices.

[14]The appendix is not included in this version of the paper.

Claim 6 *Institutionally Path Dependence can exist.*

The three parts of the dynamical systems can all contribute to path dependence. The initial strategy together with the learning rule determine which equilibrium will be attained. This is a basic result from dynamical systems: each stable point has a basin of attraction. The stable points partition the set of initial points into basins of attraction with some initial points possibly resulting in better equilibria than others. The encoding of strategies can similarly effect the dynamic (Medin and Atran 2004 Hong and Page 2004). Thus, if any of the three following conditions hold, institutional path dependence is possible:

- The representation of strategies depends upon past institutions and strategies
- The initial strategies applied to a new institution depend on past institutions and strategies
- The learning rule depends upon past institutions and strategies

These conditions reveal the relationship between institutional path dependence and cognitive structures. How people see the world, their initial conceptions of a good strategy, and how they learn determine what the effect of an institutional choice will be, whether it will induce a good equilibrium or a bad one.

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