Phase Diagrams in Historical Economics: Culture and Institutions*

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Abstract

In this paper we discuss the role of explicit formal dynamic models in our understanding of socio-economic history. Specifically, to illustrate the methodological issue, we center our analysis on studies of institutional and cultural change. Finally, we study in detail a dynamic model of institutions for property rights protection and culture of conflict as an example.

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1 Introduction

Historical economics is mostly an empirical field, centered on the application of statistical and econometric methods to the identification of causal relationships and the persistence of interesting phenomena over historical times. The field however also relies in part on formal modeling of the historical dynamics of interest, to help frame the empirical questions. This is especially the case in the study of the dynamics of institutions, starting with the pathbreaking influential work of Daron Acemoglu and James Robinson (Acemoglu and Robinson, 2001, 2006a).[1]

In this chapter, we focus, like Persson and Tabellini (2021, in this volume), on models of the interaction of institutions and culture. While providing a brief (and somewhat idiosyncratic) survey of this literature, we aim first of all at a methodological point; that is, illustrating the (metaphorical) power of explicit formal dynamic modeling, differential/difference equations and the like, for historical analysis. Deirdre McCloskey sets the methodological issue beautifully,

> The differential equation itself might be looked on as the model/metaphor. Alternatively, and I think better, the honor of the word "metaphor" might be reserved for the timeless physical or economic or historical idea behind the equation, such as [...] that people pursue profits in buying wheat or that the men of Athens were very fools in their imperial might. The actual numerical time paths from the solution of a differential equation is the narration in time, and the solution (which can also generate the numerical path) is the thematized narrative -transparent or muddy depending on how neat the solution is, when it exists. The analytic solutions correspond to simply predictable histories, that is, histories that can be reexpressed as equations. The differential equations embody what we think we know about societies as theory, such as a Marxist theory. [McCloskey (1991), p. 24]

McCloskey's discussion centers on the distinction between non-linear and linear (difference) equations. Non-linear (systems of) equations can generate chaotic dynamics, which in the historical narration corresponds to assigning "small causes" to "large events." But non linear (systems of) equations can generate other interesting phenomena, e.g., non-ergodic solutions, that is, dynamics which converge to different stationary states depending on the initial conditions. The corresponding historical narration in this case is not necessarily the identification of the "small" cause, that "if Cleopatra had a different nose; unattractive to Roman generals, the battle of Actium might not have happened;" but rather that different initial conditions (be that small or large) might have "large" effects. The initial distribution of a society's cultural traits, civic

[1] Several chapters of the Handbook survey in detail the different approaches developed to the theoretical study of the dynamics of institutions: Acemoglu et al. (2021, in this volume); Bowles et al. (2021, in this volume); Levine and Modica (2021, in this volume); Persson and Tabellini (2021, in this volume).

culture for instance, might have very persistent effects over its history, affecting its whole institutional dynamics, fostering or damaging its economic development. Non-linear dynamics can even generate historical reversal, whereby for instance poverty contains the seeds of economic success, as in Acemoglu et al. (2002) or Ashraf et al. (2010); see Bisin and Moro (2021, in this volume) for a discussion. Whatever the qualitative dynamics that is generated, it is still the case that, with McCloskey (1991), "life gets difficult for the [economist][2] and the historian when the differential equation does [...] when variables feed back into themselves, we have an exciting story to tell, but unless we know its metaphors already we have no way to tell it." More generally, phase diagrams are useful representations of interesting qualitative dynamics generated by non linear dynamical systems. The analysis of the qualitative aspects of the dynamics of a system in the long-run are (methodologically) a first step to the construction of quantitative structural models to be estimated with historical data. Most importantly, qualitative dynamics are complementary to the causal analysis of historical phenomena, e.g., in persistence studies in that they substantiate the assumptions underlying instrumental variables, natural historical experiments, regression discontinuity techniques; see Voth (2021, in this volume) and Bisin and Moro (2021, in this volume).

In this chapter we will constrain our analysis to the study of systems of differential/difference equations representing the historical, that is, long-term, dynamics of the distribution of cultural traits, norms, conventions, and of institutions. Indeed, the recent literature in historical economics has identified various aspects of culture and institutions as the principal factors explaining economic development; the importance of the interaction of culture and institutions has also been stressed in various contributions to this literature; see Section 3 for a discussion and some references. Models of institutional change often have change implemented by "large players" in a game determining policies and outcomes in society; see Acemoglu, Johnson, and Robinson (2006) and Acemoglu et al (2020, in this volume) for surveys. These models are typically referred to as *top-down*. A different class of models, where agents are "small" and institutions, norms, and cultural traits are formed as the result of some form of a selection processes, are typically referred to as *bottom-up*; see Bowles et al (2021, in this volume). For simplicity we will think of top-down change as institutional change and of bottom-up change as cultural change, but the dynamics we shall obtain are relatively fungible (some institutional change can be bottom-up, e.g., norms and conventions; some cultural change can be top-down, e.g., prescribed by religious authorities).

In the rest of the chapter we first construct abstract dynamic models of institutional and cultural change, mapping some prominent contribution to this literature into them. We then show how these models interact and illustrate graphically the qualitative properties of the dynamical paths representing the solution of systems of differential/difference equations by means of *phase*

[2]McCloskey says "engineer."

diagrams.

2 Institutional and cultural change

In the following sections we will briefly survey top-down and bottom-up models of the dynamics of institutions and culture. We will express them as dynamic differential/difference equations and discuss how can their dynamics be usefully represented qualitatively by means of *phase diagrams*.

2.1 (Top-down) models of institutional change

Top-down modeling has institutions as a representation of the relative power of different political groups. This is consistent with the traditional classic approach to political science: from the central role of city factions in Machiavelli's Istorie Fiorentine (1532), to the the concept of classes in marxist thought[3] and the concept of elites in sociology.[4] More distinctively, institutions are modelled as the mechanisms through which policy choices are delineated and implemented. Formal models along these lines have been pioneered by Acemoglu and Robinson (2001, 2006a) and taken up, along similar lines, e.g., by Acemoglu et al. (2010, 2012, 2015, 2018), Besley and Persson (2009, 2010, 2011), Bisin and Verdier (2017), Tabellini (2008b). In this class of models, institutional change takes different forms, but it is generally the way the political system imperfectly and indirectly internalizes the externalities which plague social choice problems.

A simple abstract structure should help clarify the core elements of this class of models. Consider a society constituted by two groups $i \in \{1, 2\}$, characterized by distinct preferences (cultural traits) and technologies. Each period t, a societal policy game is played between private individuals and a hierarchical public policy authority (the state) controlling socio-economic policies. Individuals in each group $i \in \{1, 2\}$ are characterized by an objective function $V^i = U^i(a^i, p, A)$ that depends on private actions a^i, a policy vector p, and some measure of socio-economic outcomes A, capturing the aggregate (society-wide) outcomes of the interactions between private agents and public authorities. These aggregate outcomes naturally depend on the vector $a = [a^1, a^2]$ of actions by individuals of the two groups and on the public policy vector p: $A = A(a, p)$.

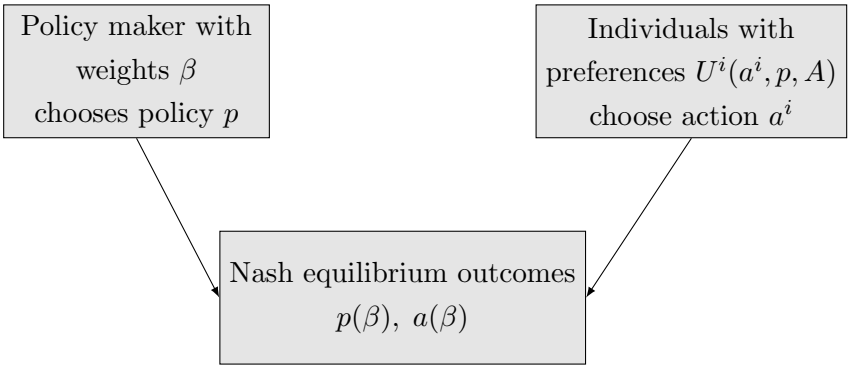
Policies are the outcome of a (collective) decision problem, in accordance with the distribution of political power between the two groups encoded and represented by institutions. Institutions can then be abstractly defined and represented by the (Pareto) weights $\beta^1 = \beta$ and $\beta^2 = 1 - \beta$ of the two groups 1 and 2 in the decision making problem regarding to the policy vector p.[5] Specifically, we could have the objective of the public policy authority identified by a Social

[3] See e.g., Balibar (1970) and Poulantzas (1973).

[4] See e.g., Pareto (1901, 1920) and Aron (1950a,b).

[5] See Gradstein (2007, 2008) and Guimaraes and Sheedy (2017) who more explicitly ground the study of institutions in the theory of coalition formation.

Figure 1: Societal policy game



welfare function

$$\beta U^1(a^1, p, A) + (1-\beta)U^2(a^2, p, A). \tag{1}$$

As illustrated in Figure 1, given institutions β, a set of policies $p = p(\beta)$ and actions $a = a(\beta)$, characterize the equilibrium of the societal policy game between individuals and the public authority.

It should be noted that the policy game is in general characterized by several economic and political externalities that are not fully accounted for by private and public decisions. Externalities typically arise because of socio-economic or political imperfections associated with the existence of various frictions going from asymmetric/incomplete information, matching problems, limited rationality and cognitive biases, strategic behaviors associated with market power, private opportunism and lack of political commitment. The equilibrium outcomes $a(\beta)$ $p(\beta)$ of the societal policy game do not fully internalize their impacts on aggregate social outcomes $A(a, p)$, and as a result inefficient policies and social allocations are implemented.[6]

The core element of this class of models, is the mechanism driving institutional change. A society characterized by a power structure β_t at any point in time t, might have an incentive to change the distribution of political power in the future, to internalize the externalities responsible for the inefficiencies at equilibrium. The direction of institutional change relates to the general principle that the political group most likely to internalize the externality is the group receiving more residual decision rights along the institutional dynamics. This mechanism for institutional change is consistent with several interesting large scale historical phenomena. For instance, McCloskey (2006, 2010, 2017) sees institutions evolving during the Industrial Revolution, alongside liberal ideas (Bourgeois Ideology), to allow the efficiency of the market economy to display its power to spread technology, innovation, and capital accumulation. Also, the process which con-

[6]For instance, political groups can strategically exploit socio-economic or political frictions to their own advantage. Interesting examples of inefficient institutional changes induced by elites with oligarchic powers, which we do not discuss in this chapter, are Puga and Trefler (2014) and Carvalho and Dippel (2016).

trolled the transfer of power from the landed aristocracy in favor of the merchant class in Medieval Western Europe is generally interpreted to have resulted in a more efficient fiscal administration; see Bates and Lien (1985). Interestingly, however, it is generally not the case that the stationary state of these processes is efficient; see Acemoglu (2003), Acemoglu, Egorov, Sonin (2010), Acemoglu and Robinson (2008, 2012), Bisin and Verdier (2017).

We illustrate this class of models of institutional change by our own rendition of four examples, North, Wallis and Weingast (2009), Acemoglu and Robinson (2000, 2006b), Besley and Persson (2011), and Bisin and Verdier (2017).[7] More specifically, consider the following environment: i) the two political groups represent elites and workers, $i = \{e, w\}$; ii) total resources are $A = A(a, p, q)$, where q is the fraction of elites in the population; iii) policy p controls the distribution of total resources A: $(1-p)A$ to workers and pA to elites; iv) the social welfare function takes the simple form $\beta U^e(pA, a^e) + (1-\beta)U^w((1-p)A, a^w)$, where a^i is individual production effort, $i = \{e, w\}$.

In North, Wallis and Weingast (2009) institutions are supported by monopoly of violence and are distinguished in terms of *Limited access* (autocracy) and *Open access* (democracy). Limited access institutions could be represented by $\beta = 1$ and Open access by $\beta = \frac{1}{2}$. The fundamental driver of institutional change is lack of commitment. It is then easy to construct an explicit formal structure such that, under no commitment on p, a Limited access $\beta = 1$ society might want to delegate power (control of violence) and allow for Open access, $\beta = 1/2$. In Acemoglu (2003) and in Acemoglu and Robinson (2006a) institutions coincide with the political pressure group exercising the power to control social choice; and institutional change takes the form of voluntary transfer of power across groups, typically under threat of social conflict.[8] In particular, institutions can be autocratic or democratic, $\beta = 1,\ 1/2$, as in North, Wallis and Weingast (2009), but can also be controlled by workers, $\beta = 0$. Institutional change is driven by lack of commitment, but the mechanism is more specifically modeled as the outcome of conflict for political power between the elites and the workers. Consider for instance the case in which institutions are autocratic. Workers are endowed with a technology of revolution, $R = \{1, 0\}$, which they can switch on at some cost C^w, imposing a (large) cost C^e on elites but allowing them access to all the resources produced. Policy p is chosen under limited commitment: with probability π, the choice of p is re-set after action a^w is taken. In this last case, elites take all resources for themselves and $p = 1$. The commitment distribution of resources p is chosen by the

[7] We do not attempt an accurate rendering the interesting complexities of the modeling of institutional change in these papers. Indeed we might trivialize them, to illustrate (what appear to us as) the core aspects of their modeling of the dynamics and to be able to project them into a common abstract dynamical system.

[8] Historical examples of the role of revolutions, or of the threat of revolutions, in fostering institutional change are discussed by Acemoglu and Robinson (2000, 2001, 2005, 2006b, 2012). A prominent case in the literature is the extension of the franchise in early nineteenth century England, as an effect of threats to the established order; see Acemoglu and Robinson (2000, 2001, 2006b), Conley and Temimi (2001); and Lizzeri and Persico (2004) for an alternative explanation.

elites as a solution to the following problem:

$$\max_{p} \pi U^e(A, a^e) + (1-\pi)U^e(pA, a^e)$$

$$s.t. \quad \begin{array}{c} \pi U^w(0, a^w) + (1-\pi)U^w((1-p)A, a^w) \geq U^w(1, a^r) - C^w \\ a^w \in \arg\max \pi U^w(0, a^w) + (1-\pi)U^w((1-p)A, a^w) \\ a^r \in \arg\max U^w(1, a) \\ a^e \in \arg\max \pi U^e(A, a^e) + (1-\pi)U^e(pA, a^e) \end{array}$$

Assume (to avoid trivial cases) that workers prefer a revolution to being completely dispossessed,

$$U^w(0, a^w) < U^w(1, a^r) - C^w.$$

If π high enough, the constraint might never be satisfied and an autocratic society might want to delegate to a democratic society $\beta = \frac{1}{2}$ (or even to a workers' society, where $\beta = 0$).

In Bisin and Verdier (2017), the policy p is chosen under no commitment, as in Acemoglu (2003) and in Acemoglu and Robinson (2006b).[9] Lack of commitment is directly modeled by having the public policy authority choosing p simultaneously with respect to the choices of the (two groups of) agents, (a^w, a^e). An equilibrium is a Nash equilibrium of this game:

$$\begin{array}{c} p \in \arg\max \beta U^e(pA, a) + (1-\beta)U^w((1-p)A, a) \\ a^e \in \arg\max U^e(pA, a) \\ a^w \in \arg\max U^w((1-p)A, a) \end{array}$$

The equilibrium is generally inefficient. The inefficiency is due to lack of commitment in the policy decision making as well as to the externalities in the determination of $A = A(p, a)$. Institutional change is a mechanism operating on the distribution of political power to internalize externalities due to some form of lack of commitment on the part of the public policy decision maker, without an explicit role of social conflict and the threat of revolution.[10] An important distinction of the

[9] On the role of commitment on institutional change, see also Tim Besley's Econometric Society Presidential address, Besley (2020) and the comments by Bisin (2020).

[10] Besides Lizzeri and Persico (2004) work on the extension of the franchise in England, other historical examples along these lines include: the transition of Western European towns in the XV-XIX centuries to inclusive forms of political institutions, as a commitment on the part of the urban oligarchies to limit the inefficiently high indirect taxes on primary goods on trade and production they imposed to the lesser strata of the bourgeoisie (Chittolini, 1979, Tabacco, 1989, Nicholas, 1992, Peytavin, 1999, Sabatini, 2010); the evolution of inclusive institutions at the town level in England, from the Norman conquest until the 1800s, as a commitment on the part of the king to allow self-government to merchant towns to check and control the "widespread opportunistic and distortionary behavior" of fiscal bureaucracies (Angelucci, Meraglia and Voigtlander, 2017); the formation of local merchant guilds in the Medieval Europe as a commitment on the part of the rulers of the polities in which they traded as a mechanism to raise fiscal revenues more efficiently (Dessi and Piccolo, 2016). Even in the context of explaining the emergence of democracy from autocratic rule, threat of revolutions explains about half the cases in Treisman (2017) classification of all historical democratization events since 1800 (see Table 1 in the paper).

analysis of Bisin and Verdier (2017) is that $\beta \in [0,1]$ allows for smooth institutional change; that is, it allows for institutional change to be incremental. Their analysis therefore captures long-run historical dynamics of institutions rather than more extreme phenomena like democratization, revolutions, regime changes like political coups leading to autocratic regimes. A rich set of examples consistent with this view, whereby institutional change occurs through gradual and piecemeal changes that manifest themselves mostly in the long run, are discussed by Mahoney and Thelen (2010). With respect to the study of dynamical systems in history which motivate this chapter, allowing for $\beta \in [0,1]$ (a continuous rather than a discrete change in political control) leads directly to the formulation of the dynamics of institutions as a differential/difference equation. Indeed, in Bisin and Verdier (2017) institutional change takes a relatively simple form:

$$\beta_{t+1} \in \arg\max \beta_t U^e(\beta_{t+1}) + (1-\beta_t)U^w(\beta_{t+1})$$

where $U^w(\beta_{t+1}) = U^w\left((1-p(\beta_{t+1})A(\beta_{t+1}), a(\beta_{t+1})\right)$ and $U^e(\beta_{t+1}) = \left(p(\beta_{t+1})A(\beta_{t+1}), a(\beta_{t+1})\right)$ are utilities evaluated at future equilibrium choices with institution β_{t+1}.[11]

In fact, there is no reason why the institutional dynamics in Acemoglu and Robinson (2000, 2006b) be restricted to discrete changes between $\beta = 1, 0, 1/2$ or why these changes be induced by unanticipated shocks. In a dynamic environment, that is, where A_t changes over time, e.g., due to q_{t+1} changing, a smooth dynamics will be induced. As in Bisin and Verdier (2017) this dynamics takes the form of delegation of power on the part of the elites, but in this case delegation is not motivated to commit policies or to internalize externalities but to avoid social conflict. For instance, assuming complete lack of commitment, $\pi = 1$, for simplicity, under certain initial conditions, in our rendition of Acemoglu and Robinson (2000, 2006b), the fundamental dynamics of β_{t+1} is represented in indirect form by the condition:

$$U^w(\beta_{t+1}) = U^w\left((1-p(\beta_{t+1}))A(\beta_{t+1}), a^w(\beta_{t+1})\right) \geq U^w(1, a^r(\beta_{t+1})) - C^w.$$

In Besley and Persson (2009a,b, 2010) a society is faced with pressure groups alternating in the power to control economic institutions regarding taxation and contractual enforcement. Policy p represents a commitment component (the choice of state capacity in the future), at some cost. Institutional change is not driven by lack of commitment in this case. Indeed, institutional change is exogenous $\beta_{t+1} = g(\beta_t)$. But the dynamics of β_t imposes an inefficiency on the choice of p: elites and/or workers might under-invest in state capacity if β changes.[12] An ex-ante choice, under commitment, of a restriction on the dynamics of β, e.g., by controlling $g(\beta_t)$ would allow for the endogenous dynamics of β_t, to improve efficiency. Indeed, in Besley and Persson (2011),

[11] For convenience we denote $A(\beta_{t+1}) = A\left(p(\beta_{t+1}), a(\beta_{t+1})\right)$

[12] More specifically, in Besley and Persson (2011), $\beta_{t+1} \in \{0,1\}$, is random, with probability of $\beta = 1$ equal to γ. In this case both elites and workers under-invest in state capacity under the risk of a change in β. We do not explicit report here on this model, as we want to restrict the dynamic analysis to deterministic systems.

assuming σ is the institutional variable for the control of institutions, the differential equation for the dynamics of β_{t+1} takes the form:

$$\beta_{t+1} = g(\beta_t, \sigma_{t+1}), \text{ with } \sigma_{t+1} \in \arg\max \beta_t U^e(g(\beta_t, \sigma_{t+1})) + (1-\beta_t)U^w(g(\beta_t, \sigma_{t+1})).$$

Our rendition of these models of institutional change is meant to show that they all induce a mapping from the institutional system at t, β_t, into the one at $t+1$, β_{t+1}, as schematically illustrated in Figure 2. We obtain therefore a differential/difference equation whose solution describes the path of institutional dynamics:[13]

$$\beta_{t+1} = \Theta(\beta_t). \tag{2}$$

2.2 (Bottom-up) models of cultural change

Bottom-up models of the dynamics of cultural traits, norms, and conventions in a society focus on evolutionary selection mechanism operating directing on agents' actions/strategies, or indirectly on preference traits, which in turn determine agents actions/strategies. Bottom-up cultural dynamics have been studied and documented in several contexts.[14] Of particular interest for the topic of this volume, are *Persistence studies* in which culture is a channel of a long-lasting influence of historical events on present-day outcomes; see Cioni et al. (2021, in this volume), Bisin and Moro (2021, in this volume) and Voth (2021, in this volume) for surveys. For instance, the importance of historical and cultural factors on inter-ethnic conflicts has been documented between Hindus and Muslims in India (Jha 2013), and against Jews in Germany (Voigtlander and Voth 2012).

[13] Formally, these models often assume that institutional design is myopic, that is, institutions are designed for the future as if they would never be designed anew in the forward future. When the institutional design is less myopic, a power structure β_t at time t will internalize the fact that by moving to a different structure of decision rights β_{t+1}, this may in turn trigger subsequent institutional changes β_{t+2}, β_{t+3}, ... leading to suboptimal outcomes from the point of view of the initial power structure β_t. In order to prevent or mitigate the logic of this institutional "slippery slope", the current system β_t may then try to reduce the speed or even stop the process of institutional change, leading therefore to stronger institutional inertia than what myopic institutions would design; see Acemoglu, Egorov and Sonin (2015) for such an analysis in a discrete institutional policy context, Bisin and Verdier (2017) for a simple discussion in the continuous institutional policy context outlined here, and Lagunoff (2009) who provides a general study of the theoretical properties of political economy equilibria with dynamic endogenous institutions. While this assumption simplifies the analytics, it is also factually motivated, e.g., in the historical process which underlies the emergence of democracy. Treisman (2017) argues that in the majority of the democratization events he classifies (in about 65% of them, in fact) democracy has not been primarily the outcome of deliberate institutional choice but rather of various forms of miscalculation and lack of anticipation of the effects of the process set in motion by institutional change. In particular, in almost in half of these instances, the process inducing democratization is characterized by the fact that the "incumbent initiates a partial reform, [...] but cannot stop" (see Table 2 in the paper), a representation which closely maps our modeling of myopic institutional change.

[14] This large literature is too vast to be even cursorily discussed here; see Bisin and Verdier (2010) for a survey.

The evolutionary dynamics induced by bottom-up selection mechanisms are typically represented by a (logistic) replicator dynamics. Formally, consider a society composed of agents identifying in one of two distinct cultural groups $i = \{1, 2\}$. Let q denote the fraction of group 1 in the population and $1 - q$ the fraction of group 2. At each time t, the (logistic) replicator dynamics of q_t is given by

$$q_{t+1} - q_t = q_t(1 - q_t)S(q_t), \tag{3}$$

where $S(q_t)$ is the *cultural relative fitness* of that trait in the population.

The replicator dynamics can be derived from several micro-founded cultural selection mechanisms. We illustrate these different evolutionary selection mechanisms through our rendition of several examples: from simple evolutionary models in large populations games as in Hofbauer (1995) and Weibull (2005), to the indirect evolutionary models in Güth and Yaari (1992) and Besley and Persson (2019, 2020a, 2020b); and to the cultural anthropology models developed by Cavalli-Sforza and Feldman (1973) and Boyd and Richerson (1985).

Consider first evolutionary models based on payoff imitation protocols in large population games, as in Hofbauer (1995) and Weibull (2005). At each time t, each agent is randomly matched with another to play a simple simultaneous stage game. The strategic interaction is described in a stylized way by two possible actions/strategies, $A = \{1, 2\}$. The payoff of an agent playing $a \in A$ matched with an agent playing $a' \in A$ is $\pi(a, a')$. The fraction q_t of agents playing strategy $a = 1$ evolves then according to the replicator dynamics in Equation 3, with

$$S(q_t) = E\pi(1, a') - E\pi(2, a')$$

where

$$\begin{aligned} E\pi(1, a') &= q_t\pi(1, 1) + (1 - q_t)\pi(1, 2) \\ E\pi(2, a') &= q_t\pi(2, 1) + (1 - q_t)\pi(2, 2) \end{aligned}$$

are the expected payoffs of agents adopting actions/strategies 1 and 2 respectively.[15] Stable

[15] In several applications, society is composed of two distinct groups, $i \in \{1, 2\}$, each with action/strategy space $\{1, 2\}$. At each time t, individuals of one group are randomly matched with individuals from the other group to play the simultaneous stage game. Let $a^i \in \{1, 2\}$ denote the action of an agent of group i and $\left[\pi^i\left(a^i, a^j\right)\right]_{i=1,2}$ the payoff matrix. Let the fraction q_t^i of agents of type i playing strategy $a^i = 1$. In this case the dynamics of q_t^i, $i \in \{1, 2\}$, is represented by

$$q_{t+1}^i - q_t^i = q_t^i(1 - q_t^i)\left[E\pi^i(1, q_t^j) - E\pi^i(2, q_t^j)\right] \quad \text{for } i, j = 1, 2 \text{ and } i \neq j$$

where

$$\begin{aligned} E\pi^i(1, q_t^j) &= q_t^j \cdot \pi^i(1, 1) + (1 - q_t^j)\pi^i(1, 2) \\ E\pi^i(1, q_t^j) &= q_t^j \cdot \pi^i(2, 1) + (1 - q_t^j)\pi^i(2, 2) \end{aligned}$$

are the expected payoffs of individuals of group i adopting actions/strategies 1 and 2.

stationary states of these dynamics describe specific cultural conventions on how the stage game is played in the long run, and they generally correspond to a Nash equilibrium of the stage game.[16]

The precise formulation of the strategic environment depends on the application. The pioneering studies by Greif (1989, 1994) on the Maghrebi and Genoese traders in the historical economics literature can be mapped into this formal structure. In this case, the strategic environment is one of cooperation with internal punishment and the actions/strategies on which cultural selection acts are bilateral vs. multi-lateral punishment of non-cooperators, respectively adopted by the Genoese and the Maghrebi. Greif (1989, 1994)'s analysis shows how networks (of merchants, in his environment) can enforce contracts in the absence of any formal institutions.[17] Relatedly, Young and Burke (2001) highlight how an evolutionary process along these lines helps explain the structure of customary crop-sharing contracts in the context of Illinois agriculture.[18]

A distinct class of bottom-up models of the dynamics of cultural traits, norms, and conventions has evolutionary selection processes applying on preferences rather than on action/strategies. In these models the agents' preferences determine their actions/strategies (typically as rational choices) which then are transmitted across and within generations through various imitation and socialization mechanisms; see e.g., Güth and Yaari (1992); Besley and Persson (2019, 2020a, 2020b.) Consider a society with two cultural groups $i = \{1, 2\}$. Let a^i denote the action of an agent in group i and let the fraction of group $i = 1$ in the population be denoted q. Each group is characterized by a specific preference trait, $U^i(a^i, a^j, q)$, $i, j \in \{1, 2\}$. In this case, equilibrium actions are a Nash equilibrium of the game, given the preferences, and q_t evolves according to the replicator dynamics in Equation 3, where the cultural relative fitness of trait 1 in the population, $S(q_t)$, depends on the societal equilibrium set of actions a that individuals undertake, as well as on the specific cultural transmission process through which cultural traits are learnt in society. Typically, $S(q)$ takes the form

$$S(q) = W^1(a, q) - W^2(a, q), \tag{4}$$

[16]Because of strategic complementarities, the stage game often involves multiple equilibria (social conventions). Consequently an equilibrium selection mechanism needs to be included to explain where the social system converges and how a specific social convention may persist or eventually transit to another one. Introducing stochastic elements in the evolutionary selection process is instrumental to this end; see Young (1998). For instance, Bowles and Choi (2019) introduces idiosyncratic random (non-best-response) play in a modified Hawk-Dove-Bourgeois game (Maynard Smith 1982) to analyze the transition from foraging to farming and the origins of private property; Hwang, Naidu‡ and Bowles (2018) add intentional idiosyncratic play to study unequal conventions in an environment in which disadvantaged groups may try to force institutional change by withdrawing their consentment from current institutional arrangements; see Bowles, Choi , Hwang, and Naidu (2021, in this volume) for a survey.

[17]In the context of development, Fafchamps (2003) has demonstrated the pervasive importance of social networks and customary enforcement mechanisms for trade in Africa.

[18]Hwang, Naidu, and Bowles (2018) discusses several other application of these mechanisms, from the move from selfdom to land leasing contracts in agricultural England between 1350 and 1450, to the political transition from apartheid to democracy in South Africa, or racial desegregation of the U.S. South in the 1960s. See Bowles, Choi, Hwang and Naidu (2020) in this volume for an exhaustive survey.

where $W^i(a,q)$ is an appropriate "cultural fitness" function of trait i in the population. More specifically, in *pairwise comparison random matching* models with imitation driven by dissatisfaction or success, the cultural fitness $W^i(a,q)$ of trait i is simply proportional to the payoff function of type i, $U^i(a^i,a^j,q)$; see Weibull (1995) and Sandholm (2010). In *indirect evolutionary* models, similar dynamics are obtained, though cultural evolution on preferences occurs indirectly through the consequences of their induced behaviors on some material reproduction or survival criterion $W^i(a,q)$, generally distinct from $U^i(a^i,a^j,q)$; see Güth and Yaari (1992), Güth (1995), Dekel et al. (2007), Heifetz et al. (2007).

Finally, evolutionary anthropology models also provide "cultural fitness" functions which are derived from the modelling of explicit processes of cultural transmission across and within generations; see Cavalli-Sforza and Feldman (1973) and Boyd and Richerson (1985). These models emphasize the relative importance of different channels of socialization (parents, peers, or society at large), as well as forces of social influence (frequency-bias, prestige-bias). Expanding on this perspective, Bisin and Verdier (2000b,a, 2001) considers intergenerational cultural transmission mechanisms resulting from the joint influence of paternalistic parents (who spend costly resources to bias the process of preference acquisition of their children) and other role models in society at large. In this case, the cultural fitness function of trait i, $W^i(a,q)$ is increasing in $\Delta V^i(a,q)$, the paternalistic utility gain a parent of cultural type i obtains when he/she successfully socializes his/her child to his/her own trait rather than the other trait. It also depends on pecuniary and non pecuniary opportunities, as well as the technological environment in which socialization typically occurs.[19]

3 The interaction of culture and institutions

Along the course of history, over the long term at least, institutional and cultural change interact in interesting ways and with great significance.[20] A vibrant historical literature identifies (or can

[19] See Bisin and Verdier (2010) for an extensive survey of this approach and of applications. More recently, models of the dynamics of cultural traits along these lines, in different institutional contexts have been studied in the literature: Ticchi, Verdier, and Vindigni (2013) and Besley and Persson (2019) on the evolution of civil culture and its interaction with the structure of political systems; Bidner and Francois (2011) on the emergence of internalized norms of honesty, given incentives from top-down institutions; Bidner and Francois (2013) on political norms (specifically, the extent to which leaders abuse office for personal gain and citizens punish such transgressions); Grosjean (2014) on the culture of honor in the U.S.; Besley (2016) on the dynamics of aspirational preferences and their consequences for the political economy of redistribution; Grosjean and Khattar (2019) on gender bias; Besley and Persson (2020) on the diffusion of corporate culture and its implications for the internal organization of firms.

[20] A number of papers study the implications of the interaction of culture and institutions for economic activities. These papers typically focus each on a distinct context-specific case: e.g., Bisin and Verdier (2000b) on work norms and the welfare state; Dixit (2004) on informal (cultural) and formal (institutional) contract enforcement; Doepke and Zilibotti (2008) on preference for discounting and labor markets in the Industrial Revolution; Tabellini

be interpreted to identify) the interaction of culture and institutions as a fundamental factor for long run prosperity.[21] In this section we show how, combining models of top-down institutional dynamics with models of bottom-up cultural dynamics, we obtain a useful representation of these interactions, as a system of differential/difference equations represented by a phase diagram.[23]

Specifically, consider for simplicity an environment in which the dynamics of aggregate social outcomes, A_t, are driven by the dynamics the distribution of the population by cultural trait, q; so that $A_t = A(a_t, p_t, q_t)$ and the equilibrium outcomes also depend on q_t: $a_t = a(\beta_t, q_t)$, $p_t = p(\beta_t, q_t)$, so that $\Theta(.)$ in equation (2) writes as $\Theta(\beta_t, q_t)$. Similarly, consider the case in which the relative cultural fitness of the two groups depends on the institutional set-up in which the policy game is played, β_t; so that $S(.)$ in equation (3) writes as $S(\beta_t, q_t)$. The institutional and cultural dynamics of the society are then characterized by $(\beta_t, q_t))$ as described in Figure 2.

Joining together the top-down dynamics of institutional change in (2) and the bottom-up dynamics of the distribution of cultural traits in (3), the dynamics of institutions and culture are summarized by a dynamic non-linear system:

$$\beta_{t+1} - \beta_t = \Theta(\beta_t, q_t) - \beta_t \tag{5}$$

$$q_{t+1} - q_t = q_t(1 - q_t)S(\beta_t, q_t) \tag{6}$$

Bisin and Verdier (2017) provide conditions for this system to eventually reach a long run steady state (β^*, q^*) which, when *interior,* solves:

$$\Theta(\beta, q) - \beta = S(\beta, q) = 0. \tag{7}$$

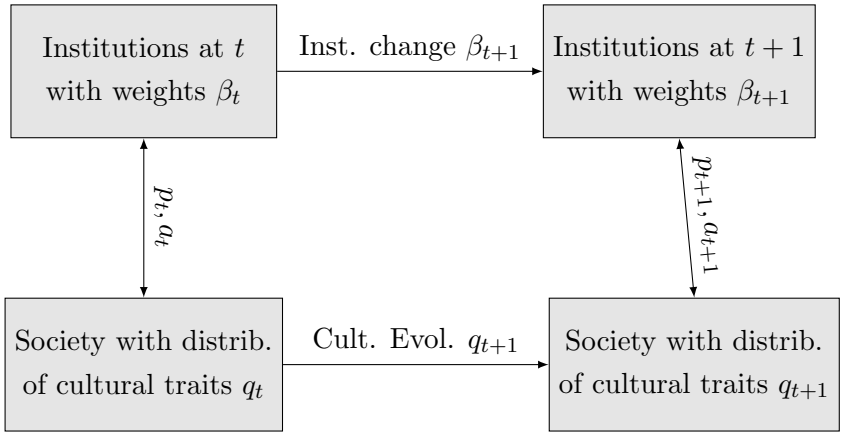
At this level of generality, it is however difficult to get a precise analytical characterization of the trajectory of the system (5) and (6). Still, one may obtain interesting qualitative insights about

(2008b) on norms of cooperation and legal systems; Aghion, Algan, Cahuc, and Shleifer (2010) on trust and regulation; Besley and Ghatak (2016) on organizational culture and incentives. See also Lindbeck (1995), Francois and Zabojnik (2005), Lindbeck and Nyberg (2006), Bidner and Francois (2011), Greif and Tabellini (2010), Hiller (2010), Benabou, Ticchi, Vindigni (2013), Ticchi, Vindigni, and Verdier (2013), Hori (2017), Jeong (2018), Besley and Persson (2019).

[21] Studies along these lines include: Ortiz (1963) on the authoritarian culture of the sugar plantation regions of Cuba operated with slave labor as opposed to the liberal culture of the tobacco farms; Miguel, Gertler and Levine (2006) on capital and industrialization in Indonesia; Guiso, Sapienza, and Zingales (2008, 2016) on social capital and Italian independent city states in the Renaissance; Greif and Tabellini (2010, 2017) on the role of different moral systems and kinship organization in explaining China's and Europe's historical growth divergence over the last millennium; Alesina, Giuliano and Nunn (2013) on patriarchal institutions and gender attitudes; Grosjean (2014) on the traditional (Scottish-Irish) pastoral society honor code and the differential institutional environment in the North and the South of the U.S.; Gorodnichenko and Roland (2017) and Roland (2017b) on the parallel development, since antiquity, of broad institutional and cultural systems (planning institutions associated to collectivist cultural traits and market institutions to individualistic traits); McCloskey (2006, 2010, 2017) on the relative role of *bourgeoise* culture as a complement to inclusive institutions in the understanding of the historical factors giving rise to the Industrial Revolution in England;[22]

[23] We follow Bisin and Verdier (2017) in this exposition.

Figure 2: Joint dynamics of culture and institutions

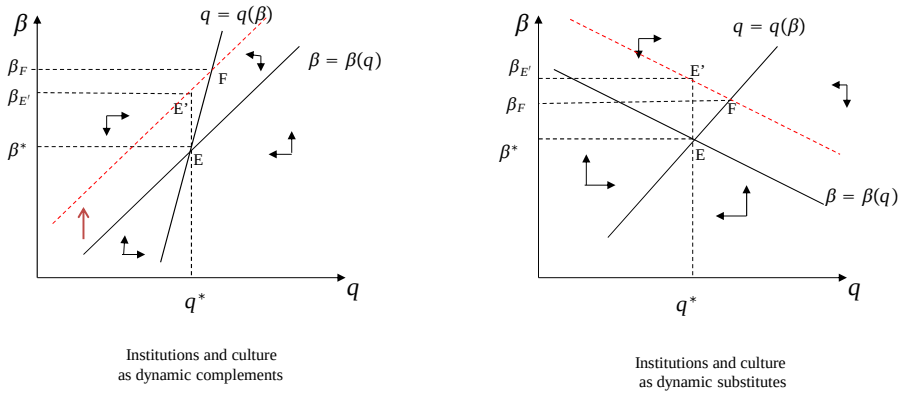


how culture and institutions display interactions, analyzing the associated phase diagram in the space of the state variables (q_t, β_t).

To this end, denote $\beta = \beta(q)$ the steady state manifold associated with equation (5), that is, the set of points $(\beta, q) \in [0,1]^2$ such that $\Theta(\beta(q), q) = \beta$. Intuitively, $\beta = \beta(q)$ represents the set of steady state institutional structures, for given time invariant distribution of cultural trait. Similarly denote $q = q(\beta)$ the steady state interior cultural manifold associated with Equation (6); that is, the set of points $(\beta, q) \in [0,1]^2$ such that $S(\beta, q(\beta)) = 0$. The manifold $q = q(\beta)$ represents the set of steady states distribution of cultural traits, for given time invariant institutional structure.

Consider then an interior long run steady state (β^*, q^*) towards which the joint dynamics of culture and institutions converge, located at the intersection of the two manifolds $\beta = \beta(q)$ and $q = q(\beta)$. The stability conditions of this steady state imply that around the steady state the local dynamics can be immediately inferred: i) β_t increases (resp. decreases) when the system is in the region below (resp. above) the curve $\beta = \beta(q)$; and similarly, ii) q_t increases (resp. decreases) when the system is in the region below (resp. above) the curve $q = q(\beta)$. This is qualitatively well illustrated by the phase diagram in Figure 3. Suppose also, for the sake of exposition, that the diffusion of cultural trait of a given group is favored when that group gets more political power in the societal policy game, i.e., $q(\beta)$ is increasing in β. As illustrated in Figure 3a) and 3b), two generic cases may occur depending on whether the slopes of the manifolds at (β^*, q^*) have the same signs or different signs. This feature matters for the comparative dynamics of culture and institutions and for the response of the system to exogenous shocks, e.g., natural historical experiments. Indeed when the manifolds' slopes share the same sign (resp. opposite signs) the joint dynamics reinforce (resp. hinder) each other in response those shocks, and culture and institutions are dynamic complements (resp. substitutes).

Figure 3: Joint Evolution of Institutions and Culture
Phase diagram



To get an intuition for the mechanism, consider for instance the case of dynamic complementarity. Take then an exogenous shock to the system that makes more salient the existence of an externality or a political commitment issue. Such a shock triggers an institutional response aimed at internalizing the externality and/or committing policy choices. This institutional response implies augmenting the political weight to the group who gains relatively more from a policy change that helps correct the externality and/or the commitment issue. When the strength of this institutional response is positively related to the frequency of the cultural traits carried by that group, and that such more empowered group has in turn a higher success at diffusing those specific traits, then complementarity between institutions and culture prevails. Over time, institutional and cultural dynamics re-inforce each other and therefore act as dynamic complements. This is illustrated in Figure 3a) where the exogenous shock triggers an institutional response that translates upward the institutional manifold $\beta = \beta(q)$ at any given cultural state of the society q. As long as cultural evolution has not yet taken place and starting from the initial steady state at point E, the shock implies a new pattern of institutional change that moves the political weight β of group 1 eventually up to $\beta = \beta_{E'}$ at point E'.[24] In the joint dynamics and because of the

[24] With much faster institutional adjustment than cultural adjustment, the value of β will directly jump to $\beta_{E'}$, as the institutional dynamics are always located on the manifold $\beta = \beta(q)$

dynamic complementarity, this in fact stimulates the successful diffusion of the cultural trait of that group. As its frequency q increases, the institutional and the cultural dynamics reinforce each other to end up at the new steady state F with corresponding higher steady state values β_F and q_F. The ratio $\frac{\beta_F - \beta_{E'}}{\beta_{E'} - \beta_E}$ corresponds to what Bisin and Verdier (2017) describes as a *cultural multiplier*, namely the ratio of the long run change in institutions relative to the counterfactual long run change that would have happened had the cultural composition of society remained fixed.[25] Conversely, Figure 3b) illustrates the case of dynamic substitution between institutions and culture. The positive institutional response to a given shock at any fixed cultural state, triggers a cultural dynamic that in that case mitigates the initial impact of the shock on institutional change. Correspondingly, the new resulting steady state value β_F is such that the cultural multiplier $(\beta_F - \beta_{E'})/\beta_{E'}$ is now negative.

The cultural (and symmetrically institutional) multipliers are in principle important conceptual tools, useful alongside causation analysis, to identify and measure the relative contribution of different factors to economic development. While no empirical study has yet attempted to estimate the size of these multipliers in a relevant context, several papers provide explicit quantitative evidence about their sign; that is, they document whether culture and institutions acted as complements or substitutes, reinforcing or hindering economic activity after an exogenous shock to either. More specifically, reveral recent studies of the interactions of culture and institutions in various specific historical processes, can generally be interpreted as qualitative evidence of either complementarity or substitutability. This is the case, for instance, of the study by Lowes, Nunn, Robinson, and Weigel (2017) on the creation of the Kuba Kingdom in Central Africa in the 17th century as a natural historical experiment for the formation of a well-functioning institutional system. They find evidence for substitution between culture and institutions in the development process. A more centralized and effective administrative structure associated to the Kuba Kingdom gave rise to "weaker norms of rule following and a greater propensity to cheat for material gain," as measured in the field experiments run by the authors (see Table I in the paper). Even more directly, Lowes and Monteiro (2017) study the effects in terms of economic outcomes of the concession to extract rubber granted in the north of the Congo Free State during the colonial era, as a natural historical experiment for a negative institutional shock. They also find evidence for substitution, in that exposure to the concessions has led to worse economic outcomes but positive effects on various cultural traits like e.g., pro-social attitudes. Related, though less clearcut, results are also found in the study of the effects of the Cultivation System for producing sugar of the Dutch colonial enterprise in 19th century Java by Dell and Olken (2017). On the other hand, Dell (2010)'s study of the effects of the forced mining labor system in effect in Peru and Bolivia in the 16th century provides suggestive evidence of complementarity between culture and institution, inasmuch as extractive institutions have lead to large negative effects on present day living

[25] Obviously, symmetric arguments and conditions hold for the existence of an *institutional multiplier*.

standards as well as education and other measures of cognitive and psychological development of children.

The property of dynamic complementarity or substituability between institutions and culture, also matters for the shape of the trajectories taken by society. Indeed as suggested by the direction of variation of the state variables in phase diagrams 3a) and 3b), the local joint dynamics between institution and culture tend to generate cyclical and non monotonic trajectories under substitution, while on the contrary they tend to show some degree of joint monotonicity under complementarity. Specifically, Bisin and Verdier (2017) show that when institutions and culture are dynamic complements, the joint local dynamics do not exhibit any converging oscillatory dynamics, while on the contrary such spiraling trajectory may occur under dynamic substitution. Such feature is interesting as it provides a rationale for why societies need not follow linear and monotonic paths along their historical trajectories. Furthermore, it suggests that empirical studies that only consider the impact of far away historical conditions on current outcomes, obviate potentially important cyclical or oscillatory dynamics that in themselves could have socio-economic implications from an efficiency or welfare point of view.[26]

4 Property rights and conflict

In this section we illustrate the methods and the concepts outlined previously by means of a simple analytical example which we study and solve in some detail, showcasing the explanatory power of phase diagrams in the study of the dynamics of culture and institutions.[27] Specifically, we study a conflictual society and characterize conditions under which the cultural and institutional dynamics in this society, between groups with different propensities to act violently, favor or hinder the development of a legal system for the protection of *property rights*.[28]

[26] Bidner-Francois (2013), in their study of the evolution of honesty norms, find a dynamic complementarity between norms and institutions, with two types of possible social outcomes. The first one is a functional institutions/high trust equilibrium with widely diffused honesty norms and efficient trade between individuals. The second one is is a dysfunctional institutions/low trust equilibrium, where honesty norms are not followed and trade is limited.

[27] See Bisin and Verdier (2017) for two applications of similar methods and concepts. In the first example, we study conditions under which the cultural and institutional dynamics may maintain or reverse *extractive institutions*. The second example focuses on the dynamics of *civic culture* either complementing or substituting public governance institutions. See also Bisin et al. (2020) for a model of religious legitimacy, where culture and institutions support either theocratic or secular states, providing an explanation the *Long Divergence* between Middle Eastern and Western European economies.

[28] See Nisbett (1993), Cohen and Nisbett (1994), and Grosjean (2014), for the study of societies where a *culture of honor* may breed violence in social interactions and is supported and transmitted because of weak institutions of property rights protection. The society we study has characteristics consistent also with various anthropological observations that suggest that cultures of violence are more likely to develop in pastoralist societies since property rights protection on cattle is more difficult to enforce than property rights on land in agrarian societies (see Campbell

A legal system for property right protection is the main policy variable in this society. Property rights reduce the incentives to engage in violent conflict at equilibrium and are therefore valuable in terms of efficiency. The dynamics of culture and institutions in this society display several complex features, including, notably, an interesting form of hysteresis. More specifically, societies where the more conflict-prone group is relatively small but powerful tend to rely on limited property rights protection. When however this group is relatively large, it develops enough incentives to devolve institutional power to the other group to build institutions for property right protection. The qualitative dynamics represented in the phase diagram display interesting patterns where a society with a powerful conflict-prone group in control of its institutional arrangement is up-rooted by cultural dynamics which, by leading to the expansion of the size of the conflict-prone group, trigger the formation of institutions favoring property rights protection.

More in detail, consider a society where couples of agents are matched randomly in contest. Each agent's endowment prior to the contest is $\omega > 0$. Property rights protection is represented by the fraction $p \in [0,1]$ of each agent's endowment which is protected in the contest. After two agents match, their relative effort in the conflict determines the probability that each of them succeeds in the contest, hence winning the fraction of the endowment of the opponent which is not protected by property rights. More specifically, let a^{ij} denote the effort exerted by an agent of group i when matching with an agent of group j. The probability of agent i winning the contest is $\frac{a^{ij}}{a^{ij}+a^{ji}}$.[29] The winner of the contest appropriates of the fraction of the total endowment of the other agent which is not protected by property rights, $(1-p)\omega$.

We assume that there are two political groups $i \in \{1,2\}$ which are fully identified to cultural groups. The two groups are culturally differentiated by their propensity to act into conflict: group 1 is more prone to violence. Formally, group 1 has cultural traits inducing, for a fixed initial cost $F > 0$, a higher propensity for violent action, i.e., a low marginal cost of effort in conflict, c^1.[30] Group 2 is instead composed of *conflict-averse,* agents, with a higher marginal cost of effort in conflict, $c^2 > c^1$. The size of "conflict-prone" agents is $q^1 = 1 - q^2 = q$.

Agents observe the opponent type before choosing their effort.[31] The Nash equilibrium effort of an agent of type i in his contest with an agent of type j, for given property rights p is

$$a^{ij}(p) = 2(1-p)\omega \frac{c^j}{\left(c^i + c^j\right)^2}.$$

Matching is random, so that an agent in group i will match another agent in the same group with probability q^i and an agent in the other group with probability $1 - q^i$. Let the ex-ante expected payoff for agents of each of the groups at equilibrium be denoted $U^i(p,q)$. It is

(1965), Edgerton 1971, Peristiany1965).

[29] Formally, this is the case if $a^{ij}, a^{ji} > 0$; while the probability of winning is $1/2$ if $a^{ij} = a^{ji} = 0$.

[30] Cost F could represent the cost of rituals and practices to develop a "culture of honor."

[31] That is, the contest is a complete information game. The expected payoff of an agent of cultural group i matching with an agent of group j is $W^i(a^{ij}, a^{ji}) = p\omega + 2(1-p)\omega\frac{a^{ij}}{a^{ji}+a^{ij}} - c^i a^{ij}$.

decreasing in q as a larger fraction of conflict-prone agents hurts both groups ex-ante. It induces a larger rent dissipation for the conflict-prone agents and a larger probability of extortion (loss of endowment) for the conflict averse agents. On the other hand, while $U^2(p,q)$ is always increasing in p, $U^1(p,q)$ is increasing in p only for a large enough fraction q. Indeed, conflict-averse agents always benefit from property rights protection, while conflict-prone agents gain as a consequence of better property rights protection only when their fraction in the population is large enough. Finally, assume that implementing a level p of property rights protection requires a resource cost $C(p)$ satisfying standard convexity properties.

Denote by $\beta^1 = 1-\beta^2 = \beta$, the institutional weight of the conflict prone group. Consider first the equilibrium outcome of the societal policy game between the agents and a public authority that chooses the degree of property rights protection, taking as given the effort choices in conflict of the agents of the two groups, a^{ij}.[32] When $\beta \geq q$, *this societal equilibrium* involves no property right protection and therefore $p^*(\beta,q) = 0$. For $\beta < q$, instead, $p = p^*(\beta,q) > 0$. Moreover, $p^*(\beta,q)$ is decreasing in β and increasing in q. The larger the weight of the "conflict prone" group, the smaller the level of property rights protection, as such group benefits less from this protection. On the other hand, the larger the fraction of the conflict prone agents in society, the larger the social welfare from a reduction of conflict effort dissipated into contests.

Institutional dynamics. Modeling institutional change in this society along the lines of theoretical constructs in Section (2), we postulate that the dynamics of the political weight of the conflict-prone group β_t, for given q, $\beta_{t+1} = \Theta(\beta_t, q)$, is determined as the solution of the following program:

$$\beta_{t+1} = \arg\max_{\beta\in[0,1]} \beta_t V_1(\beta,q) + (1-\beta_t)V_2(\beta,q) \tag{8}$$

where $V_i(\beta,q) = U^i(p^*(\beta,q),q)$ are the societal equilibrium expected payoffs of members of group i. The resulting dynamics can be formally and intuitively represented with the help of the function $p^{com}(\beta,q)$ defined as the solution of the optimal choice of property rights protection a public authority with weight β would want to implement if it could fully internalize the impact of such choice on the agents equilibrium actions $a^{ij}(p)$:

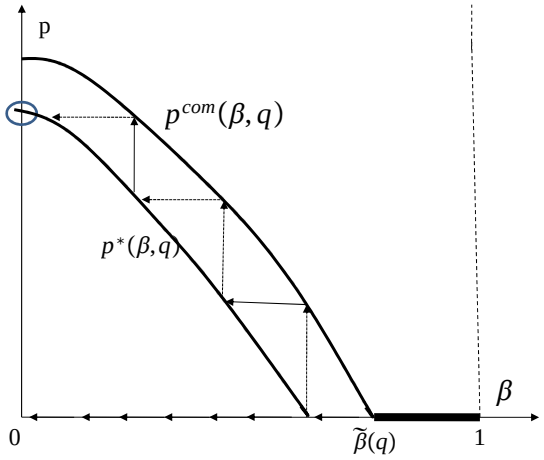
$$p^{com}(\beta,q) = \arg\max_{p\in[0,1]} \beta U_1^1(p,q) + (1-\beta)U^2(p,q). \tag{9}$$

In fact, the dynamics of β_{t+1} induced by (8) can be written in terms of $p^{com}(\beta,q)$ and the equilibrium policy function $p^*(\beta,q)$ in the following way:

$$\beta_{t+1} = \begin{cases} \beta \text{ such that } p^{com}(\beta_t,q) = p^*(\beta,q) & \text{if it exists} \\ \left[\begin{array}{ll} 1 & \text{if } p^{com}(\beta_t,q) > p^*(\beta,q),\ \forall 0 \leq \beta \leq 1 \\ 0 & \text{if } p^{com}(\beta_t,q) < p^*(\beta,q),\ \forall 0 \leq \beta \leq 1 \end{array}\right. & \text{else} \end{cases}.$$

[32] See the Appendix for detailed calculations.

Figure 4: Property rights and conflicts
Institutional dynamics



Intuitively, institutional change is driven by the difference between the equilibrium protection of property rights $p^*(\beta, q)$ and the normative protection level $p^{com}(\beta, q)$, which internalizes the inefficient dissipation of effort in conflict. Indeed, $p^*(\beta, q) \leq p^{com}(\beta, q)$ since at the societal equilibrium the public authority does not provide the efficient (higher) level of property rights protection: see Figure 4, the phase diagram summarizing the dynamics of institutions.[33] For any given q, i) if $\beta_0 > \widetilde{\beta}(q)$, then $\beta_{t+1} = \beta_t = \beta_0$ and there is no institutional change; ii) if instead $\beta_0 < \widetilde{\beta}(q)$, then β_t converges towards $\beta = 0$, namely full power to the conflict-averse group.

Cultural dynamics. Following Bisin and Verdier (2001), the cultural fitness function of each trait $i = 1, 2$ is increasing in the paternalistic incentives $\Delta V^i(\beta, q)$ to transmit that trait. Conflict-prone agents have positive incentives $\Delta V^1(\beta, q)$ to transmit their trait, but such incentives decrease with their fraction q in society. The incentives for conflict-averse agents, $\Delta V^2(\beta, q)$, are also positive. They are increasing with the fraction q of conflict-prone agents in the population.[34] As a consequence, the cultural dynamics has a unique interior stationary state $q(\beta)$,

[33] See the Appendix for the characterization of the properties of $p^*(\beta, q)$ and $p^{com}(\beta, q)$. $p^{com}(\beta, q) = 0$ when $q < \widetilde{q}(\alpha)$ and $\beta \geq \widetilde{\beta}(q)$, with $\widetilde{q}(\alpha) \in]0, 1[$ and $\widetilde{\beta}(q) \in [0, 1]$ an increasing function of q. Furthermore, $\widetilde{\beta}(q)$ is increasing in q and satisfies $\widetilde{\beta}(0) < 1$ and $\widetilde{\beta}(q) = 1$ for $q < 1$ large enough. Conversely $p^{com}(\beta, q) > 0$ when β, q do not satisfy such relations. In such a case, $p^{com}(\beta, q)$ is as well decreasing in β and is increasing in q.

[34] A larger value of q in fact has two opposing effects on the incentive to socialization of conflict-averse agents:

which is increasing in the weight of the "conflict-prone" group β. Property rights protection affects negatively the socialization incentives of the conflict-prone and promotes on the opposite the socialization incentives of conflict-averse agents.

Joint dynamics of culture and institutions. The joint dynamics of culture and institutions is summarized by the phase diagram in the space $(\beta, q) \in [0,1]^2$ in Figure 4.[35] When initial conditions (β_0, q_0) are in the highlighted region in the figure and the conflict-prone group is powerful but relatively small, there are no institutional dynamics, no protection of property rights and a diffusion of the cultural traits of the conflict-prone group towards a long run value $\widehat{q}(\alpha)$. On the other hand, outside of this region of initial conditions the institutional dynamics evolve towards increasing the political power of the conflict-averse group, inducing more protection of property rights. Indeed the system converges towards an institutional set-up giving no power to the conflict-prone group ($\beta = 0$). In this case, $p^*(\beta, q) > 0$ along the equilibrium path and the interaction of the dynamics of institutions and culture leads progressively towards a reduction of the size of the conflict-prone group and in turn a reduction of the resources spent in conflict.

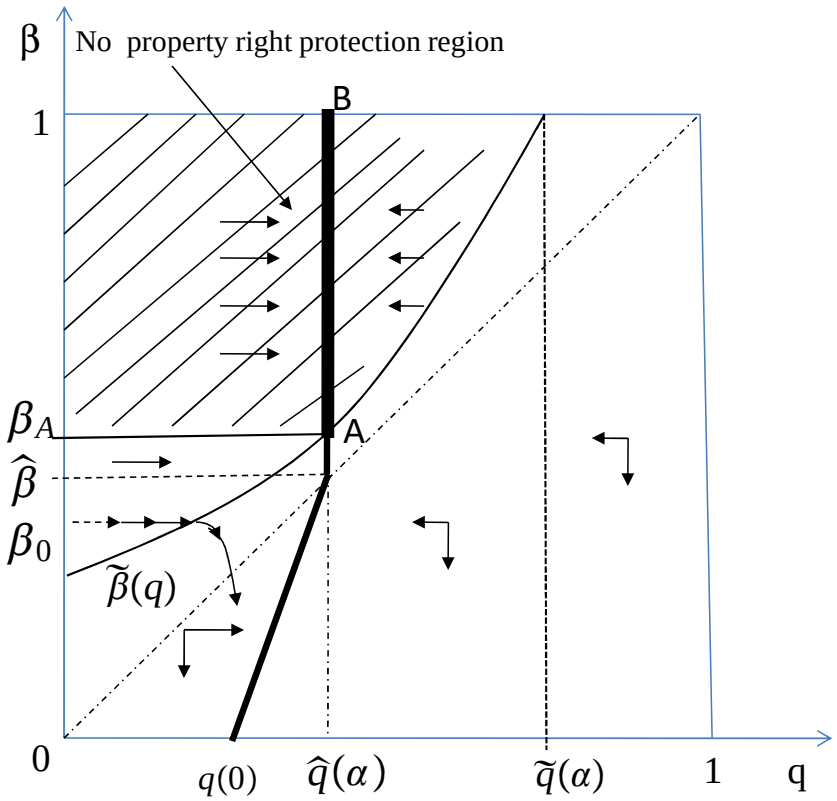
Interestingly, when the conflict-prone is initially at some intermediate degree of political power, i.e., such that $\beta_0 \in \left[\widetilde{\beta}(q_0), \beta_A\right]$, even a small fraction of conflict-prone individuals in society can be ultimately self-defeating in terms of institutional dynamics. While the system does not exhibit any institutional change, in this case, the underlying cultural dynamics tend to favor the socialization of the conflict-prone agents towards $\widehat{q}(\alpha)$. As soon as q_t passes the threshold of $\widetilde{\beta}^{-1}(\beta_0)$, endogenous institutional dynamics are triggered which induce the implementation of more extensive property rights and institutions biased in favor of the conflict-averse group. As a consequence, q_t regresses towards the long run steady state $q(0)$ and the conflict-prone group ends-up with no power ($\beta = 0$).

Similar non-monotonic dynamics of culture and institutions in this society may manifest themselves also as interesting forms of hysteresis after an exogenous institutional shock. Indeed a temporary shock giving more political power to the conflict-averse group might irreversibly take the system into a new long run trajectory of the institutional and cultural dynamics. Suppose for instance that the society has settled to a point like point A in Figure 5 with no property rights and $\widehat{q}(\alpha)$. A political power shock, e.g., reducing β below β_A, would induce an endogenous

it reduces their expected payoff when matched with conflict-prone agents, thereby reducing their incentives to transmit their own trait; but at the same time, a larger q also increases the cost of effort for conflict-averse agents whose children turn out to be conflict-prone and undertake effort a^{11} when facing other conflict-prone agents in a contest. It turns out that this last effect dominates.

[35] We consider for simplicity the case in which $\frac{c^2 - c^1}{c^1}$ is large enough, so that conflict-prone agents have a significant advantage in conflict. When instead the marginal effort costs c^i are similar across groups property rights are protected for any initial conditions. The joint dynamics of culture and institutions converge to a stationary state characterized by institutions giving all power to the conflict-averse group, supporting a maximal level of protection of property rights.

Figure 5: Property rights and conflicts
Joint dynamics ($\alpha = \frac{c_2}{c_1} - 1$ large enough)



institutional response conceding further power to the conflict-averse group. This in turn would trigger a complementary reinforcing cultural dynamics favoring this group. A successive opposite institutional shock of similar amplitude would not bring back the system towards to region with no property right protection. Indeed even when/if the conflict-prone group regains some formal power, the cultural dynamics might have irreversibly driven the system into a region of the phase diagram where property rights are protected.

This example illustrates the importance of initial institutional and cultural conditions for the long run of society and the non ergodicity properties of this system. It suggests that external interventions that change the balance of power domestically between groups may have long term effects in terms of institutional and cultural evolution.

5 Conclusions

Motivated by a rich rapidly expanding economic and historical literature studying institutional and cultural change, this chapter emphasized the role of explicit formal dynamic models in our understanding of socio-economic history. Coming back to the initial quote of Mc Closkey, systems of differential/difference equations are interesting frames useful to identify and organize historical narratives by means of simple phase diagrams between relevant historical state variables. In the context of the joint interactions of culture and institutions, this approach provides a simple and easily applicable analysis uncovering the nature and source of important feedback effects between these variables.

Indeed depending on whether culture and institutions are dynamic complements or substitutes, exogenous historical shocks propagating over the joint dynamics induced by institutions and culture may have magnified or mitigated effects on long-run socio-economic outcomes. Importantly, this type of analysis identifies the extent of the comparative dynamic bias that is generated by conditioning on one of the two dynamics, when the other one is affected by an exogenous shock (the *cultural and institutional multipliers*).

Again, consistently with Mc Closkey's view, this approach indicates that in general the joint evolution of culture and institutions has some highly non linear components. This feature has a number of implications involving for instance the fact that the dynamics of culture and institutions are prone to display sensitivity of equilibrium trajectories to initial conditions, existence of irreversibility and thresholds effects, and non-monotonicity of cultural and institutional changes over transition paths. From an empirical point of view, these phenomena appear quite consistent with the great diversity of development trajectories encountered across the world and in time. They also suggest that beyond standard causal identification strategies based on the use of specific instrumental variables or restricted natural experiments, focusing more structurally on the pos-

itive or negative interactions between prominent state variables such as institutions and culture along the development process might result more fruitful in terms of historical understanding, as well as in terms of policy implications.

Appendix on Property Rights and Conflict

In this Appendix we report the detailed characterization of the equilibrium dynamics in the example on Property Rights in Section 4.

Equilibrium expected payoffs. Given random matching in contests, the expected payoffs of conflict-prone and conflict-averse agents are:

$$\begin{aligned} U^1(p,q) &= p\omega + 2(1-p)\omega\left[\frac{q}{4} + (1-q)\left(\frac{c^2}{c^1+c^2}\right)^2\right] - F \\ U^2(p,q) &= p\omega + 2(1-p)\omega\left[q\left(\frac{c^1}{c^1+c^2}\right)^2 + \frac{(1-q)}{4}\right] \end{aligned}$$

Letting $c^1 = c$ and $c^2 = c(1+\alpha)$ with $\alpha > 0$:

$$\begin{aligned} U^1(p,q) &= p\omega + 2(1-p)\omega\left[\frac{q}{4} + (1-q)\left(\frac{1+\alpha}{2+\alpha}\right)^2\right] - F \\ U^2(p,q) &= p\omega + 2(1-p)\omega\left[q\left(\frac{1}{2+\alpha}\right)^2 + \frac{(1-q)}{4}\right] \end{aligned} \tag{10}$$

It readily follows that:

$U^1(p,q)$ is decreasing in q and

$$\frac{\partial U^1(p,q)}{\partial p} \geq 0 \quad \text{iff} \quad q \geq \widetilde{q}(\alpha) = \frac{\left(\frac{1+\alpha}{2+\alpha}\right)^2 - \frac{1}{2}}{\left(\frac{1+\alpha}{2+\alpha}\right)^2 - \frac{1}{4}};$$

$U^2(p,q)$ is decreasing in q and that

$$\frac{\partial U^2(p,q)}{\partial p} \geq 0.$$

Societal equilibrium. The expected payoffs of conflict-prone and conflict-averse agents in a *societal equilibrium* are given by:

$$G_1(p,q,a^{11},a^{12},a^{21}) = p\omega + q\left(2(1-p)\omega\frac{a^{11}}{a^{11}+a^{11}} - c^1a^{11}\right) + (1-q)\left(2(1-p)\omega\frac{a^{12}}{a^{12}+a^{21}} - c^1a^{12}\right) - F$$

$$G_2(p,q,a^{21},a^{12},a^{22}) = p\omega + q\left(2(1-p)\omega\frac{a^{21}}{a^{21}+a^{12}} - c^2a^{21}\right) + (1-q)\left(2(1-p)\omega\frac{a^{22}}{a^{22}+a^{22}} - c^2a^{22}\right)$$

where a^{ij} is the Nash equilibrium effort level exercised in a contest by an agent of type i matched with one of type j, for any $i, j \in \{1, 2\}$. It can be readily shown that the Nash equilibrium effort levels are:

$$a^{11} = \frac{2(1-p)\omega}{4c},\ a^{22} = \frac{2(1-p)\omega}{4c(1+\alpha)},\ a^{12} = 2(1-p)\omega\frac{1+\alpha}{c\,(2+\alpha)^2},\ a^{21} = 2(1-p)\omega\frac{1}{c\,(2+\alpha)^2}. \quad (11)$$

The public authority in the policy game chooses the level of property right protaction p to solve the following problem:[36]

$$\max_{p\in[0,1]} \beta G_1(p, q, a^{11}, a^{12}, a^{21}) + (1-\beta)G_2(p, q, a^{21}, a^{12}, a^{22}) - C(p)$$

taking as given the values a^{ij}, for any $i, j \in \{1, 2\}$. The First Order Condition of this problem are:

$$\begin{aligned} & \beta\omega\left[1 - 2\left(q\frac{a^{11}}{a^{11}+a^{11}} + (1-q)\frac{a^{12}}{a^{12}+a^{21}}\right)\right] \\ & +(1-\beta)\omega\left[1 - 2\left(q\frac{a^{21}}{a^{21}+a^{12}} + (1-q)\frac{a^{22}}{a^{22}+a^{22}}\right)\right] \\ = \quad & C'(p) \end{aligned}$$

At equilibrium, the level of property right protection p^* is then characterized by the following condition:

$$\beta\omega\left[1 - 2\left(\frac{q}{2} + (1-q)\frac{1+\alpha}{2+\alpha}\right)\right] + (1-\beta)\omega\left[1 - 2\left(q\frac{1}{2+\alpha} + \frac{(1-q)}{2}\right)\right] = C'(p). \quad (12)$$

As a consequence, we obtain the following characterization:

When $\beta < q$, the societal equilibrium policy outcome involves strictly positive protection of property right with $p^*(\beta, q) > 0$. Moreover $p^*(\beta, q)$ is decreasing in β and increasing in q. When $\beta \geq q$, there is no property right protection in the societal equilibrium (i.e., $p^*(\beta, q) = 0$).

Institutional Dynamics. The dynamics of the political weight of the conflict-prone group β_t, evolves according to the solution of the following program:

$$\beta_{t+1} = \arg\max_{\beta\in[0,1]} \beta_t V_1(\beta, q) + (1-\beta_t)V_2(\beta, q) \quad (13)$$

where $V_i(\beta, q) = U^i(p^*(\beta, q), q)$ are the societal equilibrium expected payoffs of members of group i. As in the text, in Section 4, consider the following auxiliary policy problem:

[36] We assume for regularity that the property rights cost function $C(p)$ is increasing and convex, i.e., $C'(p) \geq 0$, $C"(p) > 0$; and that it satisfies $C(0) = C'(0) = 0$, and $C'(1) = +\infty$.

$$\max_{p\in[0,1]} W(p,q,\beta) = \beta U^1(p,q) + (1-\beta)U^2(p,q) \tag{14}$$

Under the convexity assumption in Footnote 36, problem 14 has a unique solution. Using the expressions of $U^i(p,q)$ from (10), the solution p^{com} of this problem satisfies the following First Order Condition:[37]

$$\beta\omega\left[1-2\left(\frac{q}{4}+(1-q)\left(\frac{1+\alpha}{2+\alpha}\right)^2\right)\right]+(1-\beta)\omega\left[1-2\left(q\left(\frac{1}{2+\alpha}\right)^2+\frac{(1-q)}{4}\right)\right]=C'(p^{com}). \tag{15}$$

We obtain the following characterization, which we prove next:

If $1/\sqrt{2} < \phi(\alpha) = \phi(\alpha) = \frac{1+\alpha}{2+\alpha}$,

i) there exist a threshold $\widetilde{q}(\alpha) \in]0,1[$ *and an increasing function* $\beta = \widetilde{\beta}(q)$ *with* $\widetilde{\beta}(0) < 1$ *such that* $p^{com}(\beta,q) = 0$ *if and only if* $(\beta,q) \in [0,1]^2$ *are such that* $q < \widetilde{q}(\alpha)$ *and* $\beta \geq \widetilde{\beta}(q)$.

ii) When $p^{com}(\beta,q) > 0$, *then it is decreasing in* β *and increasing in* q.

iii) One has $p^*(\beta,q) \leq p^{com}(\beta,q)$.

Proof. To prove i) note that the First Order Condition of problem 14 implies that

$$p^{com}(\beta,q) = 0 \quad \text{when} \quad \beta \geq \widetilde{\beta}(q) = \frac{\frac{1}{4}+q\left[\frac{1}{4}-(1-\phi(\alpha))^2\right]}{q\left[\frac{1}{4}-(1-\phi(\alpha))^2\right]+(1-q)\left[\phi(\alpha)^2-\frac{1}{4}\right]}$$

with $\widetilde{\beta}(q) > q$ for all $q \in [0,1]$ and $\phi(\alpha) = \frac{1+\alpha}{2+\alpha}$, an increasing function of α. Notice as well that for all $\alpha > 0$, one has

$$\frac{1}{4} - (1-\phi(\alpha))^2 > 0 \text{ and } \phi(\alpha)^2 + (1-\phi(\alpha))^2 > \frac{1}{2}.$$

Moreover $\widetilde{\beta}(q) = 1$ at $\widetilde{q}(\alpha) \in (0,1)$ given by

$$\widetilde{q}(\alpha) = \frac{\phi(\alpha)^2 - \frac{1}{2}}{\phi(\alpha)^2 - \frac{1}{4}}.$$

Hence it follows that a $p^{com}(\beta,q) = 0$ if and only if

$$\frac{1}{\sqrt{2}} < \phi(\alpha) \text{ and } q < \widetilde{q}(\alpha).$$

It is also immediate to see that $\widetilde{\beta}(q)$ is increasing in q with

$$\widetilde{\beta}(0) = \frac{\frac{1}{4}}{\left[\phi(\alpha)^2 - \frac{1}{4}\right]} \quad \text{and} \quad \widetilde{\beta}(1) > 1.$$

[37] We assume the solution is interior.

To prove ii) note that, by differentiating the First Order Condition of problem 14, it follows that the (assumed interior) solution $p^{com}(\beta, q) > 0$ satisfies:

$$\frac{\partial p^{com}}{\partial \beta} < 0 \quad \text{and} \quad \frac{\partial p^{com}}{\partial q} > 0.$$

To show iii), i.e., that $p^*(\beta, q) \leq p^{com}(\beta, q)$, consider the difference of the Left-Hand-Side of the two equations (15) and(12) :

$$\beta\omega\left[1-2\left(\frac{q}{4}+(1-q)\left(\frac{1+\alpha}{2+\alpha}\right)^2\right)\right]+(1-\beta)\omega\left[1-2\left(q\left(\frac{1}{2+\alpha}\right)^2+\frac{(1-q)}{4}\right)\right]$$
$$-\beta\omega\left[1-2\left(\frac{q}{2}+(1-q)\frac{1+\alpha}{2+\alpha}\right)\right]-(1-\beta)\omega\left[1-2\left(q\frac{1}{2+\alpha}+\frac{(1-q)}{2}\right)\right].$$

This difference can be written as:

$$2\beta\omega\left[\frac{q}{2}+(1-q)\frac{1+\alpha}{2+\alpha}-\left(\frac{q}{4}+(1-q)\left(\frac{1+\alpha}{2+\alpha}\right)^2\right)\right]$$
$$+2(1-\beta)\omega\left[\left(q\frac{1}{2+\alpha}+\frac{(1-q)}{2}\right)-\left(q\left(\frac{1}{2+\alpha}\right)^2+\frac{(1-q)}{4}\right)\right];$$

and finally, as:

$$2\beta\omega\left[\frac{q}{4}+(1-q)\frac{1+\alpha}{(2+\alpha)^2}\right]+2(1-\beta)\omega\left[q\frac{1+\alpha}{(2+\alpha)^2}+\frac{(1-q)}{4}\right]>0$$

Hence $C'(p^{com}) > C'(p^*)$ and the result $p^*(\beta, q) < p^{com}(\beta, q)$ follow. Obviously, for $\beta > \widetilde{\beta}(q)$, $p^*(\beta, q) = p^{com}(\beta, q) = 0$. ■

Consider β_t. The solution $p^{com}(\beta_t, q)$ of problem 14 reflects the optimal choice of property right protection p a public authority with weights $(\beta_t, 1-\beta_t)$ wants to implement when it fully internalizes the impact of such choice on the agents equilibrium actions $a^{ij}(p)$. The resulting effort level in conflict $\left[a^{ij}(p^{com}(\beta_t, q))\right]_{i,j\in\{1,2\}}$ are therefore associated to the maximal social outcome from the point of view of this public authority, using a policy of protection of property rights $p \in [0, 1]$. The public authority designs an institutional structure $\beta \in [0, 1]$ such that this preferred outcome is implemented (when reachable) as an equilibrium outcome $\left[a^{ij}(p^*(\beta, q))\right]_{i,j\in\{1,2\}}$ of a feasible societal equilibrium with institutional weights $(\beta, 1-\beta)$.

Three cases may happen:

There exists $\beta \in [0, 1]$ is such that $p^*(\beta, q) = p^{com}(\beta_t, q)$. In such a case, the solution of problem (13) is to set $\beta_{t+1} = \beta$. Indeed, a societal policy game with a public authority with weights $(\beta, 1-\beta)$ generates the best possible equilibrium allocation from the point of view of the public authority with weights $(\beta_t, 1-\beta_t)$.

For all $\beta \in [0,1]$ $p^*(\beta,q) < p^{com}(\beta_t,q)$. In such a case, then the fact that $p^*(\beta,q)$ is decreasing in β and the concavity of $W(p,q,\beta_t)$ with respect to p, ensures that the best implementable policy that can be reached from the point of view of the public authority with weights $(\beta_t, 1-\beta_t)$ is obtained when $p^*(\beta,q)$ is as close as possible to $p^{com}(\beta_t,q)$, namely when $\beta_{t+1} = 0$. This ensures that the equilibrium societal policy game with a public authority with weights $(0,1)$ generates the best possible equilibrium allocation from the point of view of the public authority with weights $(\beta_t, 1-\beta_t)$.

For all $\beta \in [0,1]$ $p^*(\beta,q) > p^{com}(\beta_t,q)$. This case is symmetric to case ii). By the same reasoning setting $\beta_{t+1} = 1$ ensures that the equilibrium societal policy game with a public authority with weights $(1,0)$ generates the best possible equilibrium allocation from the point of view of the public authority with weights $(\beta_t, 1-\beta_t)$.

As a conclusion, the solution of problem 13 is given by:

$$\beta_{t+1} = \begin{cases} \beta \text{ such that } p^{com}(\beta_t,q) = p^*(\beta,q) & \text{if it exists} \\ \left[\begin{array}{ll} 1 & \text{if } p^{com}(\beta_t,q) > p^*(\beta,q),\ \forall 0 \le \beta \le 1 \\ 0 & \text{if } p^{com}(\beta_t,q) < p^*(\beta,q),\ \forall 0 \le \beta \le 1 \end{array} \right. & \text{else} \end{cases}.$$

Cultural dynamics. We adopt the economic cultural transmission model of Bisin and Verdier (2000a,b; 2001). Cultural transmission is modeled as the result of *direct vertical* (parental) socialization and *horizontal/oblique socialization* in society at large. Denote the cultural state of the population by $q^1{=}1-q^2=q$:

i) direct vertical socialization to the parent's trait $i \in I = \{1,2\}$ occurs with probability d^i;

ii) if a child from a family with trait i is not directly socialized, which occurs with probability $1-d^i$, he/she is horizontally/obliquely socialized by picking the trait of a role model chosen randomly in the population inside the political group (i.e., he/she picks trait i with probability q^i and trait $i' \neq i$ with probability $q^{i'}$.

Let $P^{ii'}$ denote the probability that a child, in (a family in) group $i \in I$, is socialized to trait i'. From i) and ii) above, we obtain:

$$P^{ii'} = d^i + (1-d^i)q^{i'}. \tag{16}$$

Let $V^{ii'}(p,q)$ denote the utility to a cultural trait i parent of a type i' child when the policy p is implemented and the state of the cultural population is q. Let $C(d^i)$ denote socialization costs.[38] Direct socialization, for any $i \in I = \{1,2\}$, is then the solution to the following parental

[38] We assume for simplicity and convenience that socialization costs are quadratic, $C(d^i) = \frac{1}{2}\left(d^i\right)^2$.

socialization problem:

$$\max_{d^i \in [0,1]} -C(d^i) + \sum_{i' \in I} P^{ii'} V^{ii'}(p,q), \text{ s. t. } (16).$$

As usual in this literature, define $\Delta V^i(p,q) = V^{ii}(p,q) - V^{ii'}(p,q)$ as the paternalistic motive to transmit trait i. It follows that the direct socialization, with some notational abuse, has the form:

$$d^i(p,q) = (1-q^i)\Delta V^i(p,q) \; i \in I = \{1,2\}. \tag{17}$$

The dynamics of culture $q_t^1 = 1 - q_t^2 = q_t$ is then governed by the following difference equation:

$$q_{t+1} - q_t = q_t(1-q_t)\left[d^1(p,q_t) - d^2(p,q_t)\right];$$

Evaluated at the societal equilibrium policy $p = p^*(\beta_t, q_t)$,, the dynamic equation becomes:

$$q_{t+1} - q_t = q_t(1-q_t)S(\beta_t, q_t); \tag{18}$$

where $S(\beta_t, q_t)$ is the relative cultural fitness of trait 1:

$$\begin{aligned} S(\beta,q) &= d^1(p^*(\beta,q),q) - d^2(p^*(\beta,q),q) \\ &= (1-q)\Delta V^1(p^*(\beta,q),q) - q\Delta V^2(p^*(\beta,q),q). \end{aligned}$$

In the specific case of our example, the socialization incentives $\Delta V^1(p,q)$ of conflict-prone agents are readily obtained:

$$\begin{aligned} \Delta V^1(p,q) &= q\left(2(1-p)\frac{\omega}{2} - c^1 a^{11}\right) + (1-q)\left(2(1-p)\omega\frac{1+\alpha}{2+\alpha} - c^1 a^{12}\right) - F \\ &\quad - \left[q\left(2(1-p)\omega\frac{1}{2+\alpha} - c^1 a^{21}\right) + (1-q)\left(2(1-p)\frac{\omega}{2} - c^1 a^{22}\right)\right]. \end{aligned}$$

After substitution of the Nash equilibrium a^{ij}, for all $i,j \in \{1,2\}$ from equation 11, these socialization incentives become:

$$\begin{aligned} \Delta V^1 &= 2(1-p)\omega\left[q\left(\frac{1}{4}\right) + (1-q)\left(\frac{1+\alpha}{2+\alpha}\right)^2\right] - F \\ &\quad -2(1-p)\omega\left[q\frac{1+\alpha}{(2+\alpha)^2} + (1-q)\frac{1+2\alpha}{4(1+\alpha)}\right] \\ &= 2(1-p)\omega\left[q\left(\frac{1}{4} - \frac{1+\alpha}{(2+\alpha)^2}\right) + (1-q)\left(\left(\frac{1+\alpha}{2+\alpha}\right)^2 - \frac{1+2\alpha}{4(1+\alpha)}\right)\right] - F \\ &= \frac{2(1-p)\omega\alpha^2}{4(1+\alpha)(2+\alpha)^2}\left[(3+\alpha) - q(2+\alpha)\right] - F \end{aligned}$$

Similar calculations for the conflict-averse agents produce the following expression for socialization incentives:

$$\begin{aligned}\Delta V^2 &= 2(1-p)\omega\left[q\frac{1}{(2+\alpha)^2}+(1-q)\frac{1}{4}\right]\\ &\quad -2(1-p)\omega\left[q\left(\frac{1}{2}-(1+\alpha)\frac{1}{4}\right)+(1-q)\frac{1+\alpha}{(2+\alpha)^2}\right]+F\\ &= 2(1-p)\omega\left[q\frac{\alpha^2}{4\,(2+\alpha)}+\frac{\alpha^2}{4(2+\alpha)^2}\right]+F>0\end{aligned}$$

The locus $q_{t+1}=q_t$ of stationary culture is then obtained from (18), as the set of points $(\beta,q)\in[0,1]^2$ such that

$$\frac{\Delta V^1(p^*(\beta,q),q)}{\Delta V^2(p^*(\beta,q),q)}=\frac{q}{1-q}. \tag{19}$$

After straighforward computations, we obtain

$$\frac{\Delta V^1(p,q)}{\Delta V^2(p,q)}=\frac{\frac{1}{(1+\alpha)}\left[(2+\alpha)\,(1-q)+1\right]-\frac{2F(2+\alpha)^2}{(1-p)\omega\alpha^2}}{q\,(2+\alpha)+1+\frac{2F(2+\alpha)^2}{(1-p)\omega\alpha^2}}=\Phi\left(q,p,\alpha\right).$$

It follows that $\Phi\left(q,p,\alpha\right)$ is a decreasing function of p and q.[39] The characterization of the interior cultural steady state is obtained from 19:

$$\Phi\left(q,p^*\left(\beta,q\right),\alpha\right)=\frac{q}{1-q}. \tag{21}$$

The Left-Hand-Side of equation (21) is a decreasing function of q. In fact, $\Phi\left(q,p,\alpha\right)$ is decreasing in q; $p^*\left(\beta,q\right)$ is increasing in q; and $\Phi\left(q,p,\alpha\right)$ is decreasing in p. The Right-Hand-Side of (21) is increasing in q and goes from 0 to ∞ when q goes from 0 to 1. Hence, since $\Phi\left(0,p^*\left(\beta,0\right),\alpha\right)>0$ by 20, it follows that Equation (21) has a unique solution $q=q(\beta)$ and $q(\beta)<1/2$. Moreover $q(\beta)$ is an increasing function of β. Finally there is a unique value $\widehat{\beta}\left(\alpha\right)$ such that $q\left(\beta\right)=\beta$. Indeed such β is determined by

$$\Phi\left(\beta,p^*\left(\beta,\beta\right),\alpha\right)=\Phi\left(\beta,0,\alpha\right)=\frac{\beta}{1-\beta};$$

or after substitution

$$\frac{1-\beta}{(1+\alpha)}\left[(2+\alpha)\,(1-\beta)+1\right]-\beta\left(\beta\left(2+\alpha\right)+1\right)=\frac{2F(2+\alpha)^2}{\omega\alpha^2}. \tag{22}$$

[39] We assume that F/ω is small enough,

$$\frac{F}{\omega}<\frac{(1-p\,(0,0))}{2(1+\alpha)}\left(\frac{\alpha}{2+\alpha}\right)^2\left[3+\alpha\right], \tag{20}$$

to ensure that for all $(\beta,q)\in[0,1]^2$, one has $\Delta V^1/\Delta V^2$ to be strictly positive. Otherwise we could get a cultural steady state without conflict-prone individuals.

Denote the Left-Hand-Side of (22) as a function $\Sigma(\beta,\alpha)$. Simple differentiation shows that $\Sigma(\beta,\alpha)$ is decreasing in β and takes value $\Sigma(0,\alpha)=\frac{4+\alpha}{1+\alpha}>0$ and $\Sigma(1,\alpha)=-((2+\alpha)+1)<0$. Therefore, 20 implies

$$\frac{2F(2+\alpha)^2}{\omega\alpha^2}<\frac{(1-p(0,0))}{(1+\alpha)}[3+\alpha]<\frac{4+\alpha}{1+\alpha}=\Sigma(0).$$

We conclude that there exists a unique value $\widehat{\beta}(\alpha)\in(0,1)$ satisfying (22); and there exists a corresponding unique value $\widehat{q}(\alpha)=q(\widehat{\beta}(\alpha))$.

Joint dynamics of culture and institutions. We can show the following result, which we prove next,

The dynamics of culture and institutions represented in the phase diagram in Figure 4 holds for $\alpha=\frac{c^2}{c^1}-1$ *large enough.*

Proof. Recall that $\widetilde{\beta}(q)=1$ at a value $\widetilde{q}(\alpha)\in(0,1)$ given by

$$\widetilde{q}(\alpha)=\frac{\phi(\alpha)^2-\frac{1}{2}}{\phi(\alpha)^2-\frac{1}{4}},$$

with $\phi(\alpha)=\frac{1+\alpha}{2+\alpha}$. Consider then

$$\Sigma(\widetilde{q}(\alpha),\alpha)=\frac{1-\widetilde{q}(\alpha)}{(1+\alpha)}[(2+\alpha)(1-\widetilde{q}(\alpha))+1]-\widetilde{q}(\alpha)(\widetilde{q}(\alpha)(2+\alpha)+1).$$

Recall that $\widetilde{q}(\alpha_{\min})=0$ and $\lim_{\alpha\to\infty}\widetilde{q}(\alpha)=\frac{2}{3}$, for $\alpha_{\min}=\frac{2-\sqrt{2}}{(\sqrt{2}-1)}$. It then follows that

$$\Sigma(\widetilde{q}(\alpha_{\min},\alpha_{\min}))=\frac{(3+\alpha_{\min})}{(1+\alpha_{\min})}>\frac{(1-p^*(0,0))}{(1+\alpha_{\min})}[3+\alpha_{\min}]>\frac{2F(2+\alpha_{\min})^2}{\omega\alpha_{\min}^2};$$

and therefore that $\widetilde{q}(\alpha_{\min})<\widehat{\beta}(\alpha_{\min})=\widehat{q}(\alpha_{\min})$. Clearly, this also holds for α close enough to $\alpha_{\min}$, by continuity. Similarly

$$\lim_{\alpha\to\infty}\left[\Sigma(\widetilde{q}(\alpha),\alpha)-\frac{2F(2+\alpha)^2}{\omega\alpha^2}\right]=\lim_{\alpha\to\infty}\Sigma(\widetilde{q}(\alpha),\alpha)-\frac{2F}{\omega}=-\infty.$$

Thus, for α large enough,

$$\Sigma(\widetilde{q}(\alpha),\alpha)<0<\frac{2F(2+\alpha)^2}{\omega\alpha^2}=\Sigma(\widehat{q}(\alpha),\alpha);$$

and therefore $\widehat{q}(\alpha)<\widetilde{q}(\alpha)$. ■

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