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Reform paths and institutional resilience

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Abstract

Broadly speaking, institutional reformers decide about the sequencing of types of reforms, either addressing institutional quality or macroeconomic stability. This paper develops a dynamic population game, in which agents play a simple anonymous-exchange game of cooperating or defecting. Agents switch to the strategy with higher expected payoff. Reformers can affect the payoff structure of the stage game in order to maximize the number of cooperators in the population by either enacting legal reform (rule of law) or focusing on the macro outlook of the economy facilitating cooperation. Reform is cumulative and starts from initial conditions. Reform effort per period of time is capped. On the basis of the theoretical model the paper makes predictions under which conditions which types of reforms should be enacted first and under which conditions reform will not be successful. In addition, the notion of institutional resilience is introduced as a minimum threshold of legal quality, which allows the population to better withstand exogenous shocks.

JEL codes: C61, C72, C73, D78, P16

Declaration of interest: none

1 Introduction

I propose a theoretical model of the sequence of reform on the basis of a population game. Agents in an economy play a simple anonymous exchange game in which they can either carry out the promise of a contract or renege on it. Over time, agents adjust their behavior in the game switching to the strategy with a higher expected payoff. A reformer can step in and alter the payoffs in the stage game and thereby influence individual behavior and the overall payoff of the population.

The model captures stylized facts about the interplay between fundamental coordination problems and a society's institutional responses to them. First, reform takes time because institutions can only be changed in a piecemeal fashion. That is, a reformer cannot simply choose the 'efficient' level of an institution, but has to deal with initial conditions, which can be gradually adjusted. Second, different reform efforts can either aim at the general macro economic outlook in the economy or address the institutions of a country. That is, there are distinct types of reforms that can be implemented. Third, optimal sequencing of types of reforms depends on the fundamentals of the game agents play and the initial conditions a country faces. Fourth, reform can be too little, too late. Depending on the underlying structure of the societal game and the initial conditions, if reform is enacted too late, the society will take a long time to reach a desired equilibrium, because the population has already gone too far into the basin of attraction of the undesired equilibrium. On the other hand, and fifth, it is also possible that late reform still leads to a success story. It depends on the structure of the game and the model can make predictions about the conditions under which this is possible. Sixth, the same equilibrium play can be reached with different levels of institutional quality. This depends again on initial conditions and the type of chosen reform paths.

While the model is meant to be general enough to capture generic reform efforts in any environment, it is in part inspired by the experience of post-

socialist transition countries in the 1990s. Tracking their reform progress over time a clear pattern emerges. While all Central and Middle European transition countries fell into an early recession, after a while some managed to start growing consistently while others did not. The transition literature early on discussed the problem of sequencing of reform as one of the root causes for the divergent experiences of countries, that is, the fundamental question which kind of institutional reforms should come first or whether the macro economic environment should be gotten under control first. There the focus was primarily on privatization and market liberalization efforts. Roland (2000) and Havrylyshyn (2006) provide overviews of these debates. Relatedly, in his account of the transition period, Havrylyshyn (2006) develops a model, in which early reforms have a lasting impact on a country, because they set it on a path of a virtuous cycle where investment and growth follow. If early reforms do not come forth, corruption becomes entrenched and the country is trapped in a vicious cycle, which is hard to escape. My model captures this basic idea of a country slipping towards a bad equilibrium, although corruption per se is not needed for that, just plain inaction. Ialnazov and Nenovsky (2011) model the transition process as a game, in which the equilibria change because of reform and economic development. They argue that early transition from socialism is characterized by the low-payoff equilibrium of a prisoners' dilemma. Over time, payoffs and incentives change making it possible for players to cooperate.

In terms of modeling strategy, my model is squarely in the tradition of Aoki (2001) and Bowles (2004). The basic idea is to express the coordination problems present in all societies as simple stage games, which provide a micro foundation of interactions between firms or individuals or other entities in an economy. This basic approach in terms of methodology is, to name but a few, also present in Nunn (2007) for the choice between productive work and crime, or Acemoglu and Jackson (2015) for general choices of cooperating or not cooperating, or, more recently, Bowles and Choi (2020) for the choice

between dividing gains or fighting over them and its impact on the formation of property rights.

In my model, the basic stage game captures the fundamental challenge of anonymous exchange; will the contract partner fulfill the contract, or not? Thus, any player employs one of two strategies, cooperate or deviate from the contract. On this basis, reform will then change the payoff structure of the underlying game in two ways. First, strengthening the rule of law, or institutional, legal reform, allows a wronged party to seek damages in court. Second, affecting the overall macro outlook of the economy, the gains from cooperation can be increased as a result of decreased uncertainty. These two effects constitute the main trade off for a reformer in this model. The game is then embedded into a population game, in which the dynamics of the different strategies can be studied. Individuals in the population change behavior according to which strategy promises higher expected payoffs. This creates different possible equilibria of the game, which can be stable or unstable. In this set-up, the reformer's goal is then to guide the population as fast as possible to a situation where all individuals stick to the agreed contracts. At the same time the reformer takes into account the direct welfare effect any reform type will have. Reform therefore has a double impact. On the one hand, it influences behavior and in this way impacts on the adjustment processes within a population. This constitutes an indirect effect on the total payoff from population game. On the other hand, reform directly changes the total payoff in the population by directly impacting on the payoffs of the underlying game.

There are reasons to believe that the baseline model underestimates the effects of the rule of law, because it focuses on its very narrow sense as a transfer of resources from a defendant to a plaintiff. Rule of law, of course, is much more than this. Therefore, in an extension to the basic model, I introduce a notion of *institutional resilience* of the population, which is related to a minimum level of rule of law. The concept of resilience is well

established in ecology, where it refers to the ability of an ecological system to revert to its original form or function after a shock (Holling, 1973). The concept has made inroads into economics mainly through dynamic risk management of environmental factors and climate change. See Li et al. (2017) for an overview of this literature. In the context of the model presented here, the notion of institutional resilience captures the role that a functioning legal system can play in averting an unraveling of the population in the wake of an exogenous shock. Given the reasonable assumption that the macro outlook in a population depends to a considerable degree on outside factors beyond a reformer's control, this variable can be affected by exogenous shocks. At the moment an adverse shock hits, if the quality of the rule of law is not sufficiently high, the population is at risk of being put on a path towards a stable no-cooperation equilibrium. A minimum level of rule of law ensures that the negative effects of an exogenous shocks can be contained by stabilizing the population at a stable equilibrium and avoiding entering the basin of attraction of the no-cooperation equilibrium. This line of reasoning introduces a long-term consideration for the rule of law alongside the more immediate problem of guiding a population of agents towards cooperating. In this sense, a high enough quality of the legal system can be understood as *institutional resilience* of the population. Institutional resilience gained through the quality of the legal system neither prevents exogenous shocks from happening nor does it completely insulate the population from adverse effects on the payoff. But, in the wake of a shock⁹, resilience can help stabilize the population and ensure that cooperation does not entirely break down.

The model highlights the institutional complementarity between long-term cooperation and the strength of the enforcement of property rights. The rule of law undergirds a population, a society, because it can help contain the damage in case of exogenous shocks. It is well known that long-term cooperation is the result of self-enforcing, mutually beneficial contracts. But

it is a functioning legal system that prevents this system from fully collapsing in the event of a crisis.

2 A dynamic model of reform

The fundamental idea of the model is the following. In an infinitely large population of agents, each agent is randomly matched to play a symmetric one-shot stage game with one other player. Therefore, in a first step, I will present an augmented version of a model used by Bowles (2004, chapter 7) as the stage game. It is important to understand, and it will be made more precise at a later stage, that the agents adopt one of the pure strategies of this game as their employed strategy. As time goes by agents will change strategies depending on the difference of expected payoffs between strategies. On the basis of the stage game I will then discuss different reform types and how they impact the stage game and how reform can develop over time. At that point, I will put the stage game into a population game and describe the dynamics of the prevalence of the strategies more precisely. Finally, I will formulate a dynamic optimization problem and present and discuss the results.

2.1 Stage game

The stage game has two possible strategies, *Cooperate* or *Defect*. This set-up is meant to be general enough to capture all sorts of contractual relationships, which can be seen as anonymous exchange. Suppose a contract is written for the production and delivery of an input and this contract is not a spot contract. In terms of this model to play *Cooperate* is to honor the contract and to play *Defect* is to renege on it.

If both players cooperate the pairing results in a payoff of 1 for each. Mutual cooperation now allows for the possibility that agents parlay their random encounter into a repeated interaction. With ρ as the probability of

	Cooperate	Defect
Cooperate	$\frac{1}{1-\rho}$	$b + \theta(1 - b)$
Defect	$c - \theta(1 - b)$	0

Figure 1: Row player's payoffs in the stage game

repeated interaction, the expected number of rounds becomes $\frac{1}{1-\rho}$. However, if the other player defects, a cooperator incurs a loss of $b < 0$ and the relationship ends right away. In this case the cooperator seeks damages through the legal system. Damages in this model cover the difference between the expectation to earn 1 and the actual payoff b , so $1 - b$.¹ The variable $\theta \in [0, 1]$ captures the probability that the court awards damages. A defector can earn a rent $c > 1$ if the partner happens to cooperate. If deemed liable by the court, again, this occurs with probability θ , the defector pays damages $1 - b$. If both defect, each earns 0 and the relationship ends right away. Figure 1 gives the row player payoffs of the symmetric game.

I assume that $c > 1$ and $b + c < 2$. This implies that with $\theta = \rho = 0$ the game constitutes a prisoners' dilemma with defecting as dominant strategy, but in which cooperation of both players would be welfare maximizing.

2.2 Reform types

Against the backdrop of the game agents in this society play an institutional reformer can carry out two types of reform. The first type addresses the institutional quality, or, rule of law, which will be represented by the efficiency of the legal system. More to the point, efficiency is captured by θ , the probability that one contracting party can recover damages in a court of

¹From a law-and-economics perspective these are expectation damages. Other types exists, such as reliance damages $-b$. This would not change the analysis.

law. As mentioned above, if player 1 plays Cooperate while player 2 plays Defect, player 1 can seek redress in court. The higher the institutional quality of the legal system the higher the probability that player 1 is successful in gaining damages. This implies certainly a broad range of what the reformer could specifically do to affect the variable θ . For example, the commercial code could be updated or streamlined to make its application more readily available. Also, the training of judges could be improved, more personnel helping with a backlog of cases could be hired, or incentives for judges for speedy resolution of cases as a whole could be made more favorable. All of this has an impact on how the institution of resolving a contractual dispute in courts can be improved and it is all captured in θ .

The second type of reform impacts the general economic outlook of the economy. This entails any measures, which would make the macro outlook in the economy more stable, for example, getting inflation under control. Recall from the discussion of the stage game that in principle the one-shot game can be translated into a repeated relationship. This is captured by ρ , the probability that the pairing continues for one more round in the future. Now, the more stable and the more predictable the economic outlook the higher the likelihood that agents are willing to plan ahead and therefore feel inclined to enter repeated interactions. If future expectations are favorable and predictable, that is, if agents expect future economic growth, low inflation, and so on, and both agents play Cooperate, this increases the chance that the one-shot relationship is developed into a recurring one.² Keep in mind that the stage game attempts to capture anonymous exchange. It is certainly the case that in periods of an unfavorable economic outlook, such as during a period of hyperinflation, individuals retreat to personal relationships, informal dealings, and barter. In terms of the stage game this would

²This could easily be operationalized keeping ρ exogenous. With an inflation rate π future incomes are depreciated by a factor $(1 + \pi)^{-1}$, so the expected payoff from a repeated interaction would become $(1 - \rho(1 + \pi)^{-1})^{-1}$. Now, all else equal, decreasing inflation increases the expected payoff.

actually be expressed by playing Defect in an anonymous setting. In my model the result of mutual cooperation can be the creation of *new* repeated business interaction, possibly taking up a lengthy project which would need continuous attention by both parties over an extended period of time. In this case, a favorable economic outlook clearly fosters this kind of relationship. But one can envision also other kinds of reforms having a similar impact on the probability that players enter a repeated game, such as investment in infrastructure, or entering into trade agreements. What is important for the model at hand is that the reformer can influence the number of repeated interactions by creating a stable, predictable and favorable outlook for the economy. Stated differently, this reform variable is aimed at reducing the degree of uncertainty from the point of view of the players. For the sake of the workings of the model I assume that the reformer can simply directly impact the variable ρ .

To summarize, I have two types of reform in mind. The first one increases the efficiency of the institutional set-up, specifically, of the legal system. In this way, the off-diagonal payoffs of the game in Figure 1 are affected by decreasing the expected value of defecting and increasing, all else equal, the expected value of carrying out the contract. The second type of reform aims at making cooperation between individuals more attractive, independent of the institutional framework in which they find themselves. Technically, this affects the upper left cell of the game in Figure 1.

Reform choice will be captured by the reform variable $\mu \in [0, 1]$. This can be interpreted as the weight that the reformer puts on either of the two reforms. Using the common “dot notation” of a derivative with respect to the time, the change of the two variables follows two differential equations:

$$\begin{aligned}\dot{\theta} &= \mu(1 - \theta) \\ \dot{\rho} &= (1 - \mu)(1 - \rho)\end{aligned}$$

Focusing entirely on institutional reform (θ) means setting $\mu = 1$, whereas throwing all reform effort at the economic outlook (ρ) implies $\mu = 0$, accordingly. Both reform types exhibit decreasing returns throughout the entire reform period and neither variable would actually reach the value 1.

The economy starts with initial values, θ_0 and ρ_0 . Initial conditions are important in this model. The reformer cannot simply choose an optimal level in either of the variables, but rather has to decide, which variable should be marginally increased in each period. In other words, reform is piecemeal and cumulative. Either reform type is costless for the reformer. This assumption is without loss of generality, because I focus on the sequencing of reforms.

2.3 Population dynamics

The next step is to embed the stage game into a dynamic population game. In each instant of time members of the population are randomly paired to play the one-shot stage game of anonymous exchange. Each player in the population starts with a pure strategy that they stick to. Denote v_i , $i \in \{c, d\}$ the expected values of each pure strategy, and x the fraction of the population employing strategy Cooperate at any instant of time. Then $1 - x$ gives the fraction playing Defect. It is easiest to think of members of the population to fall into either of two categories: they are either coordinators or defectors, meaning they play either of the two pure strategies when they are matched to play the game. Over time, however, these roles can be changed as players can learn about the relative payoffs from either of the two roles. In general, one would expect that over time those strategies that promise a higher expected payoff will increase in prevalence in the population, while those with a lower payoff should wane, or, formally:

$$\begin{aligned}\dot{x} > 0 &\iff v_c > v_d \\ \dot{x} < 0 &\iff v_c < v_d \\ \dot{x} = 0 &\iff v_c = v_d\end{aligned}$$

The simplest way to formalize this is to use a linear equation:

$$\dot{x} = v_c - v_d \quad (1)$$

The linear dynamics go back to Friedman (1991) where the right hand side is still divided by the number of available strategies. Lahkar and Sandholm (2008) offer a behavioral interpretation: If a player experiences their chosen strategy earning less than an unweighted average of all available strategies, this player considers switching strategies. The propensity to switch is greater the smaller the fraction of players still employing this player's strategy.³ For the game in Figure 1 the dynamic (1) becomes:

$$\dot{x} = \begin{cases} 0 & \text{if } x = 0 \\ x \left(\frac{1}{1-\rho} - b - c \right) + b + \theta(1 - b) & \text{if } x \in (0, 1) \\ 0 & \text{if } x = 1 \end{cases}$$

This first-order differential equation has possibly one interior stationary point ($\dot{x} = 0$) which does not have to be necessarily $\in [0, 1]$. For $x = 0$ and $x = 1$ stationarity has to be imposed, otherwise the system would leave the simplex.

As can be seen from (1), the evolutionary process is analyzed on a deterministic model. Recall that, firstly, the number of individuals playing the stage game is assumed to converge to infinity, and secondly, the time horizon of the analysis is going to be finite. If these two assumptions are met, the stochastic Markov process of how the variable x changes over time can be approximated by the deterministic dynamic.⁴

The latter assumption of a finite time horizon is justified since the focus is on a period of institutional reform. The assumption of infinite population size is congruent with the aim to analyze the role of institutions in fostering

³In this case the choice of a linear dynamics in (1) is more general than it might appear at first glance. For two-strategy stage games of two players the rest points and their stability are exactly the same as in other dynamics, such as the replicator dynamics or a best-response dynamics. The out-of-equilibrium direction of change is also the same, but the speed of the linear dynamic differs from the aforementioned alternatives.

⁴This result is known as Kurtz's theorem, see Sandholm (2011, p. 370).

anonymous exchange. If populations were small, the idea that contract partners are randomly matched to play an anonymous game would be lost. In addition, the assumption of an infinitely large population allows me to ignore sub-population effects that come from those cooperators, who form repeated interactions. These pairs are not taken out of the population, but still play on to be potentially matched with a new partner where the probability of being matched with the exact same previous partner converges to zero.

2.4 A dynamic optimization problem

At this point, the choice of the reformer comes into play. I assume that the reformer's goal is to get the fraction of cooperators to a 100 percent as fast as possible, in other words, to steer the society to $x = 1$ as quickly as possible by choosing the reform variable μ . Time t is continuous. However, in addition to the goal of speed, the reformer realizes that once $x = 1$ is reached in some time $t = T$ in the future, this creates a payoff for the population. This implies that, in mathematical terms, the dynamic optimization problem involves a salvage value, once the reform effort is over. The salvage value is given by the total payoff generated from the game $\Omega = \delta \left(2x^2 \left(\frac{1}{1-\rho} - b - c \right) + 2x(b + c) \right)$, which is then evaluated at $t = T$. At the time T the reform effort is over and the payoff from the game accrues from then on. This is expressed by the discount factor $\delta = \int_T^\infty e^{-rt} dt$. Suppressing the dependence on the time for the variables x , ρ , θ and μ , the dynamic optimization problem can be written as:

$$\min_{\mu} T - \Omega \quad \text{subject to} \quad (2)$$

$$\dot{x} = x \left(\frac{1}{1-\rho} - b - c \right) + b + \theta(1 - b) \quad (3)$$

$$\dot{\theta} = \mu(1 - \theta) \quad (4)$$

$$\dot{\rho} = (1 - \mu)(1 - \rho) \quad (5)$$

$$0 \leq \mu \leq 1 \quad (6)$$

See the appendix for a full-fledged treatment of this dynamic optimization problem, which provides proofs of all subsequent claims.

Any solution to a dynamic optimization problem describes a temporal path of the choice variable. The following lemma does this for the choice of the reform variable μ .

Lemma 1. *In each period t the reformer chooses the reform variable $\mu(t)$ according to:*

$$\mu(t) = \begin{cases} 1 & \text{if } \Delta(t) > 0 \\ 0 & \text{if } \Delta(t) \leq 0 \end{cases}$$

with

$$\Delta(t) = \int_t^T \lambda_1 \left((1 - \theta)(1 - b) - \frac{x}{1 - \rho} \right) d\tau - \frac{\delta}{1 - \rho_T} \quad (7)$$

and λ_1 as the costate variable associated with state equation (3). λ_1 is a function of $\rho(t)$, b , c , t and T .

Equation (7) expresses the fundamental challenge facing the reformer. In any moment of time, any decision taken about how to allocate reform effort will cause ripple effects through the entire reform period since changed variables today change the future path of the system. This is why, formally, the choice in each period t is expressed as an integral from t to the final period T . The costate variable, λ_1 , represents the dynamic shadow price of the fraction of cooperators, x . The most useful way to think about it is the following: λ_1 measures by how much faster the goal of $x = 1$ is reached, that is, by how much T is reduced, if in any period of time x were marginally increased. In this sense, it represents how much the reformer values having a higher value of x at any point during the reform process. Then the integral in (7) measures the differential impact between a reform on θ and a reform on ρ on the evolution of x . Suppose that $\mu = 1$. Then the evolution of x changes by $\frac{\partial \dot{x}}{\partial \theta} \cdot \dot{\theta}$, which is equal to $(1 - \theta)(1 - b)$ in each period. Similarly, suppose $\mu = 0$. Then the impact on the change in x is given by $\frac{\partial \dot{x}}{\partial \rho} \cdot \dot{\rho}$, which

equals $\frac{x}{1-\rho}$. The difference between the two effects is valued in each period by the future value of its impact on the shortening of the reform period, λ_1 .

Whereas both reforms impact the evolution of the variable x , ρ also increases the salvage value Ω in (2), because it leads to an increase of the payoff from the game independent of the value of x . This effect is represented by the term $\frac{\delta}{1-\rho_T}$ in (7). This is not true for θ , because it constitutes a transfer of resources from defendants to plaintiffs, which cancels in the welfare calculus.

On a fundamental level, the reformer trades off different effects of reforms, both on the speed of reform and on the direct change in welfare.

The foregoing discussion leads to the first result in the following:

Lemma 2. *In the last period T the reformer chooses $\mu = 0$.*

This result is straightforward and easy to see. Once the system has arrived at $x = 1$ the reformer has no use for a yet increased value of θ , since at this point only the variable ρ will impact the welfare going forward. Relatedly, to choose a reform on ρ it is sufficient to have the marginal benefit per time of increasing ρ greater than for θ :

Proposition 1. *$x_0 \geq (1 - \rho_0)(1 - \theta_0)(1 - b)$ is a sufficient condition for choosing $\mu = 0 \forall t \in [0, T]$.*

There are two reasons for this. First, as stated above, ρ has the double impact of affecting both the evolution of x and increasing welfare. Second, the marginal effect is increasing over time. In other words, there are increasing marginal returns to the kind of macroeconomic reform modeled in this case.

If the reformer chooses to start with reforming θ in $t = 0$, then there will be one switch to ρ throughout the reform period at a time t^* . This follows from Lemma 2. In this case it is necessarily true that in $t = 0$, the marginal benefit of θ is greater than for ρ . This is made precise in the following Lemma.

Lemma 3. *$x_0 < (1 - \rho_0)(1 - \theta_0)(1 - b)$ is a necessary condition to choose $\mu = 1 \forall t \in [0, t^*]$ with $0 \leq t^* < T$.*

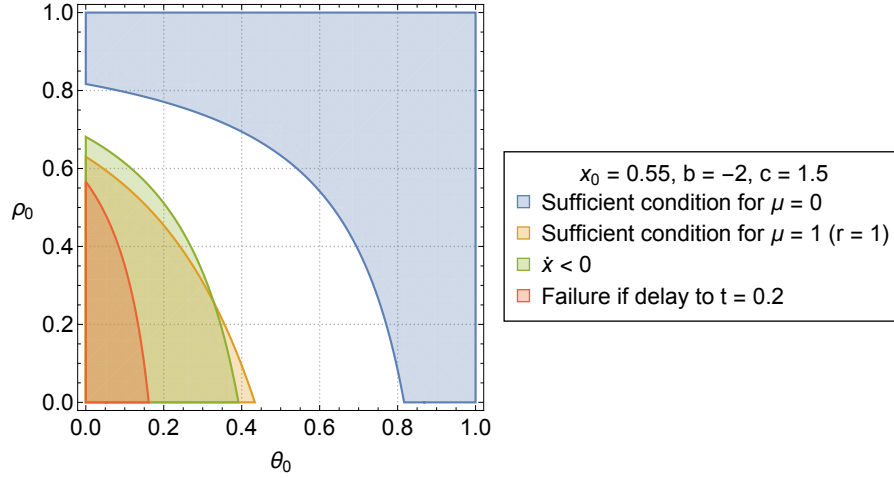


Figure 2: Numerical example

However, this condition is not sufficient, because, as stated already above, not only does the marginal benefit of θ on the increase in x have to be larger than the marginal benefit of ρ on x , but this has to be larger than the effect ρ has on the welfare. One can imagine a situation in which the reformer would choose to reform ρ even if the marginal effect of θ would be stronger on the evolution of x . This is the case if the added payoff to the population game as a whole that comes from ρ outweighs the slower adjustment of x .

In sum, there are two regimes which a dynamically optimizing reformer will choose. Under the first “institutions-first”-regime, the reformer will initially put all reform effort towards institutions and then switch to reforming—again, using all reform capacity—the economic outlook. In the second regime only the economic outlook is attended to for the entire time it takes the society to arrive at $x = 1$.

For illustrative purposes, the choice in $t = 0$ for different values of the initial values θ_0 and ρ_0 is represented in Figure 2. The initial situation has 55 % of the population being cooperators in a game with values $b = -2$ and $c = 1.5$. For all combinations of θ_0 and ρ_0 that lie within the green-

colored region, the share of cooperators is declining ($\dot{x} < 0$). For all combinations within the yellow-shaded region⁵ the reformer will embark on the institutions-first regime, whereas for all remaining possible combinations the second approach of only reforming ρ for the entire reform period is preferred. Part of the latter—the blue-shaded area—has the marginal effect of ρ on x greater than for θ . The area between the yellow and the blue part represents all combinations of the initial values where ρ is chosen even though the direct effect coming from θ is larger.

3 Discussion and extensions

The following proposition summarizes some comparative statics results.

Proposition 2. *The reformer is more inclined towards reforming ρ only, (i) the greater x_0 , (ii) the greater θ_0 , (iii) the greater ρ_0 , (iv) the smaller (in absolute value) b , and, (v) the greater c .*

Put simply, the worse the initial structural conditions, the higher the marginal payoff from institutional reform. Stated differently, if things are bad the reformer will have to focus on institutional reform first ignoring any direct welfare effects. In terms of the exchange game that players play, the rule of thumb for the reformer should be, on the one hand, to make sure it pays to cooperate (impact on ρ) if the “temptation value” of defecting, c , is high, and, on the other hand, to make sure defecting is punished (increase θ) if the “sucker value”, b , of cooperating is bad.

Under which conditions is it dangerous for a reformer to delay reform? Referring back to Figure 2, this will obviously only be a problem if the population starts out at a point where the change of cooperators is negative (green area). The following proposition provides a rule of thumb for a situation, in which even a prompt reform would not lead to the desired outcome.

⁵A quadratic approximation was used in order to arrive at these conditions, see the appendix for details.

Proposition 3. *If, in any t , approximately $\ddot{x} \leq \frac{(\dot{x})^2}{2x}$, reform will not be successful.*

The term \ddot{x} can be roughly interpreted as the returns to scale of reform. The greater \ddot{x} the more increasing the marginal return of any reform on the evolution of x becomes. Stated differently, if these returns are too small, relatively speaking, reform will not carry enough heft to lift the population towards the goal of $x = 1$.

There is an important corollary to the statement expressed in Proposition 3. All else equal, the smaller \ddot{x} the more dangerous it becomes for a reformer to delay reform, because the population will have moved too far into the basin of attraction of $x = 0$. Going back to Figure 2 this is illustrated by the red-colored area. It represents the combinations of θ_0 and ρ_0 for which a delay of $t = 0.2$ periods would render any reform effort a failure.

The statement in Proposition 3 can be turned around and written out in more detail. Swift reform will be successful if in any period the following holds:

$$\dot{x} \left(\frac{1}{1-\rho} - b - c \right) + (1-\mu) \frac{x}{1-\rho} + \mu(1-\theta)(1-b) > \frac{(\dot{x})^2}{2x} \quad (8)$$

This equation expresses the same fundamental idea as discussed above, but from a different vantage point. If the reformer finds themselves in a situation where the mere success of bringing the population to $x = 1$ is in question, in other words, a situation where the hurdle of this inequality can only be cleared just so, the total focus must be on the relative effect of each reform on the evolution of x . These are given by the second and third term on the left-hand side of (8), respectively. Then $(1-\theta)(1-b) > (<) \frac{x}{1-\rho}$ will lead the reformer to set $\mu = 1(0)$, because this maximizes the left-hand side of (8). As soon as the initial conditions are such that (8) is comfortably met, the trade-off between speed of adjustment and increasing the direct total payoff from the game comes into play.

As a rule of thumb, bad initial structural conditions will push a reformer to focus on institutional reform first. The model makes a very strong case

in favor of institutional reform as the basis of any reform. At the same time, the model arguably downplays the importance of institutional reform for at least two reasons. First, the model does not allow for spillover effects from institutions in the narrow legal sense to the overall institutional system of the economy and on the future macro outlook by individuals. To be more precise, while the model allows for an indirect effect of institutions on welfare by influencing individuals' behavior, there might very well be a more direct effect coming from positive externalities that good institutions have on different domains in society. This increases the importance of institutions even more.

In addition to that, the importance of institutional reform is heightened for a second reason. Broadening the scope a little bit, whereas the reformer has full control over the quality of the legal institutions, the macro economic outlook, or, at least, how the level of uncertainty is perceived by players, will be influenced by factors beyond the reformer's control. In other words, the value of ρ is partially exogenously determined. Take the simple example of a global economic slowdown as a result of conflict or a pandemic. In the language of the model presented here, this could let the value of ρ plummet. In this broader context, there is a case to be made that a minimum threshold for the quality of legal institutions must be reached in order to make the population resilient to an exogenous shock of this kind. In order to appreciate this point, it is crucial to understand what types of games the reformer can actually induce by changing the payoff matrix. Depending on the relative values of θ and ρ , for given values b and c , the reform path takes the population through different game types. For the stage game in Figure 1 four game types are possible, a prisoners' dilemma (PD), a hawk-dove (chicken) game (HD), a coordination game (CD) and a cooperate-dominance game (D). The four game types and the stability of their rest points are summarized in Table 1. In principle, each type can have up to three rest points, for example, the (HD) game has unstable rest points at the corners, $x = 0$ and $x = 1$,

<i>Type</i>	$x = 1$	$x = 0$	$x \in (0, 1)$	Notation
<i>PD</i>	unstable	stable	\nexists	\leftarrow
<i>HD</i>	unstable	unstable	stable	$\rightarrow\leftarrow$
<i>CD</i>	stable	stable	unstable	$\leftarrow\rightarrow$
<i>D</i>	stable	unstable	\nexists	\rightarrow

Table 1: Stability of rest points in the four game types

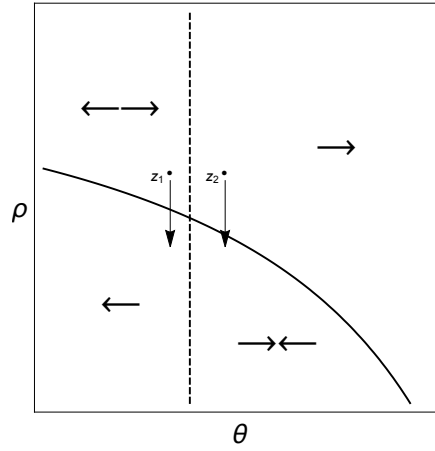


Figure 3: Game types

which implies that the monomorphic states are unstable. A small perturbation in x would lead to a movement away from either of the two equilibria. The interior rest point $x \in (0, 1)$ exists and is stable. The interpretation is similar for the three remaining possible types. The notation introduced in Table 1 (last column) symbolizes this using arrows pointing towards the stable rest point(s). This notation is carried over into Figure 3, which shows the emerging game types in the θ - ρ -plane.

The following Lemma introduces a minimum threshold for the quality of the rule of law, expressed by θ , which creates an *HD* or *D* type of game.

Lemma 4. *For $\theta \geq \frac{|b|}{1+|b|} \equiv \tilde{\theta}$, the game type is either *HD* ($\rightarrow\leftarrow$) or *D* (\rightarrow).*

On the basis of this, I am going to make an argument that the reformer should always aim at $\tilde{\theta}$ (represented by the dashed line in Figure 3) as a minimum value for θ . Suppose the point z_1 in Figure 3 is the optimal end point for a given population such that this combination of θ and ρ would allow the population to advance to $x = 1$. Note that at z_1 the game is a *CD* game and assume that x is in the basin of attraction to $x = 1$. Even if the point z_1 is sufficient for a reformer single-mindedly focused on bringing the population to $x = 1$, it can be preferable to still increase θ further and move to a point such as z_2 . At z_1 a sudden exogenous decrease of ρ (represented by the arrow pointing downwards starting in z_1) would move the population into a *PD* game, where a small perturbation of x would unravel the equilibrium at $x = 1$. In fact, the stable equilibrium would become unstable and the entire interval of x would become a basin of attraction towards $x = 0$. In this sense the point z_1 makes the population vulnerable to shocks, because a small upset of the equilibrium would put the population on the inexorable path towards defecting. On the other hand, although at z_2 the same shock on ρ (again represented by an arrow parallel to the first and of equal length) would also make the equilibrium at $x = 1$ unstable and a small perturbation of x could dislodge the equilibrium and lead to a decrease of x , the stable interior equilibrium would serve as a safety net, which would stabilize the population. At z_2 the population is more *resilient* to a potential exogenous shock on ρ , because the effects of an exogenous shock can be, at least partially, contained. In addition, once the source of the exogenous shock has ended, the path back towards cooperation is shorter.

Fundamentally, there are two ways to incorporate this idea as an extension into the model. First, introduce an additional constraint on the value of θ in the last period, $\theta_T \geq \tilde{\theta}$. Second, introduce a second objective function as payoff (salvage) once the reform process is over, which would measure the payoff from having the incremental value of θ . Capturing this in an objective function is not straightforward and open to interpretation. I propose the

following option. Let \tilde{x} the interior rest point for an *HD*. Introduce an additional salvage function measuring utility *after* the reform process has been completed, $\omega(\tilde{x})$. This function is meant to measure the population game payoff that comes from the safety net of a minimum level $\tilde{\theta}$ for the quality of the rule of law as described above. If this level of the quality of the rule of law is achieved the payoff from the game will never fall below $\omega(\tilde{x})$.

If both a constraint on θ_T and a salvage function $\omega(\tilde{x})$ are added to the optimization problem, $\Delta(t)$, the per-period yardstick of decision-making presented in Lemma 1 must be restated:

Lemma 5. *Adding both the constraint $\theta_T \geq \tilde{\theta}$ and the salvage function $\omega(\tilde{x})$ to the maximization problem (2) through (6) results in a reformulation of Lemma 1. In each period t the reformer chooses the reform variable $\mu(t)$ according to:*

$$\mu(t) = \begin{cases} 1 & \text{if } \tilde{\Delta}(t) > 0 \\ 0 & \text{if } \tilde{\Delta}(t) \leq 0 \end{cases}$$

with

$$\tilde{\Delta}(t) = \Delta(t) + \lambda_2(T)(1 - \theta_T) \quad (9)$$

In equation (9), a positive term is added to the original expression for $\Delta(t)$. In the baseline model the costate variable for equation (4), λ_2 , is equal to zero in T . Crucially, now $\lambda_2(T)$ takes on a positive value. This implies that the scope for rule-of-law reform (θ) increases, because the reformer takes the long-term welfare effect of having a value for θ at least equal to $\tilde{\theta}$ in consideration.

4 Conclusion

The model sheds light on the dual impact of reforms. On the one hand, reforms change behavior by individuals who respond to changed incentives. On the other hand, reforms directly impact the payoffs that players can gain from interaction with others. Both effects should be taken into consideration

when thinking about reform sequences. It is true that a reformer focusing on the speed of reform will look at the differential impact of either reform type on the adjustment of the number of cooperators. At the same time, at the margin, it can be preferable to trade off speed of reform against future payoff. The latter comprises both the payoff coming from cooperation and the safety net that a functioning legal system provides.

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Appendix

The Hamiltonian for the dynamic optimization problem (2) through (6) can be written as:

$$H = -1 + \lambda_1 \left(x \left(\frac{1}{1-\rho} - b - c \right) + b + \theta(1-b) \right) + \lambda_2 \mu(1-\theta) + \lambda_3(1-\mu)(1-\rho)$$

The salvage value is $\Omega = \delta 2x^2 ((1-\rho)^{-1} - b - c) + \delta 2x(b+c)$. The necessary conditions are:

$$H_\mu = \lambda_2(1-\theta) - \lambda_3(1-\rho) \leq 0 \quad (10)$$

$$H_x = \lambda_1 \left(\frac{1}{1-\rho} - b - c \right) = -\dot{\lambda}_1 \quad (11)$$

$$H_\theta = \lambda_1(1-b) - \lambda_2\mu = -\dot{\lambda}_2 \quad (12)$$

$$H_\rho = \lambda_1 \frac{x}{(1-\rho)^2} - \lambda_3(1-\mu) = -\dot{\lambda}_3 \quad (13)$$

The transversality conditions are:

$$\lambda_1(T) = \frac{\partial \Omega}{\partial x} \Big|_{x=1} = \frac{4\delta}{1-\rho_T} - \delta 2(b+c) \quad (14)$$

$$\lambda_2(T) = \frac{\partial \Omega}{\partial \theta} \Big|_{x=1} = 0 \quad (15)$$

$$\lambda_3(T) = \frac{\partial \Omega}{\partial \rho} \Big|_{x=1} = \frac{\delta}{(1-\rho_T)^2} \quad (16)$$

Let $\Delta = \lambda_2(1-\theta) - \lambda_3(1-\rho)$. From (10) it follows that $\mu = 1$ (0) if $\Delta > (<)$ 0. Differentiating Δ with respect to the time and using (4) and (5) yields:

$$\dot{\Delta} = (1-\theta)(\dot{\lambda}_2 - \lambda_2\mu) - (1-\rho)(\dot{\lambda}_3 - \lambda_3(1-\mu))$$

Substituting (12) and (13) and simplifying:

$$\dot{\Delta} = \lambda_1 \left(\frac{x}{1-\rho} - (1-\theta)(1-b) \right)$$

Integrating yields

$$\Delta(t) = \int_t^T \lambda_1 \left((1 - \theta)(1 - b) - \frac{x}{1 - \rho} \right) d\tau - \frac{\delta}{1 - \rho_T} \quad (17)$$

(Lemma 1)

This is equation (7). A few conclusions can be drawn by inspecting (7/17). Clearly, $\Delta(T) < 0$, so $\mu = 0$ in the last period (Lemma 2). Suppose $\frac{x_0}{1 - \rho_0} \geq (1 - \theta_0)(1 - b)$. Then in $t = 0$ and in any subsequent t a negative number is added to the integral, because the term $\frac{x}{1 - \rho}$ is increasing in ρ . Therefore $\mu = 0$ in all periods $t \in [0, T]$ (Proposition 1). This line of argument cannot be reversed; $\frac{x_0}{1 - \rho_0} < (1 - \theta_0)(1 - b)$ clearly is a necessary condition for $\mu = 1$ in $t = 0$, but it is not sufficient. Since $(1 - \theta)(1 - b)$ is decreasing and $\frac{x}{1 - \rho}$ is increasing in θ the integral is neither necessarily positive, nor is it necessarily greater than $\frac{\delta}{1 - \rho_T}$ (Lemma 3). The integral itself cannot be fully solved. From (10) the condition that $\mu = 1$ in $t = 0$ is

$$\lambda_2(0)(1 - \theta_0) > \lambda_3(0)(1 - \rho_0),$$

where λ_2 and λ_3 are evaluated at $t = 0$. Using a dynamic version of the envelope theorem (see Léonard and Van Long (1992, p. 153)), this can be rewritten as:

$$-\frac{\partial T}{\partial \theta_0}(1 - \theta_0) > \left(-\frac{\partial T}{\partial \rho_0} + \frac{\partial \Omega}{\partial \rho_0} \right) (1 - \rho_0) \quad (18)$$

T is implicitly defined by:

$$e^{T(\frac{1}{1-\rho}-b-c)} \left(\frac{b+\theta(1-b)}{\frac{1}{1-\rho}-b-c} + x_0 \right) - \frac{b+\theta(1-b)}{\frac{1}{1-\rho}-b-c} = 1 \quad (19)$$

Note that in (19) both ρ and θ are also functions of T and this equation does not allow for a closed-form solution of T . Instead I use a quadratic approximation of the left hand side of (19) around $t = 0$. This approximated

equation is given by:

$$x_0 + \dot{x}(0)T + \frac{1}{2}\ddot{x}(0)T^2 = 1. \quad (20)$$

The quadratic approximation will only give a useful result for T in the case of $\ddot{x}(0) > 0$. In this case, there is only one positive solution to (20):

$$T_1 = \frac{-\dot{x}(0) + \sqrt{(\dot{x}(0))^2 + 2\ddot{x}(0)(1 - x_0)}}{\ddot{x}(0)}$$

Differentiating T_1 with respect to θ_0 and ρ_0 allows to state an approximated expression for (18) and this expression was used to create the yellow-shaded area of the numerical example in Figure 2 in the text, where it was made sure that the values for $\lambda_2(0)$ and $\lambda_3(0)$ are positive. The Mathematica file used for the computations is available upon request.⁶

Next, under which conditions will a reform effort not be successful, in other words, when will it lead to $x = 0$:

$$x_0 + \dot{x}(0)T + \frac{1}{2}\ddot{x}(0)T^2 = 0. \quad (21)$$

Here, the case $\ddot{x}(0) < 0$ does not need to be excluded. (21) has two solutions if $0 < \ddot{x}(0) \leq \frac{(\dot{x}(0))^2}{2x_0}$, but the following one is always the smaller one, which is also the only positive solution in the case of $\ddot{x}(0) < 0$.

$$T_0 = \frac{-\dot{x}(0) - \sqrt{(\dot{x}(0))^2 - 2\ddot{x}(0)x_0}}{\ddot{x}(0)}$$

(Proposition 3)

Most comparative statics results in Proposition 2 can be easily deduced from how the sufficient condition to set $\mu = 0$ changes (Proposition 1) in x_0 , θ_0 ,

⁶There is an additional transversality condition, which defines the optimal T : $H(T) + \partial\Omega/\partial T = 0$. But this condition is of little help in this case, because it does not allow for a closed form solution of the optimal T .

ρ_0 and b . In order to arrive at some comparative statics results for c , first (11) can be solved holding ρ constant and using (14):

$$\lambda_1(t) = 2\delta \left(\frac{2}{1-\rho_T} - b - c \right) e^{(T-t)(\frac{1}{1-\rho} - b - c)}$$

Clearly, λ_1 is strictly decreasing in c . Next, a case distinction is needed. Suppose, first, that $\mu = 1$ in $t = 0$. Then (12) and (13) become:

$$\begin{aligned}\lambda_1(1-b) - \lambda_2 &= -\dot{\lambda}_2 \\ \lambda_1 \frac{x}{(1-\rho)^2} &= -\dot{\lambda}_3\end{aligned}$$

Holding λ_1 , x , and ρ constant this can be solved and evaluated in $t = 0$:

$$\begin{aligned}\lambda_2 &= (1-b)\lambda_1 e^{-T} (e^T - 1) \\ \lambda_3 &= \frac{\lambda_1 T x}{(1-\rho)^2} + \frac{1}{(1-\rho_T)^2}\end{aligned}$$

In this case then $\Delta(0) > 0$ (since $\mu = 1$) becomes:

$$\Delta(0) = \lambda_1 \underbrace{\left((1-b)(1-\theta)e^{-T} (e^T - 1) - \frac{T x}{1-\rho} \right)}_{>0} - \frac{\delta(1-\rho)}{(1-\rho_T)^2} > 0$$

Since the term in the parentheses must be positive to make $\Delta(0) > 0$, $\text{sign} \frac{\partial \Delta(0)}{\partial c} = \text{sign} \frac{\partial \lambda_1}{\partial c}$, and therefore $\frac{\partial \Delta(0)}{\partial c} < 0$.

The exact same steps for the case of $\mu = 0$ result in:

$$\Delta(0) = \lambda_1 \underbrace{\left(\frac{x}{1-\rho} e^{-T} (e^T - 1) + T(1-b)(1-\theta) \right)}_{>0} - \frac{\delta(1-\rho)}{e^T(1-\rho_T)^2}$$

The term in the parentheses is positive, therefore also in this case it must be true that $\text{sign} \frac{\partial \Delta(0)}{\partial c} = \text{sign} \frac{\partial \lambda_1}{\partial c}$ and therefore $\frac{\partial \Delta(0)}{\partial c} < 0$.

Resilience

The derivation of the four game types comes from the definition of the games. Denote $v(i, j)$ the payoff from playing i if the opponent plays j . The game classes follow from (with $v(d, d) = 0$):

<i>PD</i>	$v(c, c) \leq v(d, c)$ and $v(c, d) \leq 0$
<i>HD</i>	$v(c, c) \leq v(d, c)$ and $v(c, d) \geq 0$
<i>CD</i>	$v(c, c) \geq v(d, c)$ and $v(c, d) \leq 0$
<i>D</i>	$v(c, c) \geq v(d, c)$ and $v(c, d) \geq 0$

The delineation of the areas in Figure 3 follow from these conditions. Note that an *HD* game only occurs if $b + c > 1$. For both *HD* and *D* games $v(c, d) \geq 0$, or, $b + \theta(1 - b) \geq 0$. Solving for θ gives the threshold stated in Lemma 4.

Introducing the condition $\theta_T \geq \tilde{\theta}$ and an additional salvage $\omega(\tilde{x})$ changes the transversality condition (15). The new conditions read:

$$\lambda_2(T) - \frac{\partial \omega(\tilde{x})}{\partial \theta_T} \geq 0 \quad (22)$$

$$\left(\lambda_2(T) - \frac{\partial \omega(\tilde{x})}{\partial \theta_T} \right) (\theta_T - \tilde{\theta}) = 0 \quad (23)$$

Following the same steps that led to (17) results in equation (9) in Lemma 5, which is repeated here:

$$\tilde{\Delta}(t) = \Delta(t) + \lambda_2(T)(1 - \theta_T) \quad (24)$$

In principle, both earlier reform paths are still possible. In addition, since now $\lambda_2(T) \geq \frac{\partial \omega}{\partial \theta_T} > 0$, it is possible to have $\mu = 1$ in $t = T$.

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