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RESEARCH ARTICLE

Institutional resilience: how the formal legal system sustains informal cooperation

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Abstract

This paper introduces the concept of institutional resilience based on a population game. Agents in an economy are randomly matched to play a coordination game with two strategies, cooperate and defect. A breach of contract can be adjudicated in court. Agents can update their strategy, which is modelled using the replicator dynamic. In this context, cooperation is defined as the informal institution, whereas the legal system (contract law) constitutes the formal institution. Institutional resilience is defined by how the formal institution of a functioning legal system complements the informal institution of cooperation in a dynamic way. In the wake of an adverse exogenous shock, the formal institution can prevent a total breakdown of cooperation in the population.

Key words: Cooperation; coordination game; formal institution; informal institution; population game; replicator dynamics; transition

JEL codes: C73; O12; P14; P16

1. Introduction

It is well accepted that institutions both matter for structural outcomes and explain a great deal of the difference in economic development between countries. In this paper, I draw attention to a possible channel through which 'good' institutions facilitate development. Functioning legal institutions can prevent an economy from unravelling after an exogenous shock and make a country or region *resilient* to shocks. It does so because the formal institution of a functioning legal system complements an informal institution of cooperation both in a static and a dynamic way. This is the idea of *institutional resilience* I will put forth in this contribution.

There is a large and still growing literature on the institutional determinants of economic outcomes. While the kernel of the idea in modern economics is already present in North (1990), the empirical side of this question arguably started with Knack and Keefer (1995). Acemoglu *et al.* (2001) are the first to tackle the issue of causality; this literature is reviewed in Acemoglu *et al.* (2005) and recently in Durlauf (2020). For a focused analysis of post-colonialism and institutions, see contributions in Parent (2018). From a theoretical point of view, different institutions are discussed, such as democracy, the form of government, and property rights protection. Importantly, Acemoglu and Johnson (2005) show that property rights protection matters for growth but not for the variety and the structure of contracting institutions. Torvik (2020) provides a recent review of those theoretical approaches.

This paper highlights one crucial channel through which formal institutions contribute to sustained favourable economic outcomes. The following summarises the basic logic of the argument. Breaking down the functioning of an economy to the fundamental coordination problem between two individuals, the problem can be represented by a simple game with two strategies, cooperate or not (Bowles, 2004). It is long established that any cooperative equilibrium can be established in

repeated games if individuals place a high-enough emphasis on future income streams (Friedman, 1971). For players to stick to a trigger strategy of 'cooperate if you do' and 'not cooperate if you do not' can then be sustained as an *informal* institution if players value future income streams highly enough. Although this informal institution can and does allow for cooperation, it is vulnerable to exogenous shocks, increasing players' tendency to abandon cooperation. This is where the *formal* institutions of the rule of law and a legal system come in. The cooperative equilibrium can be sustained by giving players recourse to the legal system in case of a breach of contract. The formal institution of a legal system functions as an institutional complementarity (Aoki, 2001) to the informal institution. The next step is the contribution of this paper. In addition to facilitating cooperation, the presence of a well-functioning legal system (the formal institution) can make cooperation (the informal institution) *resilient* to outside shocks. If the quality of the legal system is not high enough, the population faces the danger of unravelling cooperation as a consequence of an adverse exogenous shock. On the other hand, if the quality of the legal system clears a certain threshold, it works as a buffer against a potential complete breakdown of cooperation. The reason is that a well-functioning legal system as a formal institution ensures that the payoff for defecting from a cooperative strategy has diminishing marginal returns *in the number of defectors* and that the rate of diminishing is large enough. In this way, a complete vanishing of cooperative behaviour can be avoided. There is a technical interpretation: in a dynamic setting where players update their strategies according to payoff comparisons, it makes a difference whether an interior equilibrium is stable or unstable. A stable interior equilibrium can halt a breakdown of cooperation and provide resilience, whereas an unstable interior equilibrium is more precarious.

The concept of resilience originates in ecology, where it refers to the ability of an eco-system to bounce back after a shock (Holling, 1973). The idea has made inroads into the social sciences in several ways, especially when social systems and ecological systems overlap, such as in the governance of irrigation systems or the use of commons (Carpenter and Brock, 2004; Ostrom, 2009; Young, 2010), and more generally, sustainable development (Perrings, 1998). For an overview of how the concept is used and the special care that should be applied when using it in the social sciences, see also Olsson *et al.* (2015). Recently, Brunnermeier (2021) invokes the concept of resilience through a social contract based on norms and laws in relation to societal responses to all sorts of challenges, such as pandemics and climate change.

In this paper, the concept is applied to institutional resilience. The idea refers to the ability of an institution to prevent a societal outcome (in this case, cooperation of contract partners) from breaking down in the wake of an external shock. Even simpler, the formal institution makes the informal institution of cooperation resilient to shocks. This definition does not necessarily imply that the institution itself remains unchanged but that the outcome (cooperation) is sustained so that it can bounce back.

Institutional resilience, as I will lay it out, is rooted in game theory, but it has a distant cousin in the concept of *social capital* in the political sciences. The theory is usually accredited to Coleman (1990) and Putnam (1993). Among other determinants, social capital mainly refers to trust people have towards strangers and reciprocity of actions when dealing with others. It is argued that social capital positively impacts growth and development because it fosters cooperation between individuals. In particular, the point made by Rothstein and Stolle (2008) will be useful for my argument. They argue that the causality runs from good government institutions to increased social capital in a society. This is, of course, a very similar argument to the one economists make when they find that inclusive institutions foster development (Acemoglu and Robinson, 2012). A similar sentiment will be present also in my approach as the level of institutional quality will impact the number of individuals willing to give a stranger the benefit of the doubt and trust them. Furthermore, the formal institution helps determine the trajectory of cooperation in the event of adverse shocks. The reciprocity of cooperation or the level of trust is a possible endogenous equilibrium in my model. I will come back to an interpretation of trust in light of my approach in the discussion.

The question of informal *versus* formal enforcement, or, more generally, the problem of governance, has a place in the economics literature on institutions. Kandori (1992) and Ellison (1994)

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develop models in which community enforcement can induce players to be honest. Community enforcement means that dishonest behaviour is sanctioned in some way. If the population is large, this can work through means of conveying a reputation of being honest. These ideas have their empirical application in the studies on different ways of enforcing contracts by the Maghribi traders (Greif, 1993). Dixit (2003) focuses on the role of intermediaries in the solution of governance problems. From an empirical standpoint, intermediaries such as the law merchants in Milgrom *et al.* (1990), or the Sicilian mafia in Gambetta (1993) can take over some of these functions. More recently, Kumar and Matsusaka (2009) disentangle different forms of enforcement mechanisms, local (social capital) or market-based mechanisms. My approach can be seen as complementary to these models. While the focus will be on formal enforcement and how this can create resilience, similar arguments can also be made for the impact of any kind of informal governance structure. Relatedly, there is a literature on how cooperation can emerge and how it can last. Kranton (1996) studies how cooperation can be sustained if partners can dissolve an ongoing relationship in favour of a new one. Carmichael and MacLeod (1997) focus on the role of gift giving in cooperation. Relatedly, Sobel (2006) studies the interplay between formal and informal enforcement mechanisms in facilitating long-term cooperation. While these papers cover similar questions and use similar approaches as I do, the thrust of the analysis is different. The focus there is on the exclusivity of relationships, while for me, any agent can start and sustain several relationships.

In order to present the main idea, I am availing myself of different ways in which an *institution* is defined. In the literature, the fundamental distinction is between institutions as rules of the game and institutions as (equilibrium) outcomes of games (Hodgson, 2015). The first view is the most common one and is tightly connected to the work of North (1990). Here, institutions are formal or informal rules which are exogenously given and which individuals take into account when making strategic (or any kind of) decisions. In a game-theoretic sense, institutions as rules of the game impact the payoffs that different strategies generate. The second view defines institutions as equilibria of games (Aoki, 2001; Greif, 2006; Schotter, 1981). Here, institutions are seen as the prevailing way of doing things, which may or may not coincide with how the law prescribes behaviour. Again, from a game-theoretic viewpoint, institutions are then the equilibrium strategies chosen. Hindriks and Guala (2015) attempt a synthesis of the two views. In this paper, I am putting both definitions to use: the formal institution of contract law enforced by a legal system affects the expected payoff from different strategies and, in this way, facilitates (or not) the emergence of an informal institution of cooperation as an equilibrium outcome of the game.

The argument will be presented using a model involving a population game. The goal is to boil down to its essence the fundamental problem of coordination in a two-person strategic interaction and then to study how strategic choice evolves in a large population. The basic set-up of a game of exchange is borrowed from Aoki (2001), Bowles (2004), and Acemoglu and Jackson (2015). This style of modelling is, however, prevalent in all sorts of applications, ranging from the choice between productive work and crime as a determinant of development (Nunn, 2007) to how the choice between fighting over gains or sharing them impacts the evolution of property rights (Bowles and Choi, 2020) and some of the literature on governance modes mentioned above.

As with all modelling choices in the social sciences, my focus on a two-person game will necessarily strip away some of the complexity and messiness of real-world interaction. For example, while the complexity of the legal system is not negated, for the exposition here, it will be represented by a summary variable. Furthermore, I will keep the domain of exchange between individuals and the domain of the legal system separate. Some approaches analyse potential connections between the two. Deakin *et al.* (2017) point to the role that the legal system plays in reducing complexity for agents while acknowledging that the law itself is part of a more extensive system governing social interaction. Echoing this point, Hartwell and Urban (2021) show in a case study of the transition experience in Estonia and Poland that political institutions need to be aligned to make the protection of the rule of law work. Relatedly, the theory of political settlements (Kelsall *et al.*, 2022) deals with questions of how the ground rules governing economic and political exchange are the results of agreements

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between different groups. In developing a framework to study economic development, Ferguson (2020) draws attention to the myriad collective action problems that need to be solved to create growth. These can occur not only at the level of exchange but also at the political level. Considering this literature, my approach can also be summarised differently. I am interested in an impartial legal system's static and dynamic effects on economic performance and institutional resilience. I will return to these assumptions in the discussion section.

To complement the theory part, during the discussion, I will give some implications of the results and the main idea. In particular, I will make a connection to the literature on the post-socialist transition. Once the transition of post-socialist countries of Central and Eastern Europe was underway, the role of the 'rule of law' in the transition process was seen as crucial (Carothers, 1998). The problem of post-socialist transition is a particularly fertile ground for applying the concept of institutional resilience, and I will come back to link the two in the discussion. Most transition economists have accounted for working legal systems as the primary determinant of transition success. Institutional resilience underscores this basic result and gives it an additional twist. To the static effect of institutions facilitating cooperation in the first place, there is a dynamic effect, which makes cooperative equilibria resilient and allows them to survive adverse external shocks.

2. Model of exchange

2.1. Preliminaries

Consider a game played by identical, anonymous agents in a large population. Two agents are randomly matched. Once two are matched, they agree on a contract of exchange. For both parties, the contract entails a temporal separation of contract stages. First, there is an agreement, followed by a stage of an intermediate investment. Finally, there is a payoff at a later stage. In the simplest possible example, players agree on the delivery of an item at a later stage, where both need additional outlay to start production. If both carry out the terms agreed upon in the contract, each earns a payoff normalised to 1. If one agent defects while the counterpart cooperates, the defector earns a rent of $c > 1$. The existence of a rent implies that the defector can partially appropriate some of the gains that have been created in the interim. In this context, there are two interrelated ways in which cooperation can be attained. First, agents can engage in a trigger strategy (Axelrod and Hamilton, 1981), which involves cooperating in the first meeting and then to go on cooperating in subsequent meetings if the other player cooperated as well and never to cooperate again if the other player did not cooperate.[1] If both randomly matched agents apply this strategy, there is a chance that a long-term relationship is created. Suppose after the first meeting for all subsequent meetings, the *continuation probability* that the relationship continues for another round is exogenously given.[2] The expected payoff from this strategy is then $1/(1-r)$, where $0 \leq r < 1$ is the continuation probability. The larger r, the higher players expect the payoff from this relationship to be at the outset. The continuation probability r is heavily influenced by the economic outlook individuals perceive, which is also exogenous and at least partially independent of any actions a government can take. Suppose the economic outlook is dim, for example, during a recession. In that case, individuals are very willing to start projects with others. Still, they would place a relatively low probability on the event that further projects come from the first encounter. On the other hand, the better the economic outlook, the higher individuals perceive the chance that the new relationship is continued, which increases how future incomes are valued. This corresponds to a higher value of the continuation probability r.

Then, if $r \geq (c-1)/c$, playing the trigger strategy can be induced as a repeated game equilibrium. This is an informal institution, which by itself is self-enforcing if the continuation probability is high enough.

[1]This is sometimes called a 'grim trigger'. There are milder versions, in which non-cooperation only starts after a series of defections by the other player.

[2]This approach is adapted from a basic model presented by Bowles (2004: chapter 7). Note that r is not a discount factor but works similarly in mathematical terms. If r is the continuation probability after each round, the expected number of rounds in which an agent earns the payoff 1 is given by the geometric series $1 + r + r^2 + \cdots = 1/(1-r)$.

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Definition 1 (Informal institution). *Define the rule: 'Cooperate in the first meeting. If the other player also cooperates, continue playing cooperate until the relationship ends. Never cooperate again if the other player defects'. Following this rule constitutes the informal institution.*

The higher the rent of defecting c and the smaller the continuation probability r, the harder this strategy becomes to sustain. This leads to the second way in which cooperation can be induced. At this point, an external actor can step in by setting up a legal system, which can adjudicate in case of a breach of contract. This boils down to a court awarding damages to the wronged party. This is the formal institution, which is defined as follows:

Definition 2 (Formal institution). *The formal institution is the legal system, represented by contract law and a court system. The contract law prescribes damages as remedies in case of a breach of contract. The efficiency of the formal institution is measured by the probability θ that the wronged party receives damages, and the defector pays damages.*

This probability of damages θ can be interpreted as a summary variable to capture how well the legal system works. One can imagine many ways the efficiency of the legal system can be influenced. Apart from introducing a contract law in the first place, the entire system can be better funded, and safeguards preventing corruption and regulation speeding up decisions can be introduced.

Suppose the wronged party incurs a negative loss $-b$ from the breached contract. This loss stems from any upfront investment this agent initiated to hold up their side of the contract. As a result of this loss, the agent starts a civil suit to recover damages in court. Contract law knows three fundamental ways[3] of awarding damages: *expectation damages* are designed to put the wronged party in a position as if the contract had been faithfully carried out. Conversely, *reliance damages* aim at realising for the wronged party a situation as if the contract had never been concluded, and, relatedly, *restitution damages* allow the wronged party to recover any value given to the other party. For the problem at hand, expectation damages are the most fitting choice for two reasons. First, by and large, these types of damages are most often applied by courts (Hermalin *et al.*, 2007). Second, expectation damages are, in this case, the largest of the three options resulting in the largest expected damages given a probability of paying/receiving damages.[4]

If the court applies expectation damages, they ought to recover the payoff 1 that a single contract would have generated for each party if the defector had cooperated. I assume that the judge does not consider the continuation probability because the dispute adjudication takes place only based on the one-time contract at hand. The damages are $1 + b$, and the expected payoff from defecting while the other player cooperates becomes $c - \theta(1 + b)$. In this context, a player thinking about whether to defect or to cooperate must compare the expected payoff from cooperation $(1/(1 - r))$ with the expected payoff from defecting. A little bit of algebra shows that if $\theta \geq (c(1 - r) - 1)/((1 + b)(1 - r)) \equiv \tilde{\theta}$, the legal system works well enough to enable the emergence of the informal institution also for smaller r because it ensures that the expected payoff from cooperation is at least as large as the payoff from defecting. The parameter $\tilde{\theta}$ as a minimum value for θ has a dynamic interpretation: given a combination of the parameters b and c and a value for the continuation probability r, it gives the minimum threshold for the indicator of the legal system for which cooperation is an evolutionarily stable strategy. I will return to this interpretation below.

2.2. Stage game

To summarise, the informal institution involves cooperating on the first encounter if randomly matched with a second player. The informal institution can either be self-enforcing (if r is large enough) or is propped up by the legal system, or both. The legal system represented by contract law is the formal institution. The goal is then to track how individuals change strategies. The

[3]See Hermalin *et al.* (2007, chapter 5) for an overview.

[4]For completeness, expectation damages, in this case, are $1 + b$, and reliance damages would amount to b. For the computation of restitution damages, further assumptions would be needed.

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

Figure 1. Payoff matrix in the stage game.

overarching questions are twofold. How can the informal institution become prevalent and sustained in the population and survive periods of adverse shocks? What role does the formal institution play, and how are the two institutions interlinked? The answers to this set of questions will result in the idea of institutional resilience.

For this purpose, first, the symmetric two-player game is set-up in Figure 1. This is the stage game.

Note that the formal institution – the quality of the legal system represented by the probability of gaining damages θ – influences the game's payoff matrix. The parameters b, c, and r are exogenously given. From the assumptions I made about the parameter values, it follows that for $\theta = r = 0$, the stage game constitutes a Prisoners' dilemma with defecting as a dominant strategy. In addition, I assume that $c - b < 2$. This ensures the cooperative equilibrium has the highest total payoff for $\theta = r = 0$. The parameters θ and r are exogenous but can change over time and will therefore be used with a subscript t from here on out.

2.3. Population game

Next, the stage game is embedded in a population game, allowing me to apply evolutionary game theory tools. Players in this population only employ pure strategies, never mixed strategies. In this sense, one can also refer to the two types as 'cooperators' and 'defectors'. Cooperators will always cooperate in the first meeting; that is, they employ the informal institution defined above. Defectors will always defect when matched with anybody. Before two players meet, the type of the opponent is not known to a player, so players are not able to coordinate their actions in any way. Each agent starts with one pure strategy and is periodically allowed to change strategy by observing another player's strategies and expected payoffs.

For this purpose, I normalise the population to 1 and denote x_t the fraction of cooperators in a given period t. Then $1 - x_t$ is the fraction of defectors. The stage game is embedded into a dynamic setting, which allows me to trace how strategies evolve. The goal is to model the evolution of the proportion of cooperators from one period to the next, that is, to find an expression for $\Delta x = x_{t+1} - x_t$. In any period, a subset of players in the population is given the opportunity to observe a different individual's strategy or type. Upon observation, individuals can switch to the other's strategy if it has a higher expected payoff. In other words, players can change their type if the other type's expected payoff is larger than their own. The probability of switching increases in the payoff difference. In this setting, the *replicator dynamic* is the most commonly used model.[5]

Some of the assumptions underlying this model of changing strategies bear spelling out. First, at a fundamental level, individual players are assumed to have limited access to information. Once they are exposed to the payoffs other players generate (in expectation), they can switch to the other strategy. A common misconception is that players are boundedly rational in this model, but this misses the point.

[5]The most accessible introduction to the replicator dynamics is given by Bowles (2004) in chapter 2, who focuses on the version in discrete time used here. Gintis (2009) is an accessible book-length treatment of evolutionary game theory. Sandholm (2011) is an encompassing overview.

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They are still rational in that they maximise their expected payoff but are restricted in terms of the information available to them. Second, the replicator dynamic is a deterministic model; it is not stochastic. The deterministic model is a close approximation of a stochastic one if two technical assumptions are met: the population is infinitely large, and the time frame is finite.[6] Recall that this paper focuses on the exchange between anonymous, randomly matched players. In this respect, the assumption of randomly meeting unknown other players in an infinitely large population is not restrictive.

As an intermediate summary, in each period, three things take place. First, a subset of players is randomly matched to play the stage game in Figure 1 with expected payoffs based on the matrix. In case two cooperators are matched, there is a chance that this random match is converted into a long-term relationship. This is captured by the continuation probability r_t in each period. Therefore, in this economy, there are cooperators and defectors within the domain of anonymous exchange, and this is the primary interest of the paper. At the same time, a subset of the cooperators can have a recurring relationship, resulting from having been matched before. This subset exists alongside the anonymous exchange, but its evolution is not separately tracked. From this, it follows that players who entered a recurring relationship by cooperating do not exit the population. The probability that they are randomly matched to play the stage game again converges to zero due to the assumption of an infinitely large population. Second, in each period, a subset of any type of player is allowed to observe a different type and may switch if the other type's expected payoff is greater than their own. Both for playing the game and for the payoff comparison, the size of the subset determines only the speed of the evolution, not any stability considerations. Therefore, this can be safely ignored. And third, if the population is in an equilibrium state, still a very small subset of players might try out the respective other strategy as a random act of innovation. I will return to this below.

In this context, a helpful interpretation of the replicator dynamic is to view it as a form of *reinforcement learning* (Fudenberg and Levine, 1998). As a result, players in the population will gravitate towards strategies with higher expected payoffs over time. Hence, the difference in expected payoffs will be the crucial determinant of how strategies will evolve. Define D_t the difference between the expected payoff of cooperating minus the expected payoff of defecting. For the stage game in question, this difference in a time t can be written as:

$$D_t = x_t\left(\frac{1}{1-r_t} + b - c\right) - b + \theta_t(1+b) \tag{1}$$

The following difference equation then gives the discrete-time replicator dynamic:

$$\Delta x = x_{t+1} - x_t = x_t(1-x_t)D_t \tag{2}$$

The replicator dynamic is *payoff-monotonic* in that x increases (decreases) if the expected payoff of cooperation is greater (smaller) than the expected payoff of defection. In principle, (2) allows for three rest points in which $\Delta x = 0$, implying that the fraction of cooperators does not change from one period to the next. It follows from (2) that for $x_t = 0$ and $x_t = 1$ rest points always exist. These are *monomorphic* states in which only one type of strategy exists, that is, the population consists of either all defectors ($x_t = 0$) or all cooperators ($x_t = 1$). In addition, up to one interior rest point $x^* \in (0, 1)$ can exist, which corresponds to a *polymorphic* state, in which both types of strategies are present in the population. In this rest point, the expected payoffs from the two strategies are equal ($D_t = 0$).

For the one-dimensional dynamical system (2) the characterisation of possible rest points is straightforward. Rest points can be stable or unstable. A stable rest point is self-correcting: a small perturbation away from the rest point results in a subsequent move back towards the rest point.

[6]Put simply, setting up a stochastic model would involve defining transition probabilities for each state. If the time frame is finite and the population is large enough, the stochastic path will follow the deterministic path with high probability. This result is called Kurtz's theorem (Kurtz, 1981). See also chapter 10 in Sandholm (2011).

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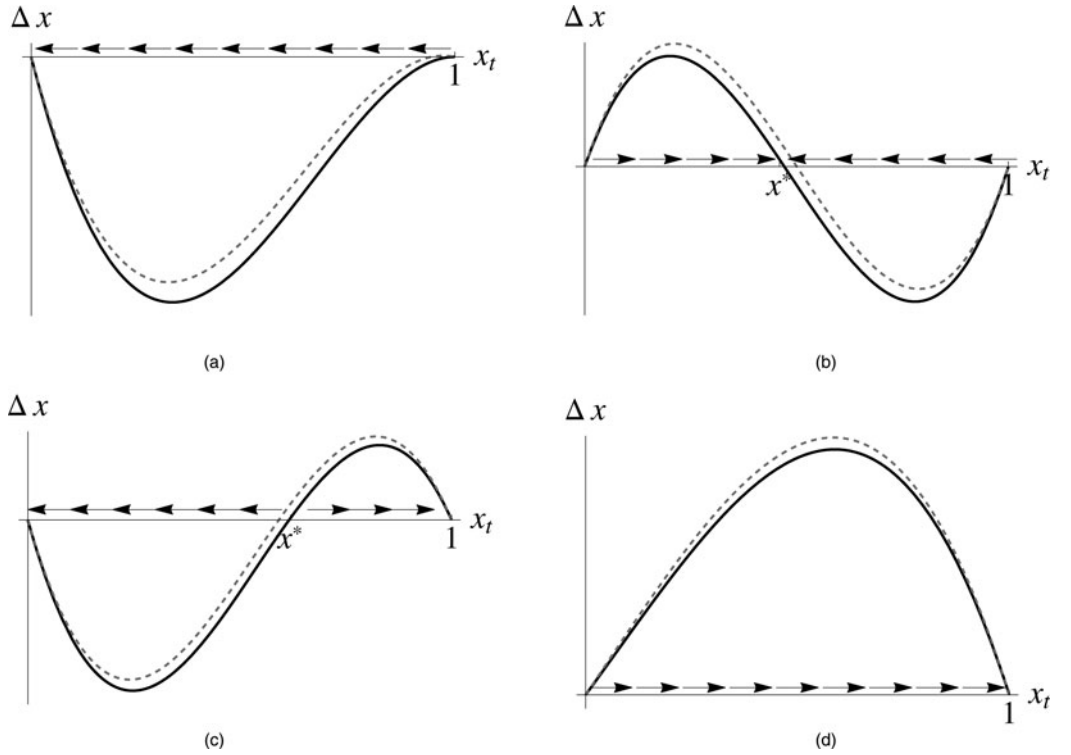

Figure 2. Game types: (a) Prisoners' dilemma, (b) Hawk–Dove, (c) coordination, and (d) cooperation dominant.

The concept of the *basin of attraction* is closely related. It consists of the set of all points of x_t such that the trajectory starting in any of these points ends in a stable equilibrium. Unstable rest points are not self-correcting because small perturbations out of the equilibrium lead to a movement away from the rest point. Put differently, an unstable rest point is surrounded by the basin of attraction of a different, stable rest point.

To be able to study the behaviour out of equilibrium, in addition to the dynamic given in (2), in each period t in which the population finds itself in one of the rest points, I allow for the possibility that a small fraction ε of the population nevertheless changes strategy. One can think of this as the possibility of some members of the population innovating and trying out the other strategy without being prompted to do so. Allowing for this possibility, one can study the effects of small perturbations on a stable or unstable equilibrium. Either these innovations are self-correcting and die out again (the stable case), or they proliferate and move the population on a trajectory to a different equilibrium (the unstable case).[7]

All parameters in (2) are exogenous, except for θ_t, representing the formal institution. Crucially, depending on the relative values of θ_t and r_t for given values b and c, different game types can emerge. These game types can be characterised according to their rest points ($\Delta x = 0$), in terms of both the number of rest points and their stability. Figure 2 shows the dynamics for the four possible types. (The dashed lines should be ignored for the moment.) The direction of arrows in the figure gives the direction of the population dynamics outside the rest points. Arrows pointing towards a rest

[7]In biological terms, these would be mutations. Either the mutations, say, of a specific gene, can invade the existing population, or they die out again.

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

Game type	$x^* = 1$	$x^* = 0$	$x^* \in (0, 1)$	Notation
Prisoners' dilemma	Unstable	Stable[a]	–	←
Hawk–Dove	Unstable	Unstable	Stable	→←
Coordination (assurance)	Stable	Stable	Unstable	←→
Cooperation dominant	Stable[a]	Unstable	–	→

[a]Asymptotically stable.

point show the basin of attraction of this particular point. For example, the hawk–dove (chicken) game is shown in Figure 2b.

Here, both monomorphic states are unstable: in $x_t = 0$ (all defectors), a small perturbation of x would move the population to the basin of attraction of the interior equilibrium x^*. The reason is that even a small number of cooperators increases the expected payoff of cooperation such that cooperators proliferate until the interior point x^* is reached. This means that a small group within the population could experiment with cooperation (using the informal institution). This group would persist over time and move the population towards the interior equilibrium. The interior equilibrium, in this case, is then stable. A small perturbation in x_t in either direction would self-correct, and the population would return to the interior equilibrium. The same mechanism is at play in $x_t = 1$ (all cooperators): defectors can invade and move the population towards the interior equilibrium. Figure 2c shows the mirror-image case of a coordination (assurance) game. Here, the monomorphic rest points are stable. However, the interior one is unstable, suggesting that a small perturbation of x_t in either direction would move the population in the respective basin of attraction and, therefore, on the path to the respective monomorphic state. In addition, there are two cases without an interior rest point, the Prisoners' dilemma in which $x_t = 0$ (all defectors) is the stable rest point (2a) and a dominant cooperation game, in which $x_t = 1$ (all cooperators) is the stable rest point (2d). In both cases, over time, the population would move inexorably towards the one stable rest point.[8] The same information is summarised in Table 1, which also provides a short-hand notation for characterising stability. This notation will be used in Figure 3.

All approaches rooted in evolutionary game theory must consider the effect that specific modelling choices have on the results. To be precise, it might matter which assumptions one makes about what agents know and on which basis they make comparisons and change strategies. This is a question of theoretical robustness checks. For a symmetric two-strategy game, any updating protocol employed by agents based in some way on payoff differences will lead to the same qualitative results in terms of the existence of equilibria and their stability as summarised in Table 1. For example, this is true for best-response dynamics (Hopkins, 1999), dynamics based on regret comparisons (Lahkar and Sandholm, 2008) or dynamics based on the comparison of realised payoffs rather than expected payoffs (Buchen and Palermo, 2022; Loginov, 2022). In this sense, the results based on the replicator dynamic presented here are more general for the fundamental exchange game under discussion than they might appear.

2.4. Institutional resilience

The way the stage game is set-up suggests that the higher the proportion of players cooperating, the higher the total payoff in the population. To make the case, for a moment, I will introduce a utilitarian social planner. Since the population payoff is highest in an all-cooperators equilibrium, there is good

[8]In the case of 2a (2d) the respective point $x = 0$ (1) is asymptotically stable, which means that this point will be reached from any initial point in $x \in (0, 1)$. In contrast, in 2b and 2c the stable points are neutrally stable. The initial condition determines which stable rest point is reached.

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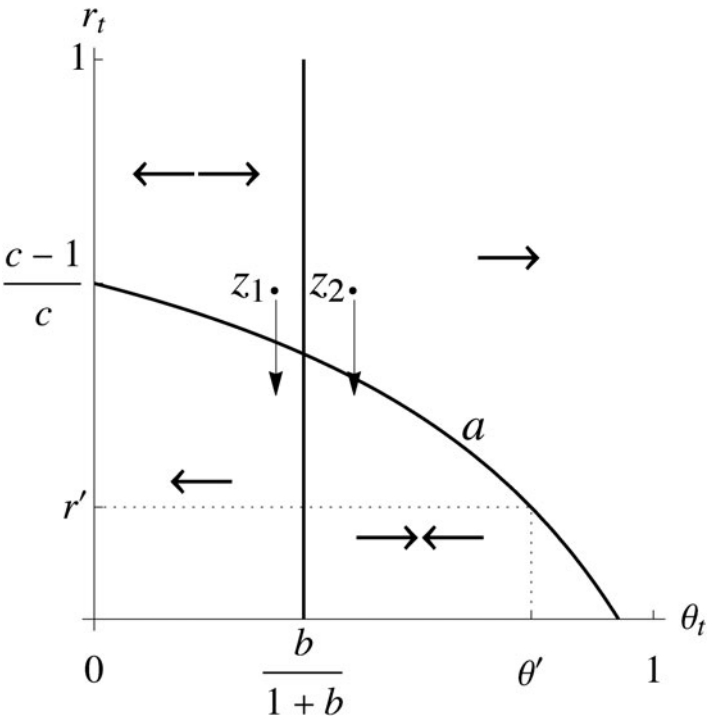

Figure 3. Possible game types.

reason to assume that the social planner would prefer this equilibrium to any other. Stated differently and from a dynamic point of view, the population should preferably be in a basin of attraction towards $x = 1$. The purpose of the model is to show the effects that the formal institution (the legal system represented by θ_t) has on the informal institution and, therefore, on increasing the total payoff from the game. This effect is twofold. First, a better functioning legal system (higher θ_t) fosters the spread of the informal institution. Second, a minimum level of θ_t makes the informal institution *resilient* to outside shocks.

The first effect is quite straightforward. It is easy to see from (1) that, all else equal, a higher value of θ_t increases the expected payoff of cooperating and as a result increases the change in x_t from one period to the next.[9] This effect is entirely independent of the type of game. For illustrative purposes, the dashed lines in the four respective games in Figure 2 show the effect of a larger value of θ_t on the dynamics. As a general rule, a better legal system accelerates the trajectory towards an all-cooperators state and slows the movement towards an all-defectors state. In particular, it increases the basin of attraction of the all-cooperators state (2c), which implies that a better legal system would allow a population in a polymorphic rest point to increase its share of cooperators. In the case of the hawk–dove game, a higher θ_t increases the value of the interior polymorphic stable state (2b), thereby increasing the stable equilibrium share of cooperators. The conclusion is that the formal and the informal institution can be viewed as *institutional complementarities* (Aoki, 2001). That is, the presence of the formal institution increases the effectiveness of the informal institution, where effectiveness refers to the speed with which the ratio of cooperators is growing.

The second effect of the legal system introduces the notion of institutional resilience. The game type and the rest points' stability depend not only on the quality of the legal system (θ_t), but also on the exogenously given value of the continuation probability, r_t. The joint impact of both parameters on the type of games is shown in Figure 3. The horizontal axis shows the value of θ_t, and the vertical

[9]Formally, the following derivative is positive: $\partial \Delta x / \partial \theta_t = x_t(1 - x_t)(1 + b) \geq 0$.

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axis plots r_t. The graph picks up the short-hand notation of game types provided in Table 1. Two curves mark off the four game types showing which emerges for which combinations of the parameters.

Suppose that the value of the continuation probability is relatively low, say, at a value r' in the graph. In such a scenario, a social planner interested in setting the population on a trajectory towards an all-cooperators state would have to increase the quality of the legal system at least to θ' (see graph) to make sure that the strategy of cooperation becomes dominant. In the case of higher given values of r_t, the same can be achieved with lower levels of θ_t. Take the point z_1 in the graph as an example. This combination of the two parameters is very well capable of achieving a goal of an all-cooperators equilibrium. If the initial value of x_t is large enough, this combination of θ_t and r_t ensures that the population is inside the basin of attraction of the all-cooperators equilibrium $x = 1$. Since increasing the quality of the legal system is costly, one could argue that the level associated with point z_1 is good enough. I will argue next that, nevertheless, a minimum threshold of θ_t should be achieved to make the institution of cooperation resilient. At z_1, a sudden exogenous decrease of r_t (represented by the arrow pointing downwards starting in z_1) would move the population into a Prisoners' dilemma. Even if the population has already arrived at $x = 1$, now a small perturbation of x_t would unravel this equilibrium. In fact, the stable equilibrium would become unstable, and the entire interval of x_t would become a basin of attraction towards $x = 0$. In other words, in the wake of an exogenous shock decreasing the continuation probability, a small number of players starting to defect could, over time, invade and proliferate. Alternatively, if the population has not yet arrived at $x = 1$, this shock would reverse the direction of change, and the population would be headed towards $x = 0$. In this sense, the point z_1 makes the population vulnerable to shocks because a minor upset of the equilibrium would put the population on the inevitable path towards an all-defector state.

Fix a second point z_2 at the same level of r_t but for a higher level of θ_t. Although at z_2, the same shock on r_t (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_t could dislodge the equilibrium and lead to a decrease of x_t, the stable interior equilibrium would serve as a safety net, which would stabilise the population. This can be seen by the fact that the arrow points towards the area of a hawk–dove game. At z_2, the population is more *resilient* to a potential exogenous shock on r_t 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. The bouncing back in the aftermath of the shock is made easier. There is a minimum level for the quality of the legal system, such that the effect of resilience is present.[10] The minimum level increases in b; that is, the higher the loss the cooperator suffers from the defection of the other party, the higher the minimum threshold for the formal institution needs to be to ensure resilience.

The line a in the graph gives for each value of r_t the minimum value $\tilde{\theta}$ (see section 2.1) that makes it impossible for the all-cooperators state to become invaded by defectors. That is, at all parameter combinations above a, if the population is at $x = 1$, some members of the population could experiment with defecting, but the defectors would die out again over time.

3. Discussion

The interpretation of institutional resilience as presented in this model is tightly connected to a technical interpretation of the underlying dynamic. In short, there is an advantage to falling back on a *stable* interior equilibrium, which cushions against further disintegration of cooperation. In addition, an economic interpretation helps to further flesh out the ways formal and informal institutions interact.

[10]The minimum level of θ_t is found by writing down one of the conditions for a hawk–dove game, in which the upper right cell in Figure 1 is a Nash equilibrium: $-b + \theta_t(1 + b) \geq 0 \Leftrightarrow \theta_t \geq b/(1 + b)$. Similarly, the threshold on the vertical axis is found by solving $1/(1 - r_t) \geq c - \theta_t(1 + b)$ for r_t if $\theta_t = 0$.

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The way the model is set-up, an exogenous negative shock on r_t is best interpreted as a sudden and substantial deterioration of the economic outlook. As a result of such a shock, individuals can (and by all expectations will) experiment with a defection strategy, which subsequently invades a population of cooperators. If, however, the probability of recovering damages in the case of a breach of contract is large enough, or, more generally, a well-enough working legal system exists, the expected marginal gains of defecting decrease with each additional defector.

The type of the hawk–dove game ($\rightarrow \leftarrow$) plays a crucial role in this argument. Suppose the population finds itself in this scenario with the fraction of cooperators greater than x^* and the number of defectors increases. In that case, the probability increases that a defector is paired with another defector, resulting in a zero payoff. At the same time, and this is the other side of the same coin, the expected gain from defecting decreases due to the relatively high probability of having to pay damages together with a decreasing number of cooperators as potential counterparts. The same argument can be made the other way around. If the fraction of cooperators is smaller than x^*, the number of cooperators increases, but the speed of growth decreases with each additional cooperator. This is so because, for relatively small values of r_t coupled with relatively high values of θ_t, the marginal gain of cooperating is so small that the marginal increase of cooperation starts to decrease at some point. To be sure, similar effects are also at play for lower levels of the rule of law. In a Prisoners' dilemma ($\leftarrow$), it holds that the higher the number of defectors, the slower the decrease of cooperators in the population, but, crucially, this slowdown does not occur fast enough to prevent a total takeover by defectors.

Following the logic of the framework, *institutional resilience* refers to the capacity of a population to conserve a level of cooperation in the face of an adverse shock. In the case of a shock, institutional resilience prevents the informal institution from a complete breakdown and stabilises it to a level from which recovery of cooperation is faster. The formal institution of contract law provides the resilience of the informal institution of cooperation. This implies that a functioning legal system has two roles. First, it gives incentives to cooperate because it increases the probability of gaining the benefits of cooperation. Second, the quality of the legal system affects the underlying structure of the game. Consequently, it ensures that cooperation cannot entirely vanish from the population. This is how institutional resilience comes about. In a technical interpretation, institutional resilience emerges from the fact that the functioning legal system renders the strategy of defecting an unstable equilibrium.

The concept of institutional resilience contributes to questions of development and transition. In particular, the transition experience in Central and Eastern Europe in the 1990s offers a view of institutional resilience in action. Essentially, all the accounts of the process, which started to be published in the 2000s (e.g. Aslund, 2007; Havrylyshyn, 2006; Roland, 2000; or Sonin, 2013) underscore the importance of the rule of law and the legal system for the transition experience. Yearly scores on reform efforts in different legal areas from the European Bank of Reconstruction and Development accompanied the process. For example, Havrylyshyn (2006) develops a model where early reforms set the economy on a virtuous cycle, from which further reforms and higher economic activity follow. On the contrary, corruption becomes entrenched if early reforms do not come forward. This, in turn, creates a vicious cycle because a corrupted elite will try to prevent any reform effort, which would endanger their rents. By and large, the available data bear this out. The earlier the reform commences, the better countries perform today.

Legal reforms must translate into maximising the potential of agents' interaction in the economy for a virtuous cycle to have any long-term staying power. For this, a minimum level of the quality of the legal system must be achieved for the population to weather intermediate setbacks and external shocks. Institutional resilience is then a necessary condition for a virtuous cycle to be sustained over a more extended period.

However, some post-socialist countries, most prominently Russia, eventually did not gravitate towards a market economy with a contract law providing impartial adjudication of disputes. There and elsewhere, forms of crony capitalism (Lamberova and Sonin, 2018) emerged. Early investigations into reform outcomes concluded that while contract law in Russia exists and is being applied (Hendley

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et al., 2001), the identity of the contracting parties influences the impartiality of the proceedings (Frye, 2002). In the years following Putin's rise to power, this lack of due process in applying the law has not improved and is unlikely to change (Popova, 2017). Regarding the model presented here, from the point of view of individual players, this politicisation introduces uncertainty about the probability of getting fair treatment in case of disputes. Compared to the baseline model, the expected value of the parameter θ_t would decrease. As a result, the expected payoff from cooperation becomes harder to ascertain, which, all else equal, will push players to cooperate less. In the Russian case, it is precisely the lack of a dependable (from the point of view of the general population) legal system which adds to the uncertainty and affects the structure of the population in two ways. First, it makes reaching higher levels of cooperation and trust harder. Second, it makes cooperative behaviour less resilient because exogenous shocks cannot be contained. This dual effect leaves the population stuck in a low-cooperation equilibrium.

This observation is related to a broader point about the possible interplay between the domain of exchange and the legal domain. Not only should the legal domain be kept independent, but it should also be shielded from adverse spillover effects from the domain of exchange. The latter can be read in two ways. On the one hand, if an exogenous shock not only affected the perception of the economic outlook but would also have spillover effects into the legal system, the resilience effect would be lost. In this way, this paper can also be read as a reminder to provide stability to the law and the practising of law and protect it as much as possible from any kind of adverse external influence. On the other hand, one could imagine that, for example, a low level of trust could impact how the legal system functions. Suppose that a prevalence of defections in the population spills over into the legal system through bribes and other kinds of corruption. While this is not modelled explicitly here, from the point of view of players in the population game, this would – similar to above – increase the level of uncertainty about the expected value of cooperation.

The transition experience offers the clearest view of the importance of resilient institutions. But, of course, any exogenous shock worsening individuals' perceived future outlook will test the resilience of institutions. For example, this is undoubtedly true in the aftermath of the global financial crisis starting in 2007. The psychologists Navarro-Carrillo *et al.* (2018) use the aftermath of this crisis to study changes in different levels of trust using several study designs. They conclude that generalised trust, that is, the idea that most people in society are honest, decreased after the crisis. On the other hand, interpersonal trust, that is, the trust directed to close people, increased. In a nutshell, in the wake of a significant crisis, people respond by trusting the outside world less and withdrawing more into their circles.

The model I base the argument of resilience on can give a strategic explanation to this phenomenon. A perceived worsening of the economic outlook tempts individuals to abandon cooperation to potentially secure short-term gains from defection. Over time, this behaviour will increase as more individuals switch to this strategy. On the surface, this will then be picked up as a lower feeling of generalised trust. The presence and quality of the formal institution will then crucially affect how bad things get and ultimately determine the resilience of trust. The model and its conclusions here predict that countries or regions with weaker institutional set-ups not only suffer more substantial setbacks in terms of trust and cooperation in the immediate aftermath of a shock, but also take longer to recover from them.

4. Conclusion

The fact that well-functioning and inclusive legal systems foster development and growth is a commonplace. In this paper, I have emphasised a channel for the impact of good institutions. They work by making the informal institution of cooperation resilient. The direct effect of a rule of law and contract law is to give players a recourse in case of disputes. The more subtle effect of institutional resilience adds a crucial dynamic layer, which is less appreciated. Especially in times of crisis, the formal institution of an independent and impartial judiciary can provide resilience, which allows bouncing back to pre-crisis levels of cooperation.

The way the model is set-up suggests that it concerns itself with the medium term; the time horizon is finite. In addition, one can think about long-term considerations. The concept of resilience applied to the interplay of formal and informal institutions suggests that the higher the quality of the legal

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system, the higher the chance that the informal institution becomes entrenched as a cultural phenomenon and becomes a *convention* (Young, 1993). To explore the interplay between a formal institution and a convention, one would have to study stochastic equilibria then.

Finally, I believe that the fundamental idea of institutional resilience presented here is relevant whenever different institutions jointly impact behaviour and payoffs. The concept is fundamentally dynamic because the trajectory of strategic choice in the population matters for any policy choices. This applies to other strategic interactions.

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