On the Spontaneous Emergence and Sustainability of Market Trade.[1]

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July 1999

[1] I thank Federico Weinschelbaum for helpful comments. All errors remain mine.

Abstract

This paper approaches the study of the spontaneous emergence and sustainability of a market economy from the angle of commitment failure. A simple model of strategic trading is developed and tools from Evolutionary Game Theory are applied. Trade is risky because agents cannot commit to honoring their contractual arrangements, while external enforcement institutions are inexistent or perform poorly. It turns out that market trade spontaneously emerges in a risky environment only if the gains from trade are large enough. However, formal enforcement institutions that penalize opportunistic breach of contract are a prerequisite to the consolidation and expansion of markets. Brief comments on the incentives to create such institutions follow.

Resumen Utilizando herramientas de Teoría Evolutiva de Juegos, investigamos el surgimiento espontáneo y el desarrollo sustentable de un mercado en un contexto donde los intercambios son riesgosos. El riesgo se debe a que los agentes no pueden comprometerse a honrar sus acuerdos comerciales en ausencia de instituciones formales o informales que penalicen las conductas deshonestas. Una economía de mercado surge espontáneamente sólo si las ganancias del intercambio interpersonal son suficientemente altas. Sin embargo, instituciones formales dedicadas al enforcement de los derechos de propiedad resultan ser un requisito para la consolidación y expansión del mismo.

JEL C7, O1

1 Introduction

Most economists would agree with the fact that well functioning markets are crucial for promoting long term economic growth. Nevertheless, we are far from a thorough understanding of the process of market emergence, consolidation, and expansion.

This paper constitutes a step in that direction. Using a simple model of strategic interaction and applying tools from Evolutionary Game Theory we investigate the spontaneous emergence and sustainability of markets in a context of risky trading. Trade is risky because agents cannot commit to honoring their contractual arrangements, while external enforcement institutions are inexistent or perform poorly.

Previous work on related issues includes those of Greif (1994), Kranton (1996), Esponda (1998) and Fafchamps (1998). This paper is closest in spirit to Fafchamps (1998), who analyzes the spontaneous emergence of markets in the presence of heterogeneous agents and commitment failure.

Fafchamps argues against many that market trade is never anonymous. Instead, he characterizes it through relational strategies: agents search for competent agents and once found engage in long lasting relationships with them. For trade to take place the value that agents attach to commercial relationships must compensate them for the cost of screening potential partners and incurring some opportunistic breaches of contractual obligations. A market then emerges in a decentralized fashion; it does not require any coordination. Moreover, once markets emerge the gains from trade needed to overcome potential costs become smaller. Therefore, market exchange is sustainable in the long run.

In this paper we work with an alternative framework and obtain different results. Fafchamps's relational strategy is herein referred to as reciprocity. It represents long lasting family-like interactions and emerges as an immediate response to a risky environment. Market interactions are embodied in a strategy that consists of trading with a different partner each period. Such interactions are usually referred to as interpersonal market trade, as opposed to intra-family-like encounters. One of its key features is that it allows agents to learn from many other agents; an advantage absent in reciprocal trade.

The population of our artificial economy consists both of reciprocal and market agents and of cheaters. The latter always breach their contractual obligations. Thus trade takes place in a risky environment as long as cheaters are potentially present.

Following Fafchamps and unlike other authors, we explicitly analyze the model's dynamics instead of focusing on static or steady state analysis. However, unlike both Fafchamps and other authors, we do not endow our agents with the rationality required for some equilibrium concepts, such as subgame perfect equilibrium, to make sense. Instead, we assume myopic agents adopt any of three strategies (reciprocity, market and cheaters) depending on their expected payoffs. We use a simple payoff-monotonic dynamic from Evolutionary Game Theory, the Replicator Dynamics, in order to account for the fact that strategies that fare better than average grow at the expense of strategies that do worse than average.

Given that we focus on a different aspect of market trade, it comes to us as no surprise that results are different from Fafchamps's. Market trade spontaneously emerges in a risky environment if the gains from trade are large enough. However, the existence of legal enforcement institutions that penalize cheating is a prerequisite for the sustainability of markets.

The paper proceeds as follows. Section 2 describes the economy and gives partial results on the model's dynamics. The dynamics are completed in Section 3. Section 4 notes that markets spontaneously emerge only under large gains from trade; and Section 5 discusses the relevance of both formal and informal enforcement institutions for the process of market emergence, consolidation and expansion. The last section concludes and considers further extensions.

2 Reciprocity, Cheaters and the Market

2.1 Description of the Economy

The economy is populated by a continuum of infinitely lived agents who engage in pairwise exchange relationships over time. Traders are indexed from 0 to 1 and discount the future by a factor $\delta \in (0,1)$. Trade takes place through an infinitely repeated sequence of trading rounds, each round divided into three stages.

First, unmatched agents are randomly matched in pairs. Second, matched partners are assumed to engage in contractual obligations and play the one-shot prisoner's dilemma shown in Figure 1, with $0 < \alpha < 1$ representing gains from trade. Agents can either Comply with their contractual obligations or Breach the contract. Last, agents must decide whether to stay matched and engage in another contractual obligation with the same partner or to break the relationship and start next period as an unmatched agent. These stages are shown in Figure 2.

Because we want to focus on the spontaneous emergence of trade in a primitive society, external contract enforcement institutions that deter opportunistic breach of contract are assumed inexistent.

	Comply	*Breach*
Comply	**a,a**	**-1,+1**
Breach	**+1,-1**	**0,0**

Figure 1: The trading stage.

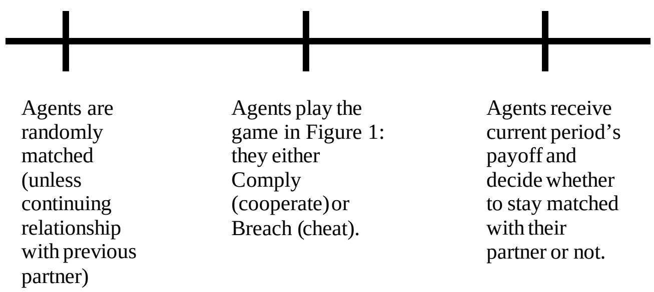

Figure 2: A trading round.

2.2 Reciprocity and cheaters

Consider the following strategy.

> Strategy R (reciprocity): Comply at stage two. At stage 3, end the relationship if you were cheated and continue it if your partner complied. (If you ever meet an agent who cheated you in the past, then cheat him at stage 2 and end your relationship at stage 3.)[1]

We call an agent playing a reciprocal strategy an R-agent. Notice that an R-agent searches for a partner who never cheats on him and, if found, stays with that partner forever. In particular, if two R-agents ever meet, they engage in an ever-lasting reciprocal relationship.

Assumption 1 Every time two unmatched R-agents become matched, two new R-agents are added to the population of unmatched agents.

[1] Two assumptions guarantee that the probability of meeting a previously met partner again is zero. First, there are always unmatched agents in the population (see assumption 1). Second, there is a continuum of agents.

This assumption captures the fact that no matter what other people are doing, there is always someone you can cheat on.[2] Assumption 1 will greatly simplify the analytical structure of our model later on. Notice that it allows us to establish a clear-cut result regarding how large gains from trade must be to prevent cheating.

Definition 1. A population profile is a Nash equilibrium if once reached no agent has incentives to change their strategy.

Proposition 1 *Given Assumption 1, there are always incentives to cheat when the entire population is playing strategy R; no matter how large gains from trade α are. Therefore the entire population playing strategy R does not constitute an equilibrium.*

Proof. This is because

$$\frac{\alpha}{1-\delta} < 1 + \frac{\alpha}{1-\delta}\delta \qquad \text{for all } \delta,$$

where the RHS comes from the fact that unmatched agents are all R-agents (due to Assumption 1) and the inequality is true because $\alpha < 1$.
■

It seems natural at this point to consider another strategy.

> Strategy C (cheating): Cheat your partner and break the relationship at stage three to find a new partner.

These C-agents never establish long-lasting relationships. They constitute a menace for traders who wish to share gains from trade and are willing to comply at stage 2 of the trading round. The existence of cheaters in a primitive economy captures the fact that when legal enforcement is absent, trade is risky.

Proposition 2 *All unmatched agents playing strategy C (i.e., by assumption 1, the entire population consists of C-agents) constitutes an equilibrium.*

Proof. By sticking to strategy C a player gets a payoff of 0 every period; by deviating and cooperating in any given round you obtain a payoff of -1 and a payoff of 0 forever after returning to your equilibrium strategy:

$$\frac{0}{1-\delta} > -1 + \frac{0}{1-\delta}\delta$$

■

[2] In fact, although not explicitly modeled here, one can forcefully interfere with an outside relationship. Stealing goods makes trade even riskier and such a possibility is open as long as there are agents trading in the population.

Propositions 1 and 2 tell us that if all (or most) agents were R-agents, then some cheaters would profit in such a population; but that if all (or most) agents are cheaters, then it pays to be a cheater because the probability of finding someone who cooperates is zero (or negligible)[3].

But what happens if some agents are R-agents and others are C-agents? We are particularly interested in finding out whether reciprocal relationships can spontaneously emerge in a context of risky trading.

Let p_t represent our population profile at time t and assume that it is the solution to a dynamical system. Let p^* be a fixed point (or steady state) of our system and let $B_\epsilon(p^*)$ represent the ball of radius ϵ around p^*. Throughout, we work with the following notion of equilibrium.

Definition 2. A population profile p^* is an asymptotically stable equilibrium if it is a fixed point (i.e. a Nash equilibrium) and if there is some $\epsilon > 0$ such that for any $p_0 \in B_\epsilon(p^*)$, the trajectory through p_0 approaches p^*.

This means that a slight ϵ-perturbation from p^* eventually returns the system to p^*. We are not interested in fixed points that are not stable because if the initial condition p_0 is chosen randomly, the probability of observing them is zero. From now on we frequently refer to an asymptotically stable equilibrium as simply an equilibrium and use the words steady state or fixed point to refer to a Nash equilibrium.

Consider a population consisting of only two type of traders, R and C-agents, in proportions p^R and p^C respectively. The expected payoff of an unmatched i-agent at time t is given by

$$V_t^i = \sum_j p^j V_t^{ij}$$

where V_t^{ij} is the expected payoff of an i-agent who is matched with a j-agent. Therefore we have

$$V_t^C = p^C V_t^{CC} + p^R V_t^{CR}$$

where

$$\begin{aligned} V_t^{CC} &= 0 + \delta V_{t+1}^C \\ V_t^{CR} &= 1 + \delta V_{t+1}^C \end{aligned}$$

and

$$V_t^R = p^C V_t^{RC} + p^R V_t^{RR}$$

[3] Words in parenthesis are conjectures to be proved later on.

where

$$
\begin{aligned}
V_t^{RC} &= -1 + \delta V_{t+1}^{R} \\
V_t^{RR} &= \alpha + \delta V_{t+1}^{RR}
\end{aligned}
$$

Solving we obtain

$$V_t^C = V^C = \frac{p^R}{1-\delta} \quad \text{for all } t$$

and

$$V_t^R = V^R = \frac{1}{1-\delta p^C}\left[p^R \frac{\alpha}{1-\delta} - p^C\right] \quad \text{for all } t.$$

Propositions 1 and 2 showed that $(p^{*C}, p^{*R}) = (1, 0)$ was the only equilibrium among pure population profiles. We now investigate whether a mixed population profile equilibrium $(p^{*C}, p^{*R}) >> 0$ exists.

A population profile $(p^{*C}, p^{*R}) >> 0$ constitutes a Nash equilibrium (i.e. a steady state) if

$$V^C(p^{*R}) = V^R(p^{*R}, p^{*C}). \tag{1}$$

We use (3) and $p^C + p^R = 1$ to solve for p^C and check whether agents have any incentive to change strategies.

Proposition 3 *$(p^{*C}, 1 - p^{*C})$ constitutes a mixed (asymptotically stable) equilibrium population profile if and only if the following expressions hold simultaneously*

$$p^{*C} = \frac{2\delta - \alpha \pm \sqrt{(\alpha - 2\delta)^2 - 4\delta(1-\alpha)}}{2\delta} \tag{2}$$

$$0 < p^{*C} < 1 \tag{3}$$

$$(1 - \delta p^{*C})^2 > (1+\alpha)(1-\delta) \tag{4}$$

Proof. See the appendix. ■

Equation (2) is the solution to (1) and represents a steady state of our implicit dynamics. For such a steady state to exist we need it to satisfy equation (3). Equation (4) is a stability condition: it says that a slight perturbation brings the system back to the steady state.

Notice that a mixed steady state need not exist. However, if it does exist, then there are two steady states, one stable and the other unstable.

Proposition 4 For any fixed α there exists a sufficiently large δ such that a solution to (4) and (5) (i.e., a steady state) exists.

Proof. Fix α. Then it is easy to verify that

$$\lim_{\delta \to \infty} p^C_{high} = 1;$$

$$\lim_{\delta \to \infty} \frac{dp^C_{high}}{d\delta} = \frac{1}{\alpha} > 0$$

and

$$\lim_{\delta \to \infty} p^C_{low} = 1 - \alpha.$$

■

Proposition 5 If a solution to (2) and (3) exists, then both

$$p^{*C}_{mixhigh} = \frac{2\delta - \alpha + \sqrt{(\alpha - 2\delta)^2 - 4\delta(1 - \alpha)}}{2\delta} \tag{5}$$

and

$$p^{*C}_{mixlow} = \frac{2\delta - \alpha - \sqrt{(\alpha - 2\delta)^2 - 4\delta(1 - \alpha)}}{2\delta} \tag{6}$$

are mixed steady states. Furthermore, p^{*C}_{mixlow} satisfies eq. (4) and so constitutes an (asymptotically stable) equilibrium; but $p^{*C}_{mixhigh}$ does not.

Proof. See the appendix. ■

Figure 3 shows the case where δ is sufficiently large, so that there are three steady states, $p^{*C} = 1$; p^{*C}_{mixlow}; and $p^{*C}_{mixhigh}$; but only the first two are stable.

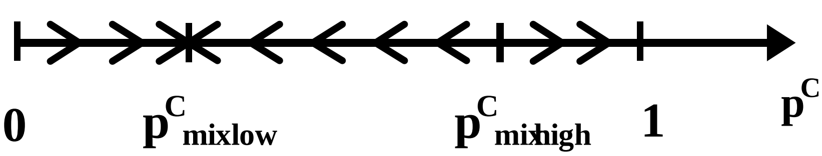

Figure 3: Reciprocity and Cheaters.

When the proportion of C-agents in the economy is large enough ($p^C > p^{*C}_{mixhigh}$) then the chances of meeting a cooperator are too small and it pays to be a cheater. Therefore, $p^{*C} = 1$ is still an equilibrium, as was to be expected from Proposition 2. However, for lower proportion of cheaters ($p^C < p^{*C}_{mixhigh}$), there is a mixed population profile equilibrium where both R and C-agents are present Thus, for large enough δ reciprocal trade spontaneously emerges in a risky environment.

Proposition 6 *For a fixed α, $p^{*C}_{mixhigh}$ is increasing in δ and p^{*C}_{mixlow} is decreasing in δ. Therefore, for larger δ reciprocal trade is more likely to emerge and, in case it does, the equilibrium proportion of cheaters is lower.*

Proof. Take derivatives in (5) and (6). ■

2.3 Market trade

The above section showed how the existence of cheaters does not eliminate trade. If agents care enough about the future, they can overcome risk by establishing reciprocal, long-lasting relationships with a partner. However, an agent is then confined to trade with the same partner over and over again.

There is still another possibility which resembles market trade and involves agents sharing the gains from trade with a different partner each period. This is represented by the following strategy:

> **Strategy M (market):** Cooperate at stage 2 and end the relationship at stage 3 (no matter your partner's behavior) in order to be randomly matched with a new partner next period.

As before, agents following strategy M are called M-agents and their proportion in the population is given by p^M.

Proposition 7 *As long as cheating is a possible strategy, $p^{*M} > 0$ is never a population profile equilibrium.*

Proof. Imagine there are some cheaters in the population. An M-agent then gets sometimes α (if he meets a cooperator) and sometimes -1 (if he meets a cheater). By cheating, however, he does strictly better: he gets sometimes +1 and sometimes 0.

In case there are no cheaters in the population, an M-agent (and also an R-agent) gets a payoff of $\alpha/(1-\delta)$. He does strictly better by deviating and cheating. ■

Proposition 7 rules out the spontaneous emergence of a market economy in the presence of risky trade; that is, when legal enforcement institutions are inexistent or perform poorly. This is illustrated in Figure 4.

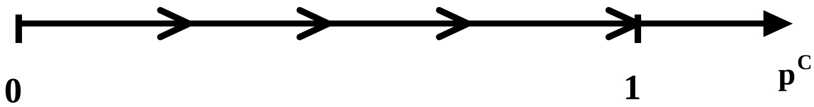

Figure 4: Market agents and Cheaters, $\alpha < 1$.

However, historical evidence suggests that legal enforcement institutions are not a prerequisite to the emergence of interpersonal exchange. In order to account for such a process, we allow the gains from trade, α, to be large enough. Notice that for $\alpha > 1$ the game in Figure 1 is no longer a prisoner's dilemma but now represents a coordination game.

To simplify, assume $p^M + p^C = 1$, so that only M and C-agents can be present in the population at any time. Then expected payoffs are given by

$$V_t^C = p^C V_t^{CC} + p^M V_t^{CM}$$

where

$$\begin{aligned} V_t^{CC} &= 0 + \delta V_{t+1}^C \\ V_t^{CM} &= 1 + \delta V_{t+1}^C \end{aligned}$$

and

$$V_t^M = p^C V_t^{MC} + p^M V_t^{MM}$$

where

$$\begin{aligned} V_t^{MC} &= -1 + \delta V_{t+1}^M \\ V_t^{MM} &= \alpha + \delta V_{t+1}^M. \end{aligned}$$

Solving and using $p^M + p^C = 1$ we finally obtain

$$V^C = \frac{1 - p^C}{1 - \delta}$$

and

$$V^M = \frac{\alpha - (1 + \alpha) p^C}{1 - \delta}.$$

Proposition 8 *For $\alpha > 1$, there are two population profile equilibria: $p^{*C} = 1$ and $p^{*C} = 0$. Furthermore, there is a mixed steady state*

$$p^{*C}_{mix} = \frac{\alpha - 1}{\alpha}$$

increasing in α but unstable.

Proof. For $p^{*C} = 1$ we have $V^M = -1 < 0 = V^C$. Then $p^{*C} = 1$ is an equilibrium, and this holds whether α is greater than one or not (see Proposition 7).

For $p^{*C} = 0$, we have $V^C = \frac{1}{1-\delta} < \frac{\alpha}{1-\delta} = V^M$, so that now $p^{*C} = 0$ is also an equilibrium.

Finally, for a mixed steady state we must have

$$V^C(p^C) = V^M(p^C).$$

The solution is given by

$$p^C_{mix} = \frac{\alpha - 1}{\alpha} > 0;$$

which is increasing in α; however, it is not an equilibrium. To see this notice that for $p^C > \frac{\alpha-1}{\alpha}$, we have $V^C > V^M$ so the population converges to $p^{*C} = 1$. And for $p^C > \frac{\alpha-1}{\alpha}$, $V^C < V^M$ so the population converges to $p^{*C} = 0$. ■

Figure 5 shows the case where $\alpha > 1$. Because p^C_{mix} is increasing in α, the greater the gains from trade the greater the probability that market emerges in a risky environment. However, for $\alpha \leq 1$ we are back to Figure 4, where cheaters eventually take over the entire population.

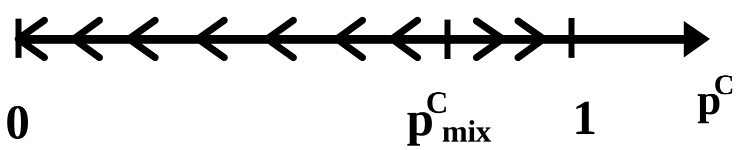

Figure 5: Market agents and cheaters, $\alpha > 1$.

Last, assume $p^M + p^R = 1$, so that only M and R-agents can be present in the population at any time. Notice that if both type of agents get α for mutual cooperation, then both get the same expected payoff. However, we assume that market agents, when meeting each other, get a payoff of $\tilde{\alpha} > \alpha$ for mutual cooperation, so that their expected payoff is now greater. This implicitly captures the fact that M-agents are interacting with many different partners and therefore have better chances of learning different skills and getting larger gains from trade. We take this to be a key feature of interpersonal, market trade.

3 Evolutionary Dynamics

Next we allow all three types of agents to be present in the population and apply tools from Evolutionary Game Theory in order to carry out an explicit dynamic analysis regarding the evolution of different forms of trade.

Conventional economic theory asserts that in equilibrium firms are maximizing profits. The argument is an evolutionary one: if they were not, they would be driven out of the market. Therefore, in equilibrium we can only observe firms which are profit maximizers. It is clear how implicit assumptions are made on out-of-equilibrium behavior.

Rather than advocating for a radical departure from conventional economic theory, evolutionary game theory attempts to formalize and make explicit the assumption that more successful behavior tend to be more prevalent in a population. In a sense, then, it constitutes a return to its roots.

Evolutionary game theory departures both from conventional (nonstrategic) economic theory and from traditional game theory by assuming that agents are not rational. In a complex world, behavior is guided by rules of thumb, norms and conventions. By trial-and-error learning processes, strategies that perform worst tend to be weeded out from the population.[4]

The origins of such an evolutionary approach are to be found in biology. Genes represent the players; and the characteristics of behavior with which these genes endow the host organism entail the strategies of the game. The relative fitness of behaviors (payoffs) is given by the number of offspring carrying that gene, and it depends on the distribution of behaviors across the entire population.

Genes (players) are programmed to behave in a specific way. A Darwinian natural selection process then operates over time and highest fitness behaviors survive.

This is not to be taken too literally in social and economic environments. Players represent people who choose strategies and may even change their choices. Behavior that is successful this period will be played by a larger fraction of the population next period. Payoff-monotonic dynamics provide such stylized formalization of Darwinian natural selection. Those strategies which fare relatively better will grow in the population at the expense of those which do relatively worse. This is the basic premise. Notice that no assumptions on rationality or common knowledge need to be placed.

It is important to recognize two crucial assumptions from the previous evolutionary story. First, we require many agents in our population; sufficiently enough to avoid repeated strategic interaction issues. This is why we work with a continuum of agents. Second, behavior is naive in the sense that agents view the world as stationary. That is, they are not aware of

[4] For a short introduction to evolutionary game theory, see Mailath (1998). For booklenght technical expositions, see Weibull (1995), Vega-Redondo (1996) and Samuelson (1997). For an informal account of how evolutionary game theory is applied to a wide variety of social phenomena, including justice, mutual aid, commitment, convention, and meaning, Skyrms (1996) is strongly recommended.

how their decisions affect everyone else's by changing the environment under which the entire population interacts. Imitation thus seems reasonable in such environments.

Consider trading in a risky environment where all three types of agents (strategies) are present in the population: C, M and R-agents. When players are unmatched they evaluate strategies according to their expected payoffs. These are a function of the population profile $p_t = (p_t^C; p_t^M; p_t^R)$ at time t and are given by

$$V_t^i = \sum_j p_t^j V_t^{ij}; \quad i; j = C; M; R;$$

where V_t^{ij} is the expected payoff of an i-agent who is matched with a j-agent.

To capture learning in interpersonal interactions we denote by $\alpha < 1$ the gains from trade under reciprocal exchanges and by $\gamma > \alpha$ the gains from trade under market exchange. Furthermore, we let β represent the gains from trade when an R-agent and an M-agent meet, with $\alpha < \beta < \gamma$.

Denote by $\mathbf{p}^e_{t+1} = (p^e_{t+1}; p^e_{t+2}; \ldots)$ the vector of expected population profiles. Then expected payoffs are given by[5]

$$V_t^C = p_t^R + p_t^M + \delta V_{t+1}^C(\mathbf{p}^e_{t+1}); \tag{7}$$

$$V_t^M = \beta p_t^R + \gamma p_t^M - p_t^C + \delta V_{t+1}^M(\mathbf{p}^e_{t+1}); \tag{8}$$

and

$$V_t^R = \frac{\alpha}{1-\delta} p_t^R + \beta p_t^M - p_t^C + (p_t^C + p_t^M)\delta V_{t+1}^R(\mathbf{p}^e_{t+1}): \tag{9}$$

Notice that expected payoffs depend both on the current population profile and on expected future population profiles. We assume agents have simple adaptive expectations.

Assumption 2. $p^e_{t+i} = p_t$ for all t, for all $i = 1; 2; \ldots$.

Assumption 2 says that agents expect the future to be just like the present, even though the present might be changing every period. This is consistent with evolutionary game theory's postulate that agents are myopic and are not fully aware of how the environment under which the entire population interacts changes.[6]

[5] We obtain (7), (8) and (9) by replacing and solving recursively, just as in section 2.

[6] What is important from Assumption 2 is that agents cannot coordinate their actions and decide to enter the market all at once because they expect everyone else to do the same; and therefore it is best reponse. Such story is far from a satisfactory account of market emergence. Of course, expectations need not be as simple as those given by Assumption 2. But they considerable simplify the model.

Assumption 2 allows us to rewrite expected payoffs (7), (8), and (9) as functions that depend on p_t only:

$$V_t^C(p_t) = \frac{p_t^R + p_t^M}{1-\delta};$$

$$V_t^M(p_t) = \frac{\alpha b p_t^R + \alpha e p_t^M - p_t^C}{1-\delta};$$

and

$$V_t^R(p_t) = \frac{1}{1-\delta\left(p_t^C + p_t^M\right)} \cdot \left[\frac{\alpha}{1-\delta} p_t^R + \alpha b p_t^M - p_t^C\right].$$

The Replicator Dynamics (RD) is a special kind of payoff-monotonic evolutionary dynamics where strategies which fare better than average grow at the expense of those which do worse than average; and the better they fare the higher their growth rate. The appropriate dynamics in our model are represented by the following system of simultaneous difference equations,

$$p_{t+1}^j = p_t^j \frac{V_t^j(p_t)}{V_t^A(p_t)}, \quad j = C, M, R; \tag{10}$$

where $V_t^A = p_t^C V_t^C + p_t^M V_t^M + p_t^R V_t^R$ is the average expected payoff; that is, the expected payoff of an agent being randomly chosen from the population of unmatched agents.[7]

Let

$$S = \left\{ p : \sum_j p^j = 1;\ p^j \in [0,1],\ j = C, M, R \right\}$$

represent the two-dimensional unit simplex, as shown in Figure 6.

Notice that the unit simplex S is invariant under the dynamics given in (10) in the sense that for initial conditions $p_0 = (p_0^C, p_0^M, p_0^R) \in S$, then

[7] Payoff-monotonic dynamics have been derived from microeconomic foundations by assuming that agents imitate most successful strategies, or even by postulating special types of learning dynamics. For example, Weibull (1995) studies social evolution of behaviors in a finite population of strategically interacting agents who once in a while review their strategies (or die and are replaced by new agents) and randomly choose a new one. Review times are modeled as the arrival times of a Poisson process and new strategies are chosen according to a probability density over all strategies, subject to the condition that strategies performing better have a greater probability of being chosen.

Assumption 2 is then pretty realistic in a context of primitive trading, where agents trade according to social customs (i.e., how they have been trading in the past) and every now and then revise their strategies and adopt a better one.

$p_t \in \Delta$ for all t.[8] Therefore, (10) together with initial conditions p_0 give a deterministic solution path p_t which can be graphically represented in Δ.

A further property of the RD is that if a strategy is absent from the population at any time, then it always has been and always will be absent. Then, when the state p_t is on one of the three border sides of the triangle shown in Figure 6, it remains in such a border forever.[9]

Observe that what we actually did in Section 2 was to analyze the dynamics on the boundary of the triangle. Figure 6 shows such dynamics for the case where δ is sufficiently large (Proposition 4) and $\alpha_e > 1$ (Proposition 8).

To consider the case where all three type of agents are present (i.e., the interior of the triangle) we simulate global dynamics on Matlab© by approximating (10) with its continuous time analogue. Results are graphically represented in Figures 7, 8, and 9. Notice that there is no equilibrium population profile such that all three strategies are present in the population in the long run.

When $\alpha = \alpha_b = \alpha_e < 1$ there are two equilibria, as shown in Figure 7[10]. When the initial proportion of cheaters is large enough, then cheaters take over the entire population. If not, then both cheaters and R-agents are present in the population. This is essentially the result obtained in Proposition 5 when M-agents were considered to be absent from the population.

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[8] This is easily seen by rewriting (10) as $p^j_{t+1} - p^j_t = p^j_t \frac{(v^j_t - v^A_t)}{v^A_t}$; $j = C; M; R$ and noticing that $\sum_j \left(p^j_{t+1} - p^j_t\right) = 0$.

[9] Notice also that if a strategy is ever present in the population, then it has always been and always will be present. This does not rule convergence to one of the borders as time goes to infinity.

[10] The vertices should be labeled as in Figure 6: p^R in the northwest; p^M in the southwest; and p^C in the southeast corner.

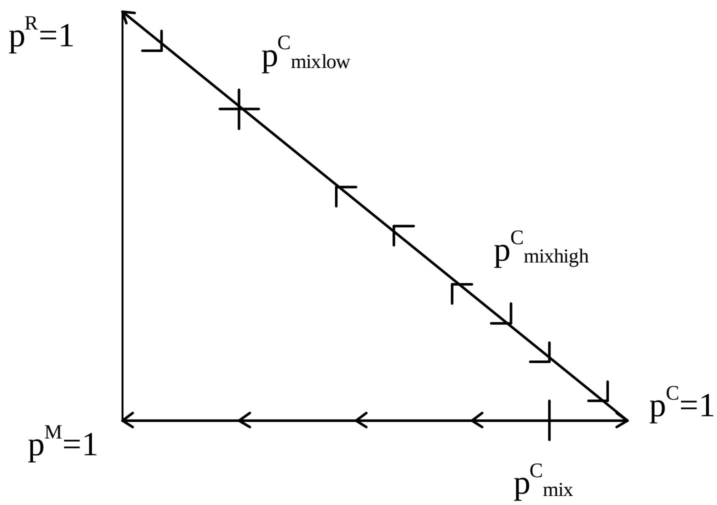

Figure 6: Border dynamics on S.

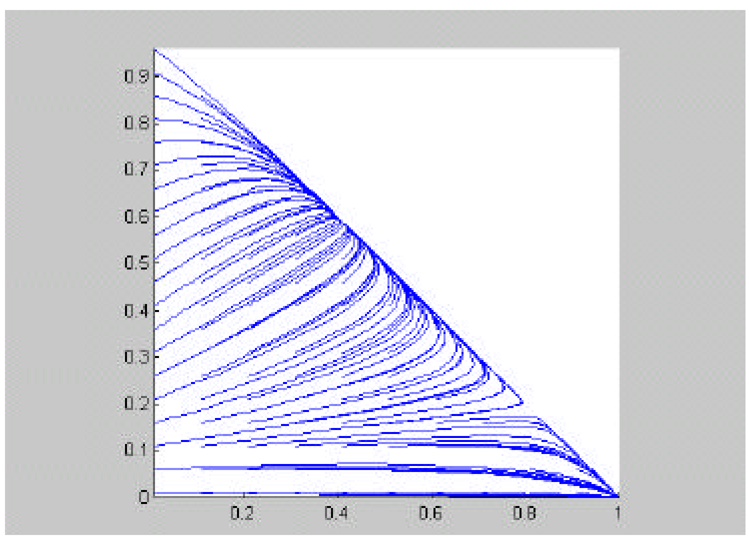

Figure 7: $\delta = 0.9; \alpha = b = e = 0.7$.

Figure 8 shows that if gains from market trade are large enough ($e > 1$), then there is a third equilibrium where M-agents take over the entire population. This efficient equilibrium is reached only if the proportion of M-agents is large enough relative to C and R-agents.

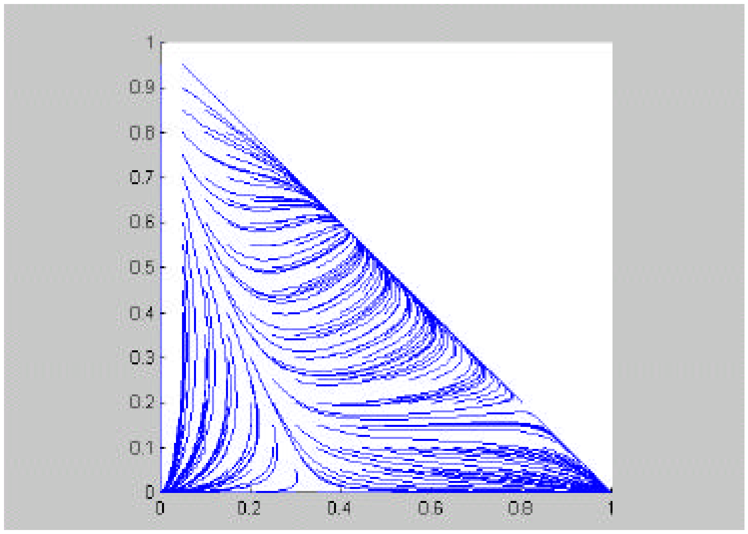

Figure 8: $\delta = 0.9; \alpha = \beta = 0.7; \gamma = 1.5$

Last, Figure 9 shows that for greater gains from trade a pure market equilibrium is reached under a larger set of initial conditions.

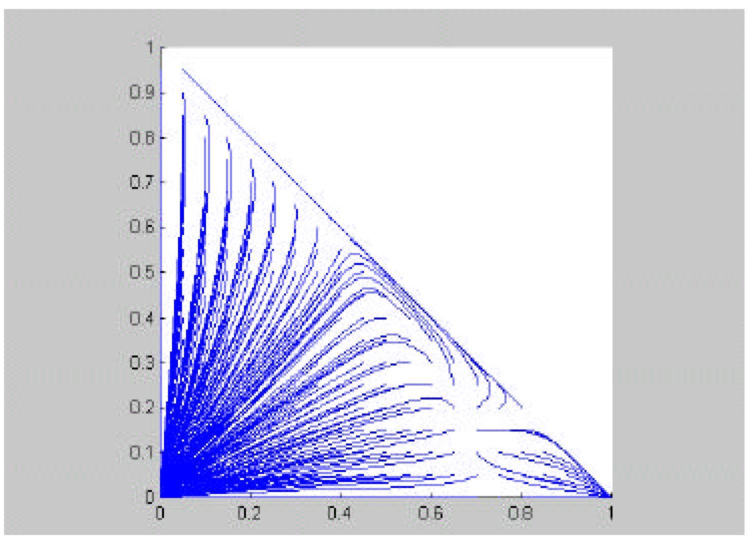

Figure 9: $\delta = 0.9; \alpha = 0.7; \beta = 3; \gamma = 6$:

We summarize our findings in the following proposition.

Proposition 9 *Suppose δ is large enough (see Propositions 4 and 5). Then for $\alpha = \beta = \gamma < 1$, $(p^C; p^M; p^R) = (p^{*C}_{mix\,low}; 0; 1 - p^{*C}_{mix\,low})$ and $(1; 0; 0)$ are the only (aymptotically stable) equilibria. For $\alpha < 1 < \gamma$ there is a third (aymptotically stable) equilibrium population profile given by $(0; 1; 0)$.*

Proof. See the appendix. ■

4 Market emergence

Last section showed how long-run equilibrium exchange arrangements depend on initial conditions and parameter values $\delta; \alpha; \beta;$ and γ. In particular, spontaneous market emergence is possible only if the proportion of M-agents is large enough relative to C and R agents. And the set of initial conditions that lead to $p^M = 1$ grows with gains from trade γ.

Nevertheless, a satisfactory analysis of market emergence needs to rule out the previous existence of a market. That is, we must explain how interpersonal trade develops from scratch, when the proportion of M-agents is zero.

But if p^M is ever zero, our dynamics imply it is zero forever: market trade cannot emerge. However, this is because we have been dealing with a deterministic dynamic system. A mutation-like component is often included that transforms deterministic payoff-monotonic dynamics such as the one we have been studying into a stochastic dynamical system. The equilibrium concept under such systems is that of stochastic stability, and results usually differ from the notion of asymptotic stability studied in deterministic systems.[11]

Mutations are taken to represent experimentation with new strategies in a social setting. From Figure 8 we can see that if the number of agents experimenting with strategy M (i.e., mutating) is large enough so as to place the system at a path convergent to $p^M = 1$, then market trade emerges. But then a smaller number of mutations towards either strategy C or R are required to place the system at a path divergent to $p^M = 1$. Thus, the system will spend most of its time in a state where the proportion of M-agents is close to zero.

Nevertheless, Figure 9 shows that if gains from market trade are large enough, then a very small number of mutations are needed to place the system at a path convergent to $p^M = 1$.[12]

Remark If gains from market trade are sufficiently large, then market trade spontaneously emerges from a situation in which the population contains only R and C agents.

Our model suggests a two-stage market development process. First, if agents care enough about their future (i.e., large δ), they engage in reciprocal long-lasting personal trade in order to avoid risky encounters. Second, as these agents experiment with strategy M and realize that there are much larger gains from interpersonal trade, growth-enhancing market arrangements eventually take over the entire population.

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[11] For analysis of stochastic stability, see the pioneering works of Kandori, Mailath and Rob (1993) and Young (1998).

[12] The entire point is raised by Esponda (1998), who endows markets with an increasing returns to scale property in order to explain its emergence.

5 Sustainability of Market Trade

5.1 Gains from trade

If gains from trade θ are large enough then market trade spontaneously emerges. However, this does not rule out the possibility of market reversals. As evident from history, markets frequently emerge only to disappear in the future and even reappear later on under new shapes and forms.[13]

In his Theory of Economic History, Hicks emphasizes the importance of studying the Exchange Economy because it is

> ... a transformation which is antecedent to Marx's rise of Capitalism, and which, in terms of more recent economics, looks like being even more fundamental. [Hicks 1991 (1967), p.7]

He then adds:

> It is evident that the transformation was a gradual transformation ... [...] ... it was not a transformation that occurred once for all; there are societies which have slipped back from being exchange economies, after which the same tale has been gone through again. [op. cit., p.7]

This section argues that legal enforcement institutions are a prerequisite for the consolidation and sustainability of growth-enhancing exchange arrangements.

Our model indicates that market trade is sustainable as long as θ remains at very high values. But there are at least two reasons why θ might decrease through time. First, gains from market trade θ are initially large due to enormous learning possibilities but eventually diminish as interpersonal interactions become more numerous and complex. Second, it is not very clear how gains from cheating a cooperator (+ 1) can remain fixed as a market economy offering greater gains from trade develops. One would also expect greater gains from cheating.

As a consequence, we expect θ to remain at low values for long periods of time. But then we are back to Figure 8, and under stochastic mutations market trade stagnates and agents switch to strategies R and C once again.

We conclude that although market trade might spontaneously emerge in our model, its emergence will be characterized by a cycle consisting of long periods of stagnation followed by periods of re-emergence. Thus a market economy is not sustainable when institutions that deter opportunistic breach of contract are absent or perform poorly.

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[13] Esponda (1998) analyzes market reversals by postulating (exogenous) decreasing returns to market trade.

Therefore, nothing guarantees that market trade will allow for everlasting growth-enhancing interpersonal exchanges to take place. As Douglass North points out, this is a very idealized view of society.[14]

> ...as the complexity of the environment increased as human beings became increasingly interdependent, more complex institutional structures were necessary to capture the potential gains from trade. Such evolution requires that the society develop institutions that will permit [interpersonal] exchange across time and space. [North 1994, p.363]

However, nothing guarantees that such institutions will evolve.

> In fact, most societies throughout history got stuck in an institutional matrix that did not evolve into the [interpersonal] exchange essential to capturing the productivity gains that came from the specialization and division of labor that have produced the Wealth of Nations. [op. cit., p.364]

We argue that the creation of institutions that penalize cheaters constitutes a first step towards sustaining complex interpersonal interactions. Special attention is given to the issue of what motivates agents to create such institutions.[15]

5.2 Informal and formal enforcement institutions

Market trade is not sustainable because cheaters are always a menace who invade the population as soon as gains from trade are small enough. For a market economy to prosper, incentives for being a cheater must be reduced. History shows that this has been carried out by both informal and formal enforcement mechanisms. Several authors have investigated the relevance of such institutions.

In the context of a medieval agency problem, Greif (1994) explores how societies with different cultural beliefs adopt different organizational forms as a response to a commitment problem among merchants and their overseas agents. Collectivist merchants never hire an agent who has cheated any merchant of their own ethnic group. This exclusion turns out to be self-enforcing because if all other merchants are punishing deviant behavior, then a cheater must receive a higher wage in order to remain honest. Therefore, it is in any merchant's interest to hire agents who have not cheated. However, relationships are established among individuals from the same ethnic group, resulting in a segregated social structure and, as conjectured by Greif, hindering economic efficiency.

[14] But which has nevertheless been emphasized by neoclassical growth models.

[15] Thus, we are interested in studying self-enforcing institutions.

Fafchamps (1998) shows how stigmatization of cheaters facilitates market emergence. Breach of contract may trigger permanent exclusion from trade if it is interpreted as a signal of impeding bankruptcy.

These studies suggest that agents may even be willing to pay some outside authority, such as a credit reference bureau, for the names of cheaters. For example, Carmichael and MacLeod (1997) show how in an evolutionary model the social custom of gift giving, by imposing costs at the beginning of the relationship, is a signal of a player's honesty and can therefore lead to trust and cooperation.

Greif (1997) is an interesting account of how inter-community exchange was supported in pre-modern Europe through an informal information transmission mechanism, the Community Responsibility System. However, as trade expanded, such informal mechanism was abolished and substituted with legal enforcement provided by the State.

There seem to be limits to informal contract enforcement mechanisms based on social networks. As trade expands, these limits become evident and formal legal enforcement institutions must be created in order to sustain gains from market trade. The State is usually involved in such a transition, probably because it has a comparative advantage at exploiting traders' willingness to pay for protection and law enforcement.

Consider how spontaneous market emergence can be sustained in our model under the introduction of a new kind of player, the State. Suppose the State wishes to maximize fiscal revenues, and that only market-like exchanges can be taxed. Then the State has incentives to promote market trade by, say, penalizing cheaters.[16] At the same time, agents will trade at the market as long as the extra efficiency gains captured from market trade are larger than the cost payed in taxes. And the State has clear incentives to make this so if it is interested in fiscal revenues.

Of course, more complex formal institutions are required as market trade expands. One example of the relevance of such institutions is given by North and Weingast (1989). They show how new institutional arrangements in seventeenth-century England led to remarkable economic success by allowing the government to credibly commit to upholding property rights.

6 Conclusion

This paper focused on how market exchange spontaneously emerges in the presence of commitment failure. However, we differ with Fafchamps (1998) in two main aspects.

First, we do not endow agents with the cognitive abilities necessary for rationality-demanding equilibrium concepts to make sense. Instead, we as-

[16] Of course, this leads to new kinds of questions, such as who controls the State in avoiding confiscatory measures, etc.

sume our agents are myopic and adopt any of three strategies (reciprocity, market and cheaters) depending on their expected payoffs. Agents are assumed to revise their strategies once in a while and imitate those which are more successful.

Second, reciprocal trade is taken to represent family-like encounters. We model market exchange by assuming that agents engage in several interpersonal transactions. Learning from several agents is a key feature of such interactions and has already been used by Esponda (1998) in a completely different framework to study the emergence of a market economy.

Under this framework, reciprocal exchange constitutes a response to a risky environment. If agents care enough about their future, then starting a long-lasting relationship with a partner saves them the potential cost of meeting an unknown cheater in the market. Furthermore, our deterministic dynamics do not allow us to explain market emergence, no matter how large gains from trade might be.

However, when we explore mutations we obtain a stochastic dynamical system that allows for market emergence. If the value that traders attach to learning in the form of interpersonal commercial transactions is high enough, then the risk of market trading is worth taking.

When exploring the sustainability of market trade through time, it is evident that gains from trade cannot remain at such large values indefinitely. As soon as they drop, our model predicts the disappearance of market trade. Thus, a cycle consistent with historical evidence results in which a market first emerges but then collapses only to reappear later in a future time.

Consequently, we argue that formal enforcement institutions are a prerequisite for the consolidation and expansion of a market economy and briefly regard some of the related literature. There are clear incentives for a third actor, the State, to provide the legal enforcement required for safe contractual arrangements.

Our model is simple enough to be analytically tractable. However, we leave many interesting issues not modeled. An exploration into the field of Computational Economics would allow for more flexibility in our model and therefore provide us with many interesting insights on the process of market emergence and sustainability. A computer program representing a virtual world filled with artificial agents who posses limited cognitive abilities and interact under an uncertain environment is left for future work.[17]

An in-depth exploration into Economic History would provide the details necessary to implement such project. There is much to learn from history, and we must not overlook such issues when building theoretical models.

Understanding the process by which a market economy emerges and expands constitutes a first step in an agenda to study the performance and functioning of market (and non-market) institutions that promote economic

[17] See Tesfatsion (1998) for an introduction to the literature.

well-being. Not only has the way individuals have decided to organize their exchanges (and their underlying motivations) been crucial for the historical success and failure of modern economies, but it will continue to be crucial in the future. The institutions that are created in order to deal with ever increasingly complex social interactions will ultimately determine the path of future economic development.

7 Appendix

Proof of Proposition 3.

A mixed steady state is the solution to

$$V^C(p^C) = V^R(p^C);$$

where

$$\begin{aligned} V^C(p^C) &= \frac{1 - p^C}{1 - \delta} \\ V^R(p^C) &= \frac{1}{1 - \delta p^C}\left[\frac{\alpha}{1-\delta} - p^C\left(1 + \frac{\alpha}{1-\delta}\right)\right]: \end{aligned}$$

Solution is given by

$$p^{*}_{mix\,high} = \frac{2\delta - \alpha + \sqrt{(\alpha - 2\delta)^2 - 4\delta(1-\alpha)}}{2\delta}$$

and

$$p^{*}_{mix\,low} = \frac{2\delta - \alpha - \sqrt{(\alpha - 2\delta)^2 - 4\delta(1-\alpha)}}{2\delta}:$$

These mixed steady states are stable if

$$\frac{d}{dp^C}\left[V^C - V^R\right]\bigg|_{p^{*}_{mix}} < 0:$$

We have

$$\frac{dV^C}{dp^C} = -\frac{1}{1-\delta} < 0$$

and

$$\frac{dV^R}{dp^C} = -\frac{(1+\alpha)}{(1-\delta p^C)^2} < 0:$$

Therefore, a steady state p^{*}_{mix} is stable if

$$(1 - \delta p^C)^2 > (1+\alpha)(1-\delta):$$

Proof of Proposition 5. The fact that they are mixed steady states comes from Proposition 3. From Proposition 3, stability requires that

$$(1-\delta p^C)^2 > (1+\alpha)(1-\delta):$$

Rewriting and replacing with p^C_{low} we get

$$2^{\frac{1}{2}}\left[-\left(2\delta-2\delta^2-\alpha^2/2\right)\right]^{\frac{1}{2}}(1-\delta+\alpha/2) > 2\delta-2\delta^2-\alpha^2/2:$$

Because we are assuming a steady state exists, then $-\left(2\delta-2\delta^2-\alpha^2/2\right) > 0$; so the LHS is positive, the RHS is negative and the inequality is satisfied. Therefore, p^C_{low} is a stable steady state.

If we replace with p^C_{high} we get

$$-2^{\frac{1}{2}}\left[-\left(2\delta-2\delta^2-\alpha^2/2\right)\right]^{\frac{1}{2}}(1-\delta+\alpha/2) > 2\delta-2\delta^2-\alpha^2/2:$$

Simplifying we obtain

$$\left(1-\delta+\frac{1}{2}\alpha\right) < -\frac{1}{2}\left(2\delta-2\delta^2-\alpha^2/2\right)^{1/2}$$

Taking square roots and simplifying we finally get

$$(1-\delta)(1+\alpha) < 0;$$

which is not possible and therefore p^C_{high} is not stable (i.e., equation 6 is not satisfied).

Proof of Proposition 9.

Border dynamics have already been analyzed in Section 2. Thus, it remains to be proved that there is no equilibrium population profile that belongs to the interior of the simplex S (i.e., there is no mixed equilibrium). We show that if such a mixed steady state exists, then it is not stable. Using $p^C + p^M + p^R = 1$; we can reduce system (14) to a simultaneous two-equation system of difference equations. One possibility is

$$p^C_{t+1} = p^C_t \frac{V^C_t}{V^A_t}$$

$$p^M_{t+1} = p^M_t \frac{V^M_t}{V^A_t}$$

where $p^R_t = 1 - p^C_t - p^M_t$. A mixed steady state is characterized by

$$V^C_t = V^M_t = V^A_t:$$

Thus we can solve the above equations for steady state values p_t^C and p_t^M.

We then proceed to analyze local stability of this mixed steady state by linearizing our system around the steady state. One possible approach is to convert our system of first-order simultaneous equation into a linear second-order difference equation. Next we find the roots of the characteristic equation. We show that there is at least one root (either real or complex) whose absolute value is greater than or equal to 1, so our steady state is not stable.

We omit such cumbersome calculations and rely instead on computer-simulated dynamics.

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