MARKETS AND COOPERATION

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Abstract. Why do money and markets crowd out cooperative relations? This paper characterizes the effects of intertemporal preferences, money, and markets on players' ability to cooperate in material-payoff supergames. Players' aversion to intertemporal substitution facilitates cooperation by decreasing their evaluation of short-run gains from deviations and increasing that of losses from punishments. Goods' markets and money may hinder cooperation by allowing players to reallocate short-run gains from deviations in time, at some cost. Allowing for free intertemporal reallocation of payoffs, perfect financial markets always make cooperation harder. Financial markets' imperfections facilitate cooperation by opposing this effect.

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1. Introduction

When isolated communities get in contact with more developed economic institutions an internal breakdown of cooperation typically occurs. This phenomenon has been often observed in the management of common pool resources. For example, Jodha (1985, 1986, 1988) finds that for the Indian villages in the ICRISAT sample, controlling for other factors, the closer are organized markets (towns), the faster is the erosion in the common resource pool.[1]

More recently, Kranton (1996) has drawn attention on "reciprocal exchange relations" in traditional societies, where compliance to informal bilateral agreements is enforced by the threat of ending the relation. She describes a number of historical episodes in which the introduction of more sophisticated methods of exchange or the development of nearby spot markets has made it impossible to sustain cooperation in traditional exchange relations.

Jodha attributes this phenomenon to the spread of "individualistic market values" within communities. Kranton explains it with a reduction in the available enforcing power caused by developed markets' low search costs, which soften the threat of ending the reciprocal relation by making anonymous transactions more attractive.[2] Spagnolo (1999) argues that there are "economies of scope" in cooperation, so that by substituting for some of the many reciprocal relations that link community members anonymous markets may make cooperation collapse in all the remaining ones.

Here I propose an alternative (or additional) theoretical explanation based on the interaction between players' aversion to intertemporal substitution, their ability to access goods and financial markets, and their ability to sustain cooperation. Real world agents are strongly averse to intertemporal substitution.[3] This turns out to facilitate cooperation, since it reduces agents' evaluation of short-run gains from unilateral deviations relative to losses from punishments. The access to money and markets, therefore, makes cooperation harder to sustain by allowing deviating agents to improve the intertemporal allocation of short-run gains from unilateral deviations; that is, by increasing agents' evaluation of direct gains from "cheating."

The phenomenon of cooperation in strategic situations which – in their static structure – resemble a Prisoner's Dilemma has been well understood thanks to three decades of work on infinitely repeated games (e.g. Friedman (1971), Aumann and Shapley (1976), Rubinstein (1979), Fudenberg and Maskin (1986), Abreu (1986, 1988)). All these studies adopt the standard game-theoretic approach by which the stage-game's payoffs are in the form of subjective (von Neuman-Morgenstern) utility. This approach allows for a parsimonious description extremely useful in the analysis of complex strategic situations. However, real world phenomena may not always be reduced to a game as usually defined without losing some of

[1] For analogous examples and further references see e.g. Dasgupta (1993), and Baland and Platteau (1996).

[2] A similar argument was made by MacLeod (1988) with regard to the role of exit rights in production cooperatives. The argument that market institutions may hinder cooperation by limiting the strength of available punishments has also been made by Baker, Gibbons, and Murphy (1994), Schmidt and Schnitzer (1995), Prendergast and Stole (1997), and Bernheim and Whinston (1998), with regard to the interaction between explicit and implicit contracts.

[3] Estimates of the coefficient of absolute aversion to intertemporal substitution range between 2 and 10; see e.g. Hall (1988), Epstein and Zin (1991), and Deaton (1992).

their interesting features.

In contrast, here I distinguish between the "material payoffs" (or "outcomes") generated in the strategic interaction and players' evaluation of such payoffs through their preference systems. This allows me to study how important aspects of the real world, such as intertemporal preferences and opportunities to access markets, affect players' ability to cooperate (or collude).

I focus on stationary equilibria of discounted repeated games generated by stage-games with a static Nash equilibrium that keeps players at their minimax. For this class of games, which includes the repeated Prisoner's Dilemma and the repeated Bertrand oligopoly, reversion to the static Nash equilibrium is an "optimal punishment" (Abreu (1986)). I can then characterize the effects of players' attitudes toward intertemporal substitution and the opportunity to access money and markets by focusing on the set of equilibria sustainable by the simple threat of "Nash-reversion" (Friedman (1971)). Of course, the results apply to any other repeated interaction – implicit contracts, reciprocal exchange relations, common pool games, etc. – in which stationary punishments are used not because they are optimal, but because they are simple, they imply few coordination problems or "complexity costs."[4] The results also apply when players use the simple renegotiation-proof strategies proposed by van Damme (1989).

I first find that players' aversion to intertemporal substitution facilitates cooperation by relaxing the necessary conditions for any stationary flow of material payoffs to be supportable in subgame-perfect equilibrium. A more concave instantaneous utility function leads players to value relatively less the short-run material gains from any deviation, which are concentrated in the period in which the deviation occurs, and to value relatively more the material losses from the punishment phase, which are distributed in many periods after the deviation.

Once means to transfer material payoffs over time are introduced, we leave the field of repeated games to enter that of stochastic ones (see e.g. Dutta (1995)). However, the qualitative effects of money and markets on cooperation can be evaluated while maintaining the more intuitive repeated games perspective.

I find that the access to a market for goods (material payoffs), and thereby to "money" as a mean to preserve wealth in time, makes cooperation harder to sustain when the transaction costs linked to market exchange and the time costs of delaying consumption are not too large. Then, a player averse to intertemporal substitution who unilaterally deviates from cooperation finds it optimal to face these costs, sell part of the short-term material gains from deviation on the market, save, and buy material payoffs during the following punishment phase. On the contrary, players who stick to cooperation expect a constant flow of material payoffs in time, which is an optimal intertemporal allocation, therefore gain nothing from the opportunity to save at a positive cost.

Perfect financial markets enable players to costlessly redistribute material payoffs in time, therefore the access to perfect financial markets always makes cooperation harder. Again, cooperating players have no use for financial markets, while perfect financial markets increase the life-time utility of a player who deviates from cooperation more than money and goods'

[4]This might be the case, for example, of tacit collusive agreements with imperfect information (see Green and Porter (1984)). To enforce collusive behavior in a complex world in which information is imperfect and communication prohibited, agents may do better by using simple mechanisms.

markets.

Financial markets' imperfections are frictions that make the intertemporal reallocation of material payoffs costly. Therefore, by the converse argument, financial markets' imperfections make cooperation easier to sustain.

Note that the negative effect of markets on cooperation identified in this paper hinges only on their role as instruments for the intertemporal allocation of wealth. Therefore, this effect adds to the other two negative effects of markets on cooperation highlighted by Kranton (1996) and Spagnolo (1999).

The paper is organized as follows. Section 2 presents a numerical example; Section 3 characterizes the effects of agents' aversion to intertemporal substitution; Section 4 focuses on markets for goods and money; Section 5 considers perfect financial markets; Section 6 deals with financial markets' imperfections; and Section 7 discusses extensions and briefly concludes. All proofs are in the appendix.

2. An example: drying apples

Consider the following bi-matrix and suppose the numbers it contains are physical measures of material payoffs, numbers of apples, say.

$$\begin{array}{cc} & \text{Player 2} \\ \text{Player 1} & \begin{pmatrix} 16,16 & 0,25 \\ 25,0 & 9,9 \end{pmatrix} \end{array}$$

Suppose this simultaneous "apples" Prisoner's Dilemma is repeated an infinite (or finite but uncertain) number of times, and that players discount future payoffs by way of a common discount factor $\delta < 1$. As usual, players are able to sustain cooperation if the loss of future gains from cooperation caused by the credible punishment phase which follows a deviation is large enough to offset the short-run gains from a unilateral deviation. When players' preferences over the physical outcomes in the stage-game are linear in apples and the intertemporal utility function is additively separable, cooperation is supportable if:

$$\frac{1}{1-\delta}16 \geq 25 + 9\frac{\delta}{1-\delta}, \quad \Leftrightarrow \; \delta \geq \frac{9}{14}. \tag{1}$$

Instead, consider players whose preferences over apples are given by the utility function $U(x^t) = \sqrt{x^t}$, where x^t is the number of apples available in period t, so that in each period τ they maximize the objective function $V^\tau = \sum_{t=\tau}^{\infty} \delta^{t-\tau}\sqrt{x^t}$. The same material payoffs bi-matrix considered before now leads to the following condition:

$$\frac{1}{1-\delta}\sqrt{16} \geq \sqrt{25} + \sqrt{9}\frac{\delta}{1-\delta}, \quad \Leftrightarrow \; \delta \geq \frac{7}{14}. \tag{2}$$

Given our "apples supergame," when the discount factor is between $\frac{7}{14}$ and $\frac{9}{14}$ only players with the second type of preferences can sustain cooperation.

Suppose now that players have the second type of preferences, as in reality, and imagine that at a certain point in time a technology for preserving apples at some cost (or for exchanging present apples against future apples) is unexpectedly discovered. Agents learn, say, to dry apples and preserve them for one period, after which they must be consumed. Unfortunately (or fortunately?), some of the dried apples or some of their nutritional value get spoiled during such a procedure.

If the rate of spoiling is not too high, an agent who deviates from cooperation obtaining 25 apples in the period in which the deviation occurs will want to save for the next period in which he will receive only 9 apples (because of the punishment). Let d denote the percentage of saved apples that survives the drying procedure, and q the percentage of apples that is consumed in the same period in which the deviation occurs, so that $(1-q)d$ is the fraction of apples that reaches the period after the deviation. The player will choose q in order to maximize his intertemporal utility. When a player deviates, he solves his simple intertemporal utility maximization problem

$$\max_q \left[\sqrt{q25} + \delta\sqrt{d(1-q)25+9} + \delta^2 \frac{\sqrt{9}}{1-\delta}\right].$$
$$\text{subject to} \quad : \quad 0 \le q \le 1.$$

The first order condition with respect to q leads to

$$q = \frac{25d+9}{25d+25\delta^2 d^2}.$$

As long as the rate of surviving in the drying process is high enough to make $\delta^2 d^2 > \frac{9}{25}$, the agent chooses $q < 1$ (saves some apples). Then, after the introduction of the drying technology, cooperation will be sustainable if

$$\frac{\sqrt{16}}{1-\delta} \ge \sqrt{25\frac{25d+9}{25d+25\delta^2 d^2}} + \delta\sqrt{9+25\left(1-\frac{25d+9}{25d+25\delta^2 d^2}\right)} + \delta^2\frac{\sqrt{9}}{1-\delta},$$

a more stringent condition than (2).

Now suppose that before the discovery of the drying technology players were sustaining cooperation, but condition (2) was satisfied with little or no slack. Then, the sudden access to a new saving technology makes cooperation collapse, leaving players with an infinite stream of 9 apples per period, and the new technology remains unused!

Let us generalize somewhat the insights gained from this example.

3. Intertemporal substitution and cooperation

A simultaneous material payoff game G is defined by the finite set N of players, the finite sets of actions A_i from which each player $i \in N$ can choose, and the material payoff functions π_i, $\pi_i : \prod_{i=1}^{N} A_i \to R$. The material payoff game $G = (N, A, \pi)$ generates different games when players with different preferences over material payoffs (outcomes) are called to play it.[5] I confine attention to players whose instantaneous preferences can be represented by utility functions that are monotonic transformations of their material payoff functions.

[5] In the rest of the paper, the absence of a subscript will mean either that the symbol refers to the whole set or vector of indexed objects - for example, $A = (A_1, A_2, ..., A_N)$ - or that, because of symmetry, there is no difference in the variable in question for the different players. The subscript $-i$ will be used to indicate a vector in which the i-th row is missing.

Assume G has at least one symmetric pure strategy Nash equilibrium which keeps players at their security material payoff level $\underline{\pi}_i$ (pure strategy Nash equilibria of static games are unaffected by monotonic transformations of the payoff functions, which lead to ordinally equivalent games). Let $\hat{\pi}_i(a_{-i})$ denote player i's material payoff from choosing a best response to other players' action profile a_{-i}. Let $r > 0$ denote players' common intertemporal discount rate and δ, with $\delta = \frac{1}{1+r} < 1$, their discount factor. Finally, let $G_\delta^\infty(U)$ denote the supergame originated by the infinite repetition of $G = (N, A, \pi)$ when each player i's instantaneous utility function is $U_i(\pi_i^t)$ and at any time τ he maximizes the additively (time) separable objective function $V_i^\tau = \sum_{t=\tau}^{\infty} \delta^{t-\tau} U_i(\pi_i^t)$. Then $G^\infty(U)$ will denote the generic supergame which has G as stage-game but allows different levels of the discount factor.

Any given stationary stream of material payoff $\{\pi_i^t = \pi_i^*\}_{t=\tau}^{\infty}$ can be supported in subgame-perfect equilibrium in $G_\delta^\infty(U)$ if the following condition holds:

$$\frac{1}{1-\delta} U_i(\pi_i^*) \geq U_i\left[\hat{\pi}_i(a_{-i}^*)\right] + \frac{\delta}{1-\delta} U_i(\underline{\pi}_i). \tag{IC.1}$$

I first need an unambiguous definition of a "more concave" function.

Definition 1. *A utility function U^1 is said to be more concave than another one U^2 if U^1 can be derived from U^2 by a strictly concave monotonic transformation.*

Now it is possible to state the first result.

Proposition 1. *The more concave players' instantaneous utility functions are, the smaller is the minimum discount factor at which any stationary material payoff stream can be supported in subgame-perfect equilibrium in $G^\infty(U)$.*

From the deterministic point of view of this paper the strict concavity of the instantaneous utility function implies aversion to intertemporal substitution, that is, a preference for smooth time paths of material payoffs, given the level of the discount factor. From a static point of view, the strict concavity of the instantaneous utility function implies decreasing marginal utility of material payoffs. A player with a strictly concave instantaneous utility function has a relatively lower valuation of the short-run material gains from deviating from a cooperative equilibrium, as his marginal utility is low at high levels of material payoffs. Conversely, the expected losses of material gains from the breakdown of cooperation have a relatively higher value for a player averse to intertemporal substitution, since at lower levels of material payoffs he has a relatively higher marginal utility of material payoffs. These two effects both make cooperation easier to sustain.

Proposition 1 focuses on the minimum level of the discount factor at which a given stream of material payoffs can be supported in subgame-perfect equilibrium in a given repeated game. However, taking the discount factor as a given, the proposition could have focused on the set of material payoffs streams supportable in equilibrium in $G_\delta^\infty(U)$, or on the set of repeated material payoffs supergames – parametrized by stage-game material payoffs – in which a given stream of material payoffs can be supported.

Remark 1. *The proof of Proposition 1 allows to state that:*

(i) Given a level of the intertemporal discount factor δ and a material payoff game $G = (N, A, \pi)$, for any two vectors of functions U and Q, with U_i more concave than Q_i $\forall i \in N$, the set of stationary streams of material payoffs which can be supported in subgame perfect equilibrium in $G_\delta^\infty(U)$ is (weakly) larger than that supportable in $G_\delta^\infty(Q)$.

(ii) Given a level of the intertemporal discount factor δ and a stationary stream of material payoffs $\{\pi_i^t = \pi_i^*\}_{t=\tau}^\infty$, the more concave are players' instantaneous utility functions, the larger is the set of material payoff supergames (parametrized by $\hat{\pi}_i(a_{-i}^*)$ and $\underline{\pi}_i$) in which players may support such stream in subgame perfect equilibrium.

Of course, this is because inequality IC.1 is a linear relation between three (sets of) parameters: the discount factor δ, the equilibrium material payoffs stream $\{\pi_i^t = \pi_i^*\}_{t=\tau}^\infty$, and the stage-game's material payoff structure $\{\hat{\pi}_i(a_{-i}^*),\ \underline{\pi}_i\}$. An increase in the concavity of the instantaneous utility function makes IC.1 less stringent and therefore, given two of the (sets of) parameters, it enlarges the set of values of the third (set of) parameter(s) that satisfy the relation.[6]

4. Markets for goods and money

Behind the result in the previous section is the implicit assumption that players cannot transfer payoffs from one period to another. Suppose this is due to material payoffs being perishable, as in our example with apples. How will players' ability to cooperate be affected by an unforeseen innovation (say, a sudden fall in transport costs) which gives them access to a market where material payoffs can be exchanged at a constant price against an imperishable good called "money"?

Players' ability to monetize, preserve, and redistribute material payoffs in time generates wealth effects that transform our repeated game into a dynamic one. However, the access to markets and money has a clear qualitative effect on players' ability to sustain cooperation that can be identified while keeping on the simpler ground of a repeated games perspective.

To save on notation let us limit attention to the symmetric case, with $U_i = U$ $\forall i \in N$ (the asymmetric case leads to identical results). Imagine that the innovation drives down the transaction cost of exchanges on the markets for goods to a finite level $C \geq 0$, and let $\overline{C} = \frac{U'(\underline{\pi}_i) - U'(\hat{\pi}_i(a_{-i}^*))(1+r)}{U'(\underline{\pi}_i)}$. Then, one can state the following result.

Proposition 2. *Suppose players are averse to intertemporal substitution (that is, $U' > 0$ and $U'' < 0$). Then if $C < \overline{C}$ material-payoff markets and money increase the minimum discount factor at which any stationary material payoff stream can be supported in subgame-perfect equilibrium in $G^\infty(U)$, while they do not affect it otherwise.*

The Proposition highlights the effects on the minimum discount factor at which cooperation is viable but it has, at any given discount factor, implications analogous to those of

[6] From now on, when writing "X facilitates cooperation" or "Y makes cooperation more difficult" I will mean that X makes the necessary and sufficient conditions for any stationary material payoff stream to be supportable in subgame-perfect Nash equilibrium less or more stringent, so that all the three statements above (or their converse) hold.

Proposition 1 stated in Remark 1 with regard to the set of supportable equilibria and to the set of supergames in which cooperation is supportable.

The logic behind this result was also anticipated in the introduction. If the costs of saving (market transaction costs plus the cost of delaying consumption) are small enough, a player who deviates from cooperation can increase his life-time utility by selling on the market part of the short-run gains from deviation and saving for the future. A player planning to stick to cooperation, instead, expects others to do the same and therefore a constant flow of material payoffs in time. Since he discounts the future and saving is costly, this player would prefer a consumption path decreasing in time, so he has no use for goods' markets and money. By making deviations relatively more attractive, the innovation makes cooperation harder to support.

5. Perfect financial markets

What if players obtain unforeseen access to perfect financial markets which allow them to save and borrow at the same interest rate?

I assume that each player faces the same interest rate on the financial market, and focus on the case in which this rate equals players' intertemporal discount rate r (but see Section 7.1). Also, I assume throughout that financial transactions are perfectly enforceable (e.g. that if a lender is not repaid he can enslave the borrower, and that slaves have infinitely low utility), and that the no-Ponzi-game condition is satisfied.[7]

Under these assumptions, if a player's choice between sticking to cooperation and deviating would be similar to an investment choice the next result would be straightforward. By Fisher's Separation Theorem (Fisher (1930)), perfect financial markets would lead players to care only about the discounted flow of material payoffs, so regardless of their intertemporal preferences they would choose not to deviate only if the following condition holds:

$$\frac{1}{1-\delta}\pi_i^* \geq \hat{\pi}(a_{-i}^*) + \frac{\delta}{1-\delta}\underline{\pi}_i. \tag{IC.2}$$

This is the usual condition for players with linear utility functions and, by Proposition 1, we already know that it is more stringent than the condition with strictly concave utility functions. It would directly follow that the access to perfect financial markets makes cooperation more difficult by "undoing" the facilitating effect of the aversion to intertemporal substitution.

However, things are slightly more complex. This direct line of reasoning would hold if players could commit to some future course of actions (e.g. to stick to cooperation) before accessing financial markets. Then the choice between cooperating and deviating would indeed resemble an investment choice to which Fisher Separation Theorem applies. But this is not the case in our model where players can choose to deviate in any of the periods which follow a financial transaction. In this framework one should keep track of how players' incentives evolve in time under the influence of the financial transactions they may undertake. In

[7] The no-Ponzi-games condition excludes that agents can raise an infinite amount of debt by servicing/repaying old debt with new and increasing debt issues. Formally, the condition is $\lim_{T\to\infty}\left(\frac{1}{1+r}\right)^T D_i^{t+T} \leq 0$, where D_i^τ denotes player i's total debt in period τ.

particular, a player who plans to deviate could try to increase the value of material gains from deviation by postponing the deviation and borrowing to increase present consumption. The following result allows us to disregard this possibility.

Lemma 1. *With perfect financial markets and players averse to intertemporal substitution the opportunity to postpone a deviation and borrow does not affect players' ability to sustain cooperation.*

The choice to postpone the deviation and borrow against the expected gains from a future deviation turns out to be always dominated either by that of deviating immediately, or by that of postponing the deviation forever. Lemma 1 enables us to state the following result.

Proposition 3. *Suppose players are averse to intertemporal substitution. Then, the opportunity to access perfect financial markets always increases the minimum discount factor at which any stationary material payoff stream can be supported in subgame-perfect equilibrium in $G^{\infty}(U)$.*

A player who deviates from a cooperative equilibrium can exploit (immediately, by Lemma 1) the opportunity offered by perfect financial markets, and this increases the ex ante value of the choice to deviate. On the contrary, players who stick to cooperation have no use of financial markets as the constant flow of material payoffs from cooperation is already an optimal intertemporal allocation.[8]

Again, the Proposition highlights the effects on the discount factor but has implications analogous to those of Proposition 1 stated in Remark 1.

6. Financial markets' imperfections

Imperfections make the use of financial markets costly, therefore we expect them to act in the opposite direction: the more imperfect financial markets are, the easier it should be to cooperate. Many different kinds of imperfections can affect the functioning of financial markets. Here I focus on "classical" imperfections that simply drive a wedge between the interest rate at which players can borrow and the one they receive on savings. Let r^S denote the interest rate on savings, r^B the one paid on borrowed material payoffs, and assume that $r^S < r < r^B$.

To verify the intuition above, I must also specify whether a player's financial transactions can be observed by other players or not.[9]

[8] An equivalent interpretation is that, by Lemma 1 and by the fact that players choosing to stick to cooperation cannot gain by undertaking financial transactions, the strategic situation does not change in time. When players have access to perfect financial markets they face a new incentive constraint which is also constant in time. Therefore, the infinitely repeated choice of whether to cooperate or deviate (and save) can ultimately be seen as a single decision problem, similar to an investment decision, to which the logic behind the Fisher Separation Theorem eventually applies.

[9] In the previous section we did not need assumptions on the observability of financial transactions. This was the case because – as shown by Lemma 1 – with perfect financial markets the only financial transaction relevant to players' ability to support cooperation is that of saving part of the one-shot material gains from a deviation, a transaction which takes place only after a player's deviation, when other players already know about it. Therefore, with perfect financial markets the observability of financial transactions is strategically irrelevant.

6.1. Observable financial transactions. When players' financial transactions can be observed by other players, a player planning to deviate would never find it convenient to postpone the deviation and borrow. This is because players who stick to cooperation can only lose from financial transactions, so any such transaction would signal a player's intention to deviate, triggering other players' reactions. Then, again, the only way in which financial markets may affect players' ability to cooperate is through the opportunity to save part of the one-shot material gains from a deviation. Let $r^{\min}$ denote the level of the interest rate below which saving after a deviation is not convenient, which is defined by the following equality:

$$U'(\hat{\pi}_i(a^*_{-i})) = \frac{1+r^{\min}}{1+r}U'(\underline{\pi}_i), \;\Leftrightarrow\; r^{\min} = \frac{(1+r)U'(\hat{\pi}_i(a^*_{-i})) - U'(\underline{\pi}_i)}{U'(\underline{\pi}_i)}. \tag{3}$$

I can now state the following corollary.

Corollary 1. *Suppose players are averse to intertemporal substitution and financial transactions are perfectly observable. Then:*

1. As long as $r^S > r^{\min}$, any increase in financial markets' imperfections which reduces r^S lowers the minimum discount factor at which any stationary flow of material payoffs can be supported in subgame-perfect equilibrium in $G^{\infty}(U)$;

2. For $r^S \leq r^{\min}$, any further increase in financial markets' imperfections does not affect the minimum discount factor at which any stationary flow of material payoffs can be supported in equilibrium.

The intuition is straightforward. The more imperfect financial markets are, the lower is the interest rate on saving r^S, the more costly is the reallocation of short-run material gains from deviation to future periods, and the lower is the *ex ante* value of material gains from deviation relative to the (fixed) value of material gains from cooperation. When financial markets' imperfections are strong enough to push the interest rate on savings below the minimum level at which saving is convenient ($r^S \leq r^{\min}$) a deviating player does not find it convenient to save, no player uses financial markets, and the relevant condition for cooperation is the original condition (IC.1). Again, the result has implications analogous to those of Proposition 1 in Remark 1.

6.2. Hidden financial transactions. When debt is not observable and financial markets are imperfect Lemma 1 does not hold and borrowing against material gains from a future deviation may be convenient. Let $r^{\max}$ denote the level of the interest rate above which borrowing today against a deviation postponed to the next period is not convenient, which is defined by the following equality:

$$U'(\pi^*_i) = \frac{1+r^{\max}}{1+r}U'(\hat{\pi}_i(a^*_{-i})), \;\Leftrightarrow\; r^{\max} = \frac{(1+r)U'(\pi^*_i) - U'(\hat{\pi}_i(a^*_{-i}))}{U'(\hat{\pi}_i(a^*_{-i}))}.$$

I can now state a second corollary.

Corollary 2. *Suppose players are averse to intertemporal substitution and financial transactions are not observable. Then:*

1. When $r^S \leq r^{\min}$ and $r^B < r^{\max}$, any increase in financial markets' imperfections which raises r^B (and decreases or leaves unchanged r^S) lowers the minimum discount factor at which any stationary flow of material payoffs can be supported in subgame-perfect equilibrium in $G^\infty(U)$;

2. When $r^S > r^{\min}$ and $r^B \geq r^{\max}$, any increase in financial markets' imperfections which decreases r^S (and increases or leaves unchanged r^B) lowers the minimum discount factor at which any stationary flow of material payoffs can be supported in subgame-perfect equilibrium in $G^\infty(U)$;

3. When $r^S \leq r^{\min}$ and $r^B \geq r^{\max}$, increases in financial markets' imperfections do not affect the minimum discount factor at which any stationary flow of material payoffs can be supported in equilibrium;

4. When $r^S > r^{\min}$ and $r^B < r^{\max}$, increases in financial markets' imperfections that both decrease r^S and increase r^B lower the minimum discount factor at which any stationary flow of material payoffs can be supported in subgame-perfect equilibrium in $G^\infty(U)$; increases in financial markets' imperfections that do not affect one of the two rates either lower the minimum discount factor at which any stationary flow of material payoffs can be supported in subgame-perfect equilibrium in $G^\infty(U)$, or they leave it unchanged.

That is, with unobservable financial transactions the interest rate on borrowed material payoffs may be as important as that on savings. When r^S is small (saving is costly) and r^B is not much larger than r, it will indeed be convenient for a player who plans to deviate to postpone the deviation and borrow against expected gains from the future deviation. In that case the optimal intertemporal allocation is obtained by postponing the deviation for one or more periods, borrowing to increase material payoffs before the deviation, and then perhaps saving after the deviation. Then an increase in the interest rate on debt may also reduce the *ex ante* value of material gains from deviation and facilitate cooperation.

Once again, the statement has implications analogous to those in Remark 1.

7. Discussion and Conclusions

7.1. Different market interest rates. The assumption that the market interest rate coincides with players' intertemporal discount rate can be justified as usual by considering an *internal* credit market, where the market interest rate is endogenous and cannot do more than reflect players' intertemporal preferences (in a closed economy in stationary equilibrium). However, a story we had in mind is also that of a community that suddenly gains access to an *external* credit market, whose interest rate is exogenous and may well differ from the community members' intertemporal discount rate. How are the results affected by a spread between the two rates?

Consider the case of perfect financial markets, let i denote the market interest rate and $\rho = \frac{1}{1+i}$ the market discount factor, and let it be $i \neq r$. Players' Euler equation becomes $U(c_i^t) = \frac{1+i}{1+r} U(c_i^{t+1})$, so that players' optimal consumption path becomes strictly increasing in time when $i > r$, and strictly decreasing when $i < r$. It is easy to check that the arguments behind Lemma 1 hold also for this case, so that Fisher's Separation Theorem applies and cooperation can be sustained if

$$\frac{1}{1-\rho}\pi_i^* \geq \hat{\pi}(a_{-i}^*) + \frac{\rho}{1-\rho}\underline{\pi}_i.$$

We know from Proposition 1 that when $i = r$ (so that $\rho = \delta$), this condition is strictly more stringent than IC.1. However, when $i \neq r$ the lower the market interest rate, the larger is the discount factor ρ, the less stringent the condition becomes. It follows that one can find a low enough interest rate $\underline{i}$ (possibly negative, depending on U and δ), such that for $i < \underline{i}$ the condition above becomes less stringent than IC.1 and the access to perfect credit markets facilitates cooperation rather than hindering it.

7.2. Alternative punishment strategies. The credibility of unrelenting trigger strategies, as most other widely used punishment strategies in the repeated games literature, is not robust with respect to ex post renegotiation. However, it can be easily shown that the results in this paper continue to hold when players use the more complex renegotiation-proof punishment strategies proposed by van Damme (1989) for the repeated Prisoner's Dilemma. These alternative strategies require a player who has deviated to "repent" – by playing "cooperate" for one or more periods during which the opponent plays "deviate" – before cooperation can restart, and are equivalent to trigger strategies in the sense that they also can keep the deviating player at his security level.

It can also be shown that the results are reinforced by assuming the strength of the punishment to be bounded by some finite renegotiation costs, as in McCutcheon (1997). The reason is that given a level of renegotiation costs, the more averse to intertemporal substitution agents are, the more they value the finite renegotiation costs which are concentrated in time, and the stronger the renegotiation-proof punishment can be.

7.3. Further extensions. Other possible extensions of the model include introducing uncertainty and asymmetric information. The simplest case is that of static payoffs that fluctuate in a perfectly forecastable way. Then, even when $i = r$, the access to credit markets may enable also cooperating players to improve the intertemporal allocation of material payoffs. Also, then players' incentive to deviate is larger in some periods than in others, as in Rotemberg and Saloner's (1986) model of "price wars during booms." Contrary to profit-maximizing firms, players sufficiently averse to intertemporal substitution have the greatest incentive to deviate in periods in which the cooperative outcome is relatively low. Then the ability to smooth material payoffs in time could reduce incentives to deviate by allowing for higher consumption in periods in which the cooperative payoffs are low.[10]

Perfectly forcastable fluctuations are not common in reality. More interesting is the extension to unforecastable uncertainty, where players' attitudes toward risk come into play. For example, consider a Bertrand supergame with stochastic demand, where each period uncertainty resolves before risk averse players choose prices. In this particularly simple case agents' risk aversion only (negatively) affects their evaluation of futures gains from cooperation, since players' security levels and short-run gains from deviation are not affected by

[10] A formal treatment of some of these issues can be found in Spagnolo (1996).

demand uncertainty. Then, attitudes toward risk and toward intertemporal substitution affect in opposite ways players' ability to cooperate, while the access to a market for insurance unambiguously facilitates cooperation. More generally, uncertainty may also affect players' security level and short-run gains from cooperation (when uncertainty resolves after players' choice of actions), and keeping track of all the effects becomes less trivial.[11]

Finally, future work should consider asymmetric information *à la* Green and Porter (1984), and characterize how players' aversion to risk and to intertemporal substitution, and access to goods, credit, and insurance markets affect the need for, and the frequency of equilibrium punishment phases.

7.4. Concluding remarks. This simple model provides a new explanation for the sudden breakdown of cooperation observed in isolated communities when they get in contact with more developed economic institutions. To say it like Hirschman (1970), markets increase the value of agents' "exit" option, since they allow the optimal reallocation of short-run gains from unilateral deviations in time. The stylized fact that the continental and Japanese economies – characterized by relatively thin and inefficient financial markets – are more collusive than Anglo-Saxon economies – which have more developed financial markets – appears to fit nicely the conclusions of the model.

8. Appendix

8.1. Proof of Proposition 1. First I need a simple lemma.

Lemma 0 *For any* $a, b, \alpha, \beta, > 0, \frac{\alpha}{\beta} < \frac{a}{b} \Rightarrow \frac{a+\alpha}{b+\beta} < \frac{a}{b}$.

Proof $\frac{\alpha}{\beta} < \frac{a}{b} \Rightarrow \alpha b < a\beta \Rightarrow \alpha b + ab < a\beta + ab \Rightarrow \frac{1}{b(b+\beta)} b(a+\alpha) < \frac{1}{b(b+\beta)} a(b+\beta) \Rightarrow \frac{a+\alpha}{b+\beta} < \frac{a}{b}$.
Q.E.D.

Now, suppose players' static objective function is linear in material payoffs so that $U_i(\pi_i) = A_i\pi_i + B_i,\ A_i > 0, \forall i$. The necessary and sufficient conditions for a stationary sequence of material payoffs vectors $\{\pi_i^t = \pi_i^*\}_{t=0}^{\infty}$ to be supportable in subgame-perfect Nash equilibrium are as follows:

$$\frac{\pi_i^*}{1-\delta} \geq \hat{\pi}_i(a_{-i}^*) + \frac{\delta \underline{\pi}_i}{1-\delta}, \ \Leftrightarrow \ \delta \geq \frac{\hat{\pi}_i(a_{-i}^*) - \pi_i^*}{\hat{\pi}_i(a_{-i}^*) - \underline{\pi}_i}, \ \forall i \in (1, ..., N). \tag{4}$$

Consider instead the case in which players' instantaneous utility functions are $U_i(\pi_i) = g_i(\pi_i)$, where $g_i' > 0$, $g_i'' \leq 0$ and $g_i''(\pi_i) < 0$ for some π_i, $\underline{\pi}_i \leq \pi_i \leq \hat{\pi}_i(a_{-i})$. For these players the necessary and sufficient conditions for the same stationary sequence of material payoffs to be supportable in subgame-perfect Nash equilibrium are

$$\delta \geq \frac{g_i[\hat{\pi}_i(a_{-i}^*)] - g_i[\pi_i^*]}{g_i[\hat{\pi}_i(a_{-i}^*)] - g_i[\underline{\pi}_i]}, \forall i. \tag{5}$$

[11] In this case the von Neumann-Morgenstern framework does not allow one to disentangle agents' attitudes toward risk from their attitudes toward intertemporal substitution, and a more sophisticated model of dynamic preferences under uncertainty – e.g. the one introduced by Kreps and Porteus (1978) – must be used. To avoid confusion I am pursuing these issues in a strictly related but distinct paper.

Comparing (4) and (5), players with strictly concave objective functions will be able to cooperate at lower levels of the discount factor if

$$\frac{g_i[\hat{\pi}_i(a^*_{-i})] - g_i[\pi^*_i]}{g_i[\hat{\pi}_i(a^*_{-i})] - g_i[\underline{\pi}_i]} < \frac{\hat{\pi}_i(a^*_{-i}) - \pi^*_i}{\hat{\pi}_i(a^*_{-i}) - \underline{\pi}_i}, \tag{6}$$

which can be rewritten as

$$\frac{g_i[\hat{\pi}_i(a^*_{-i})] - g_i[\pi^*_i]}{\hat{\pi}_i(a^*_{-i}) - \pi^*_i} < \frac{g_i[\hat{\pi}_i(a^*_{-i})] - g_i[\pi^*_i] + \{g_i[\pi^*_i] - g_i[\underline{\pi}_i]\}}{\hat{\pi}_i(a^*_{-i}) - \pi^*_i + \{\pi^*_i - \underline{\pi}_i\}}. \tag{7}$$

The LHS of (7) is the average marginal utility of material payoffs in the domain $\left[\pi^*_i, \hat{\pi}_i(a^*_{-i})\right]$, while the ratio $\frac{g_i[\pi^*_i]-g_i[\underline{\pi}_i]}{\pi^*_i-\underline{\pi}_i}$ is the average marginal utility of material payoffs in the domain $[\underline{\pi}_i, \pi^*_i]$. The assumption that $g''_i(\pi_i) \leq 0$ and $g''_i(\pi_i) < 0$ for some π_i, $\underline{\pi}_i \leq \pi_i \leq \hat{\pi}_i(a^*_{-i})$ implies that marginal utility is lower at higher levels of material payoffs, and therefore that $\frac{g_i[\hat{\pi}_i(a^*_{-i})]-g_i[\pi^*_i]}{\hat{\pi}_i(a^*_{-i})-\pi^*_i} < \frac{g_i[\pi^*_i]-g_i[\underline{\pi}_i]}{\pi^*_i-\underline{\pi}_i}$. By Lemma 1 this implies that (7) is always satisfied. By the same logic, given any set of (monotone increasing) objective functions $H = \{h_i(\pi_i)\}_{i=1}^N$, any set of strictly concave monotonic transformations $F = \{\varphi(h)\}_{i=1}^N$, with $\varphi'_i > 0$, $\varphi''_i \leq 0$, and $\varphi''_i[h_i(\pi_i)] < 0$ for some π_i in the interval $\underline{\pi}_i \leq \pi_i \leq \hat{\pi}_i(a^*_{-i})$, leads to strictly less stringent conditions, therefore to a lower minimum discount factor at which any stationary path of material payoffs is supportable in subgame-perfect Nash equilibrium. **Q.E.D.**

8.2. Proof of Proposition 2. When players discount future at the positive rate r, the Euler equation for intertemporal utility maximization is $U'(c^t_i) = \frac{1}{1+r}U'(c^{t+1}_i)$, $\forall t$, where c^t is the amount of material payoffs allocated to (consumed in) period t.

Consider first how the opportunity to access markets for material payoffs and money at a cost C affects the RHS of condition IC.1 (players' gains from cooperation). By inspection, even when $C = 0$ the Euler equation implies $c^t_i > c^{t+1}_i$, $\forall t$. A player who sticks to cooperation expects to earn the stationary flow of material payoffs $\{\pi^t_i = \pi^*_i\}_{t=0}^{\infty}$. Because

$$U'(\pi^*_i) < \frac{1}{1+r}U'(\pi^*_i)(1-C),$$

the access to a market for material payoffs cannot increase the value of the expected gains from cooperation (in any period the option of selling part of the material payoffs today and buy additional material payoffs in the future is strictly dominated by that of consuming all immediately).

Consider now how the opportunity to access markets affects players' gains from deviating from cooperation, the LHS of IC.1. The period in which a player deviates unilaterally he receives $\hat{\pi}_i(a^*_{-i})$, while in all the following periods he expects to receive $\underline{\pi}_i$. Then, a deviating player increases his lifetime utility by selling part of the short-run gains from the unilateral deviation on the market and buying material payoffs in some future period if and only if

$$U'(\hat{\pi}_i(a^*_{-i})) < \frac{U'(\underline{\pi}_i)(1-C)}{1+r} \Leftrightarrow C < \frac{U'(\underline{\pi}_i) - U'(\hat{\pi}_i(a^*_{-i}))(1+r)}{U'(\underline{\pi}_i)}.$$

Suppose this condition is satisfied. Then a deviating player can, for example, sell an amount b_i of short-run gains from deviation on the market and buy the amount $b_i(1-C)$ the period after the deviation so that

$$U'(\hat{\pi}_i(a^*_{-i})-b_i)=\frac{1-C}{1+r}U'(\underline{\pi}_i+b_i(1-C)).$$

In this case the relevant conditions for cooperation being supportable become

$$\frac{U(\pi_i^*)}{1-\delta}\geq U(\hat{\pi}_i(a^*_{-i})-b_i)+\delta U(\underline{\pi}_i+b_i(1-C))+\frac{\delta^2}{1-\delta}U(\underline{\pi}_i),\forall i,$$

which, because by construction

$$U(\hat{\pi}_i(a^*_{-i})-b_i)+\delta U(\underline{\pi}_i+b_i(1-C))>U(\hat{\pi}_i(a^*_{-i}))+\delta U(\underline{\pi}_i),$$

are always more stringent than IC.1. **Q.E.D.**

8.3. Proof of Lemma 1. With perfect financial markets the Euler equation requires $U'(c_i^t)=U'(c_i^{t+1})$, $\forall t$, $\Leftrightarrow$ $c_i^t=c_i^{t+1},\forall t$. A player who deviates receiving $\hat{\pi}_i(a^*_{-i})$ immediately and $\underline{\pi}_i$ the following periods maximizes his lifetime utility by saving $s_i\hat{\pi}_i(a^*_{-i})$ the period of the deviation and reallocating the amount b_i to each future period, where $s_i\hat{\pi}_i(a^*_{-i})=\frac{b_i}{r}$ and $\underline{\pi}_i+b_i=(1-s_i)\hat{\pi}_i(a^*_{-i})$. It follows that

$$s_i\hat{\pi}_i(a^*_{-i})=\frac{1}{1+r}(\hat{\pi}_i(a^*_{-i})-\underline{\pi}_i)=\delta(\hat{\pi}_i(a^*_{-i})-\underline{\pi}_i),$$

$$b_i=\frac{r}{1+r}(\hat{\pi}_i(a^*_{-i})-\underline{\pi}_i)=(1-\delta)(\hat{\pi}_i(a^*_{-i})-\underline{\pi}_i),$$

so the condition for cooperation being supportable are the following:

$$\frac{U(\pi_i^*)}{1-\delta}\geq\frac{1}{1-\delta}U\left[(1-\delta)(\hat{\pi}_i(a^*_{-i})-\underline{\pi}_i)+\underline{\pi}_i\right],\forall i. \tag{8}$$

Consider first the case in which (8) is satisfied as an equality:

$$\frac{1}{1-\delta}U(\pi_i^*)=\frac{1}{1-\delta}U\left[(1-\delta)(\hat{\pi}_i(a^*_{-i})-\underline{\pi}_i)+\underline{\pi}_i\right],$$

or, equivalently,

$$\pi_i^*=(1-\delta)(\hat{\pi}_i(a^*_{-i})-\underline{\pi}_i)+\underline{\pi}_i.$$

Suppose the unilateral deviation is postponed of one period. Assuming no other player deviates, the deviating player gets π_i^* the first period, $\hat{\pi}_i(a^*_{-i})$ the second, and $\underline{\pi}_i$ thereafter. Because the optimal intertemporal allocation is a constant flow of material payoffs, the deviating player cannot gain by borrowing before deviating. His optimal strategy is to consume π_i^* and the following period, when he deviates, to save and allocate $(1-\delta)(\hat{\pi}_i(a^*_{-i})-\underline{\pi}_i)+\underline{\pi}_i=\pi_i^*$ to all future periods. The same argument applies to the option of postponing the deviation for more than one period. It follows that when (8) is satisfied as an equality postponing the deviation does not change players' expected gains from deviating.

Consider the case in which condition (8) is not satisfied. After postponing a deviation it is strictly convenient to borrow if

$$\frac{1}{1-\delta}U(\pi_i^*) < \frac{1}{1-\delta}U_i\left[(1-\delta)(\hat{\pi}_i(a_{-i}^*) - \underline{\pi}_i) + \underline{\pi}_i\right],$$

or, equivalently, if

$$\pi_i^* < (1-\delta)(\hat{\pi}_i(a_{-i}^*) - \underline{\pi}_i) + \underline{\pi}_i.$$

Again, if a deviating player postpones the deviation for one period he gets π_i^* the first period, $\hat{\pi}_i(a_{-i}^*)$ the second, and $\underline{\pi}_i$ thereafter. His optimal strategy is then to maximize the value of the expected flow of material payoffs by borrowing the amount $D_i > 0$ the period before the deviation and repay it the period in which he deviates, where D_i is defined by the following equality:

$$\pi_i^* + D_i = (1-\delta)(\hat{\pi}_i(a_{-i}^*) - \frac{D_i}{\delta} - \underline{\pi}_i) + \underline{\pi}_i.$$

However, the player incurs a net loss by postponing the deviation, because

$$\pi_i^* + D_i = (1-\delta)(\hat{\pi}_i(a_{-i}^*) - \frac{D_i}{\delta} - \underline{\pi}_i) + \underline{\pi}_i < (1-\delta)(\hat{\pi}_i(a_{-i}^*) - \underline{\pi}_i) + \underline{\pi}_i.$$

By the same logic, this loss increases if the player postpones the deviation further.

Finally, consider the case in which (8) is satisfied as a strict inequality, so that

$$\frac{1}{1-\delta}U(\pi_i^*) > \frac{1}{1-\delta}U\left[(1-\delta)(\hat{\pi}_i(a_{-i}^*) - \underline{\pi}_i) + \underline{\pi}_i\right],$$

or, equivalently,

$$\pi_i^* > (1-\delta)(\hat{\pi}_i(a_{-i}^*) - \underline{\pi}_i) + \underline{\pi}_i.$$

Again, suppose the deviation is postponed for one period. Now $\pi_i^* > (1-\delta)(\hat{\pi}_i(a_{-i}^*) - \underline{\pi}_i) + \underline{\pi}_i)$, so in the period before the deviation it is not optimal to borrow, but to save. In this case a player gains by postponing a deviation. However, the same logic applies to the option of postponing the deviation for one more period, another one, and so on... Therefore the only case in which postponing the deviation is preferred to deviating immediately is when players prefer to postpone the deviation forever, i.e. not to deviate at all. **Q.E.D.**

8.4. Proof of Proposition 3. As in the previous proof the Euler equation for players' intertemporal utility maximization requires a constant consumption flow. Consider first how financial markets affect players' incentives to deviate (the LHS of IC.1). By Lemma 1, I only need to worry about periods that follow the deviation. The period in which a player deviates he receives $\hat{\pi}_i(a_{-i}^*)$, while the following periods he receives $\underline{\pi}_i$. Then, he maximizes lifetime utility by saving an amount $s_i\hat{\pi}_i(a_{-i}^*)$ the period of the deviation and reallocating an additional amount b_i to each future period, where s_i and b_i satisfy $s_i\hat{\pi}_i(a_{-i}^*) = \frac{b_i}{r}$ and $\underline{\pi}_i + b_i = (1-s_i)\hat{\pi}_i(a_{-i}^*)$. Consider how financial markets affect the incentives to cooperate (the RHS of IC.1). A player who sticks to cooperation expects to earn the stationary flow of material payoffs $\{\pi_i^t = \pi_i^*\}_{t=0}^{\infty}$ which is already an optimal intertemporal allocation and cannot be improved through financial markets. It follows that the relevant conditions for cooperation being supportable is

$$\frac{1}{1-\delta}U(\pi_i^*) \geq \frac{1}{1-\delta}U(\underline{\pi}_i + b_i)$$

which, because $\frac{1}{1-\delta}U(\underline{\pi}_i + b_i) > U(\hat{\pi}_i(a_{-i}^*)) + \frac{\delta}{1-\delta}U(\underline{\pi}_i)$, is always more stringent than IC.1. **Q.E.D.**

8.5. Proof of Corollary 1. With imperfect financial markets a player sticking to cooperation loses strictly by saving or borrowing. Instead, a deviating player may still gain to save part of the short-run gains from deviation for the future. The Euler equation requires now $U'(c_i^t) = \frac{1+r^s}{1+r}U'(c_i^{t+1})$ $\forall t$, a consumption flow decreasing in time. We defined $r^{\min} = \frac{(1+r)U'(\hat{\pi}_i(a_{-i}^*)) - U'(\underline{\pi}_i)}{U'(\underline{\pi}_i)} < r$ as the rate such that for $r^S \leq r^{\min}$ a deviating player finds it too expensive to save.

When $r^{\min} < r^S \leq r$, the lower r^S is, the more costly it is to delay consumption of material payoffs, the smaller is the amount of gains from deviation that can be reallocated to future periods, the smaller is the *ex ante* value of the choice to deviate, and the less stringent are the conditions to support cooperation. Statement 1 follows.

When $r^S \leq r^{\min}$, $U'(\hat{\pi}_i(a_{-i}^*)) > \frac{1+r^S}{1+r}U'(\underline{\pi}_i)$ and saving reduces a deviating player's lifetime utility. Because $r^B > r$ implies $U'(\hat{\pi}_i(a_{-i}^*)) < \frac{1+r^B}{1+r}U'(\underline{\pi}_i)$, no player ever gains from borrowing. Statement 2 follows. **Q.E.D.**

8.6. Proof of Corollary 2. The statement divides the parameter space into four possible cases: (1) $r^S \leq r^{\min}$ and $r^B < r^{\max}$; (2) $r^S > r^{\min}$ and $r^B \geq r^{\max}$; (3) $r^S \leq r^{\min}$ and $r^B \geq r^{\max}$; (4) $r^S > r^{\min}$ and $r^B < r^{\max}$; where $r^{\max} = \frac{(1+r)U'(\pi_i^*) - U'(\hat{\pi}_i(a_{-i}^*))}{U'(\hat{\pi}_i(a_{-i}^*))}$.

(1) When $r^S \leq r^{\min}$, a deviating player would not find it convenient to save whatever is r^B. To check whether postponing the deviation and borrowing may make the conditions to sustain cooperation more stringent I focus on the case in which such conditions are just satisfied as equalities,

$$\frac{1}{1-\delta}U(\pi_i^*) = U(\hat{\pi}_i(a_{-i}^*)) + \frac{\delta}{1-\delta}U(\underline{\pi}_i).$$

If the deviation is postponed for one period the player receives π_i^* the first period, $\hat{\pi}_i(a_{-i}^*)$ the second and $\underline{\pi}_i$ thereafter. When borrowing is also too expensive the condition with a postponed deviation becomes

$$\frac{1}{1-\delta}U(\pi_i^*) \geq U(\pi_i^*) + \delta\left[U(\hat{\pi}_i(a_{-i}^*)) + \frac{\delta}{1-\delta}U(\underline{\pi}_i)\right],$$

which reduces to the previous equality. When $r^B < r^{\max}$ so that borrowing is worthwhile, the condition for cooperation being supportable becomes

$$\frac{1}{1-\delta}U(\pi_i^*) \geq U(\pi_i^* + D_i) + \delta\left[U(\hat{\pi}_i(a_{-i}^*) - \frac{D_i}{\delta}) + \frac{\delta}{1-\delta}U(\underline{\pi}_i)\right],$$

where D_i satisfies $U'(\pi_i^* + D_i) = \frac{1+r^B}{1+r} U'(\hat{\pi}_i(a_{-i}^*) - \frac{D_i}{\delta})$, and this inequality is more stringent than the previous one. It follows that when $r^S \leq r^{\min}$ and $r^B < r^{\max}$ any increase in r^B reduces the ex ante value of expected gains from a delayed deviation and makes the conditions for cooperation less stringent by making borrowing more expensive.

(2) – (3) When $r^B \geq r^{\max}$ players do not find it convenient to borrow during the periods before a deviation. Then, Corollary 1 applies and statements 2 and 3 follow.

(4) Consider the case in which $r^S > r^{\min}$ and $r^B < r^{\max}$. I have shown above that when $r^B < r^{\max}$ and $r^S \leq r^{\min}$, if a player postpones the deviation he finds it convenient to borrow $\left(r^B < r^{\max} \Leftrightarrow U'(\pi_i^*) > \frac{1+r^B}{1+r} U'(\hat{\pi}_i(a_{-i}^*))\right)$, which makes the conditions for cooperation more stringent. This is because at the margin the gain from a better intertemporal allocation achieved through borrowing is larger than the cost of delaying the deviation of one period. Now starting from $r^B < r^{\max}$ and $r^S = r^{\min}$, let r^S increase. Saving after the deviation becomes more and more attractive, and once r^S increases over a certain level $\underline{r}^S(r^B)$ the amount a player wants to borrow in periods before a deviation starts shrinking. Expected gains from reallocating material gains from deviation by borrowing shrink, while the cost of postponing the deviation increases (the intertemporal allocation of material payoffs in periods following the deviation improves). Given that $r^B > r$, a level $\overline{r}^S(r^B)$ is eventually reached at which the cost of postponing the deviation for one period equals gains from intertemporal reallocation through borrowing. For $r^S > \overline{r}^S(r^B)$ deviating immediately and saving becomes optimal. It follows that as long as $r^{\min} < r^S \leq \underline{r}^S(r^B)$ players postpone deviations and borrow but do not save. Then increases in financial markets' imperfections which decrease r^S (given r^B) do not affect the conditions to support cooperation, while these that increase r^B make such condition less stringent. As long as $\underline{r}^S(r^B) < r^S \leq \overline{r}^S(r^B)$ players both postpone deviations, borrow, and save for periods following the deviation. Then increases in financial markets' imperfections that increase r^B (given r^S), decrease r^S (given r^B), or both increase r^B and decrease r^S, they all make the conditions for cooperation less stringent. Finally, as long as $r^S > \overline{r}^S(r^B)$ players who deviate gain by doing it immediately and save for the future, but never borrow. Then financial markets' imperfections that increase r^B (given r^S), do not affect the conditions for cooperation, while these that decrease r^S makes such conditions less stringent. **Q.E.D.**

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