Span. Econ. Rev. 7, 267–288 (2005)
DOI: 10.1007/s10108-005-0103-0

Spanish Economic Review

Testing, hold up and the dynamics of preferences*

Gonzalo Olcina, Concepción Peñarrubia

Universitat de València, Campus dels Tarongers, Av. dels Tarongers,
s/n. Edificio Departamental Oriental, 46022 Valencia, Spain
(e-mail: {Gonzalo.Olcina,Concepcion.Penyarrubia}@uv.es)

Abstract. This paper presents an overlapping generations model with cultural transmission of preferences in an economy in which players face a hold up problem. One of the players, the firm, can use a testing technology which allows him to imperfectly monitor his partner's behaviour. This technology is completely useless with homogeneous preferences. We obtain that in the stable steady state of the economy there is a mixed distribution of preferences where both selfish and other-regarding preferences are present in the population. Moreover, with a good testing technology, the steady state is characterized by the first-best result in the investment decisions.

Key words: Specific investments, hold up, social preferences, cultural transmission, testing technology

JEL Classification: C78, D23, D63

1 Introduction

In many economic situations players have to choose the *kind* of investment to be made, that is, its degree of relation-specificity. For instance, firms and workers often invest in job-specific assets and job-related training whose returns are shared through subsequent wage negotiations. If investments are not verifiable, so, noncontractible, then both parties have to make independent and simultaneous decisions between making a more specific (and costly) investment or a more general one,

* The authors acknowledge financial support from the Spanish Ministry of Science and Technology project SEC2001-2763. This paper has also benefited from comments of participants in the XXVIII Spanish Symposium of Economic Analysis in Seville (Spain), in the International Workshop on Social and Behavioral Economics in Valencia (Spain), in the 2nd World Congress of the Game Theory Society in Marseille and in the VI Spanish Meeting on Game Theory and Practice in Elche (Spain).

bearing the full costs of it in either case. This scenario generally results in a trade-off: highly specific investments yield a larger surplus to be divided between the partners but reduce the ex post bargaining position of the investor, provided his partner has chosen a less specific type of investment. When this strategic situation is played by selfish agents, under fairly general conditions, it results in a prisoner's dilemma game where the unique equilibrium is the inefficient outcome where *all* players make general investments. This inefficiency is caused by the fear of getting locked in the relationship with a very weak bargaining position and being exploited by the other party in the negotiation stage.

Undoubtedly, this hold up problem is highly influenced by the individuals' preferences. In fact, the most common version of the hold up problem relies on selfish or opportunistic behaviour on the side of both partners. But nowadays, there is overwhelming evidence to indicate that preferences in the real-world populations are heterogeneous with the presence of a significant proportion of selfish and other-regarding preferences. However, even if one of the parties (say the worker) has some kind of social preference, caring not only about his absolute payoff but also about the payoff distribution, he will still choose an inefficient general investment.

The risk of the investors being held up has inspired much of modern contract and organisation theory. Several remedies have been proposed and analyzed in depth such as property rights allocation, the design of incomplete contracts, etc. In this work we concentrate on a scenario in which it is not possible to write a contract and there is no possible reallocation of property rights, but the firm faces a possibly heterogeneous population of workers. We focus our attention on the role of monitoring or testing by the firm, that is, the costly acquisition of information about the partner's activity.

The paradox with monitoring is that it is a well-known method for improving efficiency in real-world economic relations and consequently, it is widely used. Firms usually hire new workers on trial for a few months or, in other cases, firms set an entrance or aptitude test that aims to ensure the worker has the essential qualifications for the post. Monitoring is probably more important in practice than designing contracts carefully, but paradoxically, research has neglected it.

Probably, one reason for this neglect is that, from a theoretical point of view, monitoring seems useless unless we assume the possibility of commitments by the firm. Assume imperfect monitoring. Namely, the firm can acquire a testing technology that allows him to know with a certain probability γ if the worker has made a general investment, in other words, she has not acquired the specific skills required for efficiency. Imperfect monitoring refines the firm's information but not all the way to a singleton.

Nevertheless, if the firm cannot commit to any announced strategy conditional on the information provided by the test, the testing technology is completely useless because it is not subgame perfect to use the information it provides. For instance, assume that the firm announces that he will invest in specific assets if the test does not reveal a general investment of the worker, otherwise, he will make a general investment himself. The best reply of a selfish worker if she believes the announcement and provided the test is accurate enough (γ is high enough) is to make the efficient investment. But if the firm is not committed to his announced policy and still maintains his strategic freedom, he will choose not to fulfil his promise and will make a general investment. Obviously, this will be anticipated by the worker who will not make specific investment in the first place. Unfortunately, if the structure of the investment game is a prisoners' dilemma, the same problem appears even though the worker has some kind of publicly known social preferences. Nevertheless, there is a difference now with respect to the previous case, because whereas the worker again makes a general investment because he does not believe any announcement, the firm might prefer to invest in specific assets anticipating a fair attitude of his partner in the negotiation stage. This suggests that with an appropriate heterogeneous distribution of preferences in the worker population and with incomplete information of the firm, a sufficiently effective testing technology can succeed in enhancing efficiency in the investment decisions of all the agents. However, to assume a particular heterogeneous distribution would be as ad-hoc as the usual assumption of a completely homogeneous preferences distribution. Instead of that, we work with a dynamic model of purposeful and costly cultural transmission of preferences where the distribution of preferences in the population, the monitoring and the investment and bargaining policies in the long run are determined endogenously and simultaneously.

More precisely, in our model a population of infinitely-lived firms with homogeneous selfish preferences is pair-wise matched at each period with an equal size population of short-lived workers with heterogeneous preferences. Any short-lived player lives for two periods in an overlapping generations situation. In the second period, as an adult, each one plays an investment game such as the one previously described. A firm has the option of carrying out a testing activity that allows him to know with probability γ if a worker has made a general investment. We also assume that a firm cannot previously commit to following a particular policy. In this second period, a worker also has a descendant and makes a costly decision on educational effort to try to transmit her own preferences. With a probability equal to this educational effort level, the education will be successful and the child will adopt her parent's preferences. Otherwise, the child will adopt the preferences of someone in the adult population with whom she is faced randomly. The profits derived from transmitting their own preferences depend on the parents' expectations about the firms' investment and negotiation policy.

Our main result is that when a good testing technology is available and there is a non-negligible initial proportion of other-regarding workers, the first best outcome, where all players make specific investments, is achieved in the stable steady state of the economy. In this steady state there is a mixed distribution of preferences where both selfish and other-regarding preferences are present in the population. The optimal strategy of a firm consists of acquiring the technology, making a general investment when he observes a general investment and making a specific investment otherwise. Given that the probability of discovering when a worker makes general investments is high enough, both types of worker have the right incentives to make specific investments. Therefore, the firm never observes a general investment and according to the above policy he also makes a specific investment. It turns out that this is his best reply given that there are enough other-regarding workers in the population. That is, the presence of a non-negligible proportion of this kind of worker in the initial condition of the dynamics makes the use of the testing technology by the firms credible and enhances efficiency. The basin of attraction of this steady state is greater whenever the severity of the prisoners' dilemma diminishes, that is whenever the net gain from defecting when your partner makes a specific investment diminishes. If the firm could previously commit to following a particular policy the result would be even stronger because the first best would be achieved for *all* initial distribution of preferences.

There are few works related to our paper. Besides the work of Bisin and Verdier on cultural transmission, Hauk and Saez (2002) present a model on corruption in the framework of an overlapping generations model with intergenerational transmission of preferences. They borrow a simple principal-agent model from Tirole (1996) and assume imperfect observability of the workers' type. There is also a related paper (Olcina and Peñarrubia (2004)) in which we have analyzed the hold up problem under different structures of the investment game without monitoring. In this current work we concentrate on the more inefficient situation, in which the game has the structure of a prisoner's dilemma and making a general investment is a dominant strategy. In this context we study whether imperfect monitoring can improve the result.

There is a recent evolutionary analysis on hold up. Ellingsen and Robles (2002) and Tröger (2002) have shown that when only one party makes a specific investment, followed by play of the Nash demand game, then all stochastically stable equilibria are efficient. Therefore, it would seem that evolution "solves" the hold up problem. However, Dawid and MacLeod (2001) show that these results do no extend to the case in which both parties can make relation-specific investments. On the contrary, our analysis shows that cultural transmission of preferences and imperfect monitoring can solve the hold up problem even in the latter case.

This paper is organized as follows. Section 2 introduces the model, describing the hold up game, the particular other-regarding preferences we assume: inequity aversion, and the mechanism of cultural transmission of preferences. In Section 3 we characterise the optimal strategies on investment and bargaining of both players. Section 4 presents the main results characterizing the steady state policies (investment and bargaining) and the distribution of preferences with a good testing technology. Finally, Section 5 concludes.

2 The model

We consider a dynamic random matching model where an infinitely-lived player 1 (say a firm) is matched, at each period, with a short-lived player 2 (say a worker), who only lives two periods[1].

Both populations of players are a continuum, normalized to one. From the point of view of players 2 this is an overlapping generations model. Each player 2, in the first period, is a child and is educated in certain preferences and in the second period, when she is an adult, is matched with a long-lived player 1, playing an

[1] Notice that because of random rematching reputation building is impossible for the infinitely-lived player. Alternatively, we could have assumed that firms are also short-lived.

investment game to be described later. Also, in this second period she has one offspring and makes a decision regarding her education, trying to transmit certain types of preferences. Notice that the population size of players 2 remains constant.

2.1 The hold up game

A long-lived player 1 and an adult short-lived player 2 are randomly paired in any one period and play the following sequential game. In a first stage, each player has to decide whether to make a specific investment (S) or a general investment (G) with the following timing. Firstly, player 1 has the option of acquiring a testing technology at a fixed cost ε which allows him to know with probability γ if player 2 has made a general investment. But, with probability $1 - \gamma$ the test provides no information at all. Notice that if player 2 makes a specific investment the test will again not yield any additional information. If player 1 has not bought the testing technology, then both players make theirs investment decisions simultaneously. But if player 1 has acquired the technology, he can condition his decision on the result of the test or alternatively he can ignore the information provided by the test. Note that in the latter case the players' decisions are again simultaneous in essence. We will assume that specific investment entails a higher individual cost than general investment. In particular, let $c > 0$ be the cost of specific investment and we normalise the cost of general investment to zero.

On the other hand, specific investment is more efficient. Namely, the pair of investments decided by the players determines the size of the joint surplus, which has to be divided between them at a second stage. That is, if both players make specific investments, the highest surplus $\bar{\nu}$ is obtained. If one of them makes a specific investment and the other makes a general investment, then they get a smaller but positive surplus $\underline{\nu}$. And finally, if both players make a general investment they get the lowest possible surplus, which we normalise to zero. We will assume $\bar{\nu} > \underline{\nu} > c > 0$.

Each particular pair of investments also determines the bargaining power of the players at the second stage, when the players have to negotiate the division of the observed surplus. The reason is very intuitive: when a subject makes a general investment, this investment will be valuable outside the relationship, that is, the player can bargain with another potential partner. Conversely, if he makes a specific investment, the player will be locked in the relationship because this kind of investment is not valuable outside. Therefore, in the former case, the player has high bargaining power and in the latter case he has low bargaining power.[2]

In order to simplify the analysis, we suppose that, after observing the realized surplus, players bargain following an ultimatum game with the following characteristics depending on the pair of current investments. If both players make a specific investment, they have equal bargaining power, that is, they get to be the proposer with equal probability. If one player makes a specific investment and the other makes a general investment, we assume that the latter has all the bargaining power,

[2] We formally show this result in a general bargaining model in Olcina and Peñarrubia (2002).

that is, he will be the proposer in the ultimatum game. And finally, if both players make a general investment, there is no negotiation and both get a zero payoff.

Assume that all players are risk-neutral. If we solve the game by backward induction, we find that the players are facing the following simultaneous game when they make their investment decisions:

	S	G
S	$\frac{1}{2}\bar{\nu} - c$, $\frac{1}{2}\bar{\nu} - c$	$-c$, $\underline{\nu}$
G	$\underline{\nu}$, $-c$	0 , 0

(M.1)

where player 1 is the row-player and player 2 is the column-player. We will assume that:

$$\frac{1}{2}\underline{\nu} - c > 0 \tag{A.1}$$

$$\frac{1}{2}\bar{\nu} - \underline{\nu} > 0 \tag{A.2}$$

With assumption (A.1) we rule out the less interesting case in which the cost of investment is very high in relation to the low surplus $\underline{\nu}$. Assumption (A.2) makes it easier to obtain some results. Notice that, under these two assumptions, (S, S) is the efficient allocation. Let us also establish the following condition:

$$\frac{1}{2}\bar{\nu} - \underline{\nu} < c \tag{A.3}$$

Under this condition, the investment game (M.1) has the structure of a prisoner's dilemma where making a general investment is a dominant strategy for both players and so (G, G) is the unique Nash equilibrium (the inefficient outcome).[3]

Notice that the testing activity is useless and consequently, player 1 will not acquire the testing technology. For instance, if player 1 could commit to the following strategy: making a general investment if the test reveals that player 2 has made a general investment and making a specific investment if the test does not provide additional information, then, provided γ is high enough, player 2 would make a specific investment. But, if player 1 has strategic freedom at this point in the game, he will make a general investment, not fulfilling his announced policy. As we assume that commitment is not possible, any announcement by the firm regarding this policy will not be credible because making a general investment is his dominant strategy irrespective of the result of the test.

[3] If condition (A.3) does not hold, then the game has the structure of a coordination game where both players making specific investments also constitutes a Nash equilibrium. In this paper we concentrate on the case in which making specific investments is not a Nash equilibrium when the game is played by selfish players.

2.2 Reciprocal fairness: inequity aversion

Most of the economic literature has assumed self-regarding preferences. Nevertheless, there is substantial experimental evidence to suggest that fairness and reciprocity motives affect the behaviour of many people. Therefore, a more realistic assumption would be that preferences in the population are heterogeneous.

We assume heterogeneous preferences only in the population of players 2; all players 1 are selfish. The distribution of preferences in each period is endogenously determined in our model by the decisions made by the adult players 2. In particular, there is a proportion p_t of self-interested agents in period t who are motivated exclusively by their own monetary payoff and a proportion $1-p_t$ of agents motivated by inequity aversion in the sense of Ferh and Schmidt (1999). These agents are willing to give up some material payoff to move in the direction of more equitable outcomes.

Namely, $x = (x_1, x_2)$ denotes the vector of monetary payoffs for both players, then, the utility function of player 2 is given by:

$$U_2(x) = x_2 - \alpha \max\{x_1 - x_2, 0\} - \beta \max\{x_2 - x_1, 0\}, \qquad (1)$$
$$\text{where } \beta \le \alpha \text{ and } 0 \le \beta < 1.$$

The second term in (1) measures the utility loss from disadvantageous inequity, while the third term measures the utility loss from advantageous inequity. The assumption $\beta \le \alpha$ implies that a player suffers more from inequity, which is to her disadvantage, that is, the inequity aversion is asymmetric.

We call selfish players those with $\alpha = \beta = 0$ and strongly inequity averse players those with $\alpha, \beta > 0.5$. We also assume that the following condition holds for the inequity averse players:

$$\alpha \le \frac{2\beta - 1}{2(1-\beta)}. \qquad (2)$$

This condition establishes an upper bound on parameter α, which is increasing with parameter β. With this assumption we want to rule out non-realistic cases with extremely high values of α.[4]

Long-lived players 1 do not know the true type of the player 2 with whom they are matched in a period t. However, we will assume that they know the preferences distribution p_t in the population of players 2. Consequently, the optimal investment and bargaining strategies of player 1 will depend on this distribution. Nevertheless, it is convenient to study the payoffs and the strategies of both players, in case player 1 knew for sure player 2's type. We have already analysed in the previous section the case in which a player 1 is matched with a selfish player 2.

Let us now assume that a player 1 is matched with probability one with a strongly inequity averse player 2. Solving again the game by backward induction, we study first the negotiation stage. If the inequity averse player 2 gets to be the proposer in the ultimatum game it is easy to verify that it is a dominant strategy

[4] The experimental evidence in the ultimatum game shows that the parameter α lies between 0 and 4 (see Fehr and Schmidt, 1999).

for her to always offer an equal split of the surplus.[5] This offer will obviously be accepted by player 1. On the other hand, if player 1 gets to be the proposer his optimal strategy is to offer a share of the surplus which makes player 2 indifferent between accepting or rejecting. In order to calculate this acceptance threshold t^a of player 2, we equalize the utility function (1) to zero where, without loss of generality, we have normalized the surplus to one. Thus, $t^a - \alpha(1 - 2t^a) = 0$. Therefore, $t^a(\alpha) = \alpha/(1 + 2\alpha)$. Note that this threshold t^a is increasing in α and strictly less than one-half for any finite α.

Summarising, player 1 offers the inequity averse player 2 a proportion t^a of the current surplus and player 2 accepts, although she gets a utility of zero. Backward induction yields the following game when they make their investment decisions:

	S	G
S	$\frac{1}{2}(1-t^a)\bar{\nu} + \frac{1}{4}\bar{\nu} - c \quad , \quad \frac{1}{4}\bar{\nu} - c$	$\frac{1}{2}\underline{\nu} - c \quad , \quad \frac{1}{2}\underline{\nu}$
G	$(1-t^a)\underline{\nu} \quad , \quad -c$	$0 \quad , \quad 0$

(M.2)

Note that under assumptions (A.1) and (A.2) it is a dominant strategy for player 1 to make a specific investment. And, under condition (A.3) it is a dominant strategy for the inequity averse player 2 to make a general investment.

The important feature in this case is that making a specific investment is a dominant strategy for player 1, provided he is facing an inequity averse player 2. The intuition is quite straightforward: as strongly inequity averse players are very generous proposers, player 1 does not fear being exploited in the negotiation stage when he makes a specific investment.

Notice again, that the testing activity is useless because if player 1 knows that player 2 is inequity averse, then his dominant strategy is to make a specific investment irrespective of the result of the test. Consequently, player 1 will not acquire the testing technology and the first best in the investment decisions will not be obtained.

Summarising, when player 1 knows the true type of player 2, the testing activity is useless in order to improve the efficiency.

2.3 The socialization process and the optimal education effort

Preferences among players 2 are influenced by a purposeful and costly socialization process. In particular, we will draw from the model of cultural transmission of preferences of Bisin and Verdier (1998, 2001).

Let $\tau^i \in [0, 1]$ be the educational effort made by a parent of type i with $i \in \{e, a\}$ where e denotes selfish and a denotes strongly inequity averse. With probability τ^i the education will be successful and the child will adopt her parent's preferences

[5] Normalizing the surplus to one, the utility function (1) when player 2 makes an offer $t \leq 0.5$ can be written as $U_2 = (1-t) - \beta(1-2t)$. If $\beta > 0.5$ this utility is strictly increasing in t for all $t \leq 0.5$.

(*vertical transmission*). But with probability $1-\tau^i$ the education will not be successful and the child will adopt the preferences of some other adult she is randomly matched with (*oblique transmission*).

Let P^{ij} denote the probability that a child of a parent with preferences i is socialized to preferences j. The socialization mechanism just introduced is thus characterized by the following transition probabilities:

$$P_t^{ee} = \tau_t^e + (1-\tau_t^e)p_t \tag{3}$$
$$P_t^{ea} = (1-\tau_t^e)(1-p_t) \tag{4}$$
$$P_t^{aa} = \tau_t^a + (1-\tau_t^a)(1-p_t) \tag{5}$$
$$P_t^{ae} = (1-\tau_t^a)p_t \tag{6}$$

Given these transition probabilities it is easy to characterize the dynamic behaviour of p_t:

$$p_{t+1} = p_t P_t^{ee} + (1-p_t)P_t^{ae} \tag{7}$$

Substituting (3) to (6) we obtain:

$$p_{t+1} = p_t + p_t(1-p_t)[\tau_t^e - \tau_t^a] \tag{8}$$

Notice that this cultural transmission mechanism combines direct purposeful transmission with conformist transmission. Direct transmission is justified because parents are altruistic towards their children. But, an important feature is that they have some kind of imperfect altruism: their socialization decisions are not based on the purely material payoff expected for their children but on the payoff as perceived by their parents according to their own preferences. This particular form of myopia is called *imperfect empathy*. Direct transmission is also costly. Let $C(\tau^i)$ denote the cost of the education effort $\tau^i, i \in \{e,a\}$. While it is possible to obtain similar results with any increasing and convex cost function we will assume, for simplicity, the following quadratic form $C(\tau^i) = (\tau^i)^2/2k$ where $k > 0$. Therefore, a parent of type i chooses the education effort $\tau^i \in [0,1]$ at time t, which maximizes:

$$P_t^{ii}(\tau^i, p_t)U^{ii}(\sigma_{t+1}^E) + P_t^{ij}(\tau^i, p_t)U^{ij}(\sigma_{t+1}^E) - (\tau^i)^2/2k \tag{9}$$

where P^{ij} are the transition probabilities and U^{ij} is the utility to a parent with preferences i if her child is of type j. Notice that the utility U^{ij} depends on σ_{t+1}^E, which denotes the expectation about the policy of the long-lived players for period $t+1$. In this work we will assume that parents have adaptive or backward looking expectations, believing that the long-lived player 1 will follow today's policy in the next period, that is, $\sigma_{t+1}^E = \sigma_t$.[6]

According to the notion of imperfect empathy, in order to assess U^{ij} a parent of type i uses her own utility function. Thus, parents obtain a higher utility if their children share their preferences. As a consequence, $U^{ee} \geq U^{ea}$ and $U^{aa} \geq U^{ae}$.

[6] Another alternative assumption would be that parents have rational or forward looking expectations. The results in this case are very similar to those obtained in this paper, except for some initial conditions there is multiplicity of equilibria in the dynamics of preferences.

The solution of the socialization problem is the following optimal education effort levels:

$$\hat{\tau}^e(p_t, \sigma_t) = k\Delta U^e(\sigma_t)(1 - p_t) \quad (10)$$

$$\hat{\tau}^a(p_t, \sigma_t) = k\Delta U^a(\sigma_t)p_t \quad (11)$$

Here $\Delta U^e(\sigma_t) = U^{ee}(\sigma_t) - U^{ea}(\sigma_t)$ and $\Delta U^a(\sigma_t) = U^{aa}(\sigma_t) - U^{ae}(\sigma_t)$. That is, ΔU^i is the net gain from socializing your child to your own preferences. In order to have interior solutions the parameter k must be chosen small enough so that in equilibrium $\tau^i < 1$.

Differentiation of the first order conditions with respect to p_t yields:

$$\frac{d\tau^e(p_t, \sigma_t)}{dp_t} = -k\Delta U^e(\sigma_t) < 0 \quad (12)$$

$$\frac{d\tau^a(p_t, \sigma_t)}{dp_t} = k\Delta U^a(\sigma_t) > 0 \quad (13)$$

Note that the educational effort $\tau^i(\cdot)$ of a parent of type i decreases with the proportion of individuals of type i in the population. The reason is very intuitive: the larger this proportion is, the better children are socialized to these preferences in the social environment. In other words, *oblique transmission* acts as a substitute for *vertical transmission*.[7]

The other determinant of the optimal educational effort is the relative profit ΔU^i to a parent of type i from transmitting her own cultural traits, which depends on the policy of the long-lived player in the next period which she expects will be the same as in period t. The next section analyses the players' strategies in each period.

3 The optimal negotiation and investment policies

In this section we characterize the Perfect Bayesian Equilibria of the sequential game played in each period. Recall that player 1 chooses firstly whether to acquire the testing technology or not, and then both players play the investment game. Finally, after observing the realized surplus they negotiate how to share it.

Therefore, the policy of player 1 has three components $\sigma_t = \{\sigma(x), \sigma_I, \sigma_N\}$, where $x \in \{T, NT\}$ denotes the decision to acquire the testing technology (T) or not to acquire it (NT), σ_I denotes the investment policy and σ_N denotes the negotiation policy.

3.1 The negotiation subgames

In Section 2 we characterized the optimal negotiation policy of both types of player 2. Let us next analyse the optimal negotiation policy of player 1 when he becomes the proposer in the ultimatum game.[8]

[7] Bisin and Verdier (2001) refer to this feature of educational effort as "the cultural substitution property".

[8] Obviously, if player 1 is the responder his optimal strategy is to accept any offer.

Player 1 only knows the proportion of each type of player 2 in the population but he does not know the type of the particular player 2 with whom he is matched. Nevertheless, in some cases, the particular realized surplus can also change his beliefs about his opponent's type. We will denote by μ_t the updated probability which player 1 assigns to player 2 being a selfish player after observing the realized surplus in period t. That is, $\mu_t = \text{prob}(2e|v_t)$. This implies that if he gets to be the proposer in the negotiation stage, his optimal offer will depend on his beliefs μ_t. If player 1 offers zero, only the selfish type of player 2 will accept. Therefore his expected payoff will be μ_t (where we have normalised the surplus to one). Nevertheless, if he offers the inequity averse players' acceptance threshold $t^a > 0$, both types of player 2 will accept and player 1 will get a payoff of $1 - t^a$. The following lemma summarises this result.

Lemma 1. *If $\mu_t \geq 1 - t^a$ player 1 offers zero to his opponent and if $\mu_t < 1 - t^a$ he offers the acceptance threshold t^a.*

We will denote these negotiation policies of player 1 as a proposer by $\sigma_N \in \{0, t^a\}$. Let us analyse next the investment subgames.

3.2 The investment subgame without testing technology

The following lemma characterizes the unique Perfect Bayesian Equilibrium of the subgame that starts with player 1 deciding not to acquire the testing technology.

Lemma 2. *Assume that conditions (A.1), (A.2) and (A.3) hold, player 1 plays S if $p_t \leq p' = (\frac{1}{2}\underline{\nu} - c)/\frac{1}{2}\underline{\nu}$ and plays G if $p_t > p' = (\frac{1}{2}\underline{\nu} - c)/\frac{1}{2}\underline{\nu}$ and both types of player 2 play G.*

Proof. See appendix. □

The intuition for this result is quite simple: irrespective of the policy followed by player 1, the best reply of both types of player 2 is always to make a general investment. Given that the inequity averse players 2 are very generous when they are proposers in the negotiation stage, player 1 will prefer to make a specific investment when their proportion in the population is high enough.

3.3 The investment subgame with testing technology

Alternatively, as we have indicated before, player 1 can acquire and carry out a testing technology which allows him to know with probability γ if player 2 has made a general investment. Therefore, player 1 has two possible strategies in which he uses the information provided by the test: σ_B consisting of making a specific investment when he observes a general investment and making a general investment otherwise and σ_A consisting of making a general investment when he observes a general investment and making specific investment otherwise.

Note also that, in this case, player 1 has another option: to buy the testing technology but not to use it. This implies that the equilibrium established in Lemma 2 also exists in the subgame after acquiring the testing technology: player 1 ignores the information provided by the test and makes a specific or a general investment depending on the distribution p being smaller or greater than p' and both types of player 2 make a general investment.

However, there is another equilibrium in which the testing technology is used and all players make specific investments. This equilibrium exists when the testing technology is good enough and there is a non-negligible proportion of inequity averse players in the population, that is, γ is greater than a particular value and p is smaller than a critical value. Moreover, player 1 obtains a higher payoff in this equilibrium than in any equilibrium without using the testing technology. Let us next show the existence and characterization of this equilibrium.

First, observe that the strategy σ_B cannot be part of an equilibrium. It is easy to check that the best reply of both types of player 2 is to make a general investment. As such, the payoff of player 1 if σ_B is followed is the same payoff he would obtain by always making a specific investment but multiplied by the factor γ. If this payoff is positive and as $\gamma < 1$, it will be better for player 1 to ignore the information of the test and always make a specific investment. And if this payoff is negative, then it is better for him to always make a general investment ignoring again the information of the test. Therefore, the strategy σ_B is always dominated either by always making a specific investment or a general investment.

Suppose now that player 1 carries out the testing activity and follows the strategy σ_A. It is easy to check that given this policy, there are some critical values of γ such that the best reply of both types of player 2 is to make a specific investment.

Lemma 3. *Suppose that player 1 follows the strategy σ_A then,*

(i) *When $\mu_t \geq 1 - t^a$ the selfish player 2 plays S if $\gamma \geq \bar{\gamma} = (\underline{\nu} - (\frac{1}{2}\bar{\nu} - c))/\underline{\nu}$.*
(ii) *When $\mu_t < 1 - t^a$ the selfish player 2 plays $\gamma \geq \gamma' = (\underline{\nu} - (\frac{1}{2}(1+t^a)\bar{\nu} - c))/\underline{\nu}$.*
(iii) *The inequity averse player 2 plays S if $\gamma \geq \hat{\gamma} = (\underline{\nu} - (\frac{1}{2}\bar{\nu} - 2c))/\underline{\nu}$, where $\gamma' < \bar{\gamma} < \hat{\gamma}$.*

Proof. See appendix. □

It is straightforward to check that for $\gamma < \hat{\gamma}$, either both types of player 2 make a general investment or the selfish player 2 makes a specific investment and the inequity averse player 2 makes a general investment. In the former case the payoff obtained by player 1 with σ_A is the same as the one he would obtain by always making a specific investment but multiplied by $1 - \gamma$. Therefore, a similar argument as the one used with the strategy σ_B shows that σ_A is not a best reply for player 1. In the latter case where only the inequity averse player 2 makes a general investment, it is not credible that player 1 will make a general investment after observing a general investment. In summary, for $\gamma < \hat{\gamma}, \sigma_A$ is not a best reply for player 1.

But for $\gamma \geq \hat{\gamma}$ both types of player 2 make specific investments. The following lemma establishes the existence of a critical value of p such that for $p \leq p^c$, σ_A is the best reply for player 1.

Lemma 4. *Assume that conditions (A.1), (A.2) and (A.3) hold, then if $\gamma \geq \hat{\gamma}$, there exists $p^c > p'$ such that whenever $p_t \leq p^c$ player 1 plays σ_A and both types of player 2 play S.*

Proof. See appendix. □

We are now ready to obtain the Perfect Bayesian Equilibria of the whole game. We would restrict our attention to the interesting case in which $\gamma \geq \hat{\gamma}$. For $p_t > p^c$ in both investment subgames there is a unique equilibrium continuation in which all players make general investments. Obviously, given that acquiring the technology is costly, the unique Perfect Bayesian Equilibrium of the whole game would consist of not acquiring the technology and all players making a general investment. But, for $p_t \leq p^c$, there are two Perfect Bayesian Equilibria of the whole game because there are two possible equilibrium continuations in the subgame reached after buying the technology. In one of them, both types of player 2 plan to make a general investment after player 1 has bought the technology because they believe that he is not going to use the information provided by the test. Then, player 1 does not buy the testing technology because its acquisition is costly. In the other Perfect Bayesian equilibrium, both types of player 2 plan to make a specific investment because they believe that player 1 after buying the test will play the strategy σ_A. Notice that the payoff obtained by player 1 in the latter equilibrium is greater than in any other equilibrium. Therefore, it is not reasonable at all to expect that player 1 has bought the technology with the intention of not using it because he can get the same payoff without acquiring it and thus, saving the cost of the technology. More formally, the first equilibrium will not survive any minimal refinement requirement (such as, for instance, the intuitive criterion).

Corollary. *If $\gamma \geq \hat{\gamma}$ the solution of the whole game is,*

(i) *If $p_t > p^c$ player 1 does not acquire the testing technology and all players play G.*
(ii) If $p_t \leq p^c$ *player 1 acquires the testing technology, plays the strategy σ_A and both types of player 2 play S.*

When the testing technology is good enough (i.e., $\gamma \geq \hat{\gamma}$) both types of player 2 have the right incentives to invest making specific investments (there exists a high probability of being discovered if they make general investments). However, if player 1 cannot previously commit to any testing policy, he will only apply the strategy σ_A if the proportion of selfish players 2 in the population is smaller than a critical value p^c. How big the value p^c is depends on how severe the social dilemma involved in the prisoner's dilemma structure of the investment game is.

A measure of the severity of the social dilemma is $D = \underline{\nu} - (\frac{1}{2}\bar{\nu} - c)$, that is, the net gain from defecting when your partner makes a specific investment. In a prisoner's dilemma, D is always positive. When the prisoner's dilemma is not so severe, in particular, $D \leq \underline{D} = t^a(\underline{\nu} - \frac{1}{4}\bar{\nu})$, then $p^c = p'' = (\frac{1}{4}\bar{\nu} - c)/(\underline{\nu} - \frac{1}{4}\bar{\nu})$ which is greater than $1 - t^a$. And, when $D > \underline{D} = t^a(\underline{\nu} - \frac{1}{4}\bar{\nu})$, then $p^c = p''' = ((1 - t^a)(\frac{1}{2}\bar{\nu} - \underline{\nu}) + \frac{1}{4}\bar{\nu} - c)/\frac{1}{4}\bar{\nu}$ which is smaller than $1 - t^a$.

On the other hand when the testing technology is not good enough (i.e., $\gamma < \hat{\gamma}$) player 1 will never acquire in equilibrium the testing technology. Therefore, the results in this case are the same as those obtained without testing technology established in Lemma 2 (see also Olcina and Peñarrubia, 2004).

4 Investment and the long-run pattern of preferences

Suppose that a good testing technology is available in the society in the sense that $\gamma \geq \hat{\gamma}$. In this case, as we have established in Lemma 4, whenever $p_t \leq p^c$ player 1 uses the testing technology and follows the strategy σ_A. Moreover, both types of player 2 will reply making specific investments. Hence, after observing the realized surplus $\bar{\nu}$ player 1 will not update his prior p_t, that is, $\mu_t = p_t$. Therefore, if $p_t \geq 1 - t^a$ player 1 offers zero to his opponent and if $p_t < 1 - t^a$, he offers the acceptance threshold t^a. We will denote the policy of the long-lived players in t as $\sigma(p_t) = \hat{\sigma} = (\sigma_A, 0)$ if $p_t \geq 1 - t^a$ and $\sigma(p_t) = \sigma' = (\sigma_A, t^a)$ if $p_t < 1 - t^a$. The utilities U^{ij} and the net gains for parents of transmitting their own preferences are given by:

· if $p_t < 1 - t^a$

$$U^{ee} = \frac{1}{2}\bar{\nu}(1 + t^a) - c \qquad U^{aa} = \frac{1}{4}\bar{\nu} - c$$

$$U^{ea} = \frac{1}{2}t^a\bar{\nu} + \frac{1}{4}\bar{\nu} - c \qquad U^{ae} = \frac{1}{2}\bar{\nu}(1 - \beta) - c$$

Therefore, $\Delta U^e = \frac{1}{4}\bar{\nu}$ and $\Delta U^a = \frac{1}{2}\bar{\nu}(\beta - \frac{1}{2})$.

· if $p_t \geq 1 - t^a$

$$U^{ee} = \frac{1}{2}\bar{\nu} - c \qquad U^{aa} = \frac{1}{4}\bar{\nu} - c$$

$$U^{ea} = \frac{1}{4}\bar{\nu} - c \qquad U^{ae} = \frac{1}{2}\bar{\nu}(1 - \alpha - \beta) - c$$

Therefore, $\Delta U^e = \frac{1}{4}\bar{\nu}$ and $\Delta U^a = \frac{1}{2}\bar{\nu}(\alpha + \beta - \frac{1}{2})$.

Notice that in order to assess U^{ij} we use the imperfect empathy notion. That is, a parent of type i evaluates her child's well-being using her own utility function. For instance, when $p_t \geq 1 - t^a$, U^{ae} is the utility to an inequity averse parent if her child is selfish. The child will make a specific investment and with probability one-half she will be the proposer in the bargaining stage and will claim all the surplus $\bar{\nu}$. Evaluating this payoff through the parent's utility function, the parent obtains $\bar{\nu}(1 - \beta)$. With probability one-half, the child will act as a responder in the negotiation stage and will receive a zero payoff. Evaluating this payoff through the parent's preferences, the parent obtains $-\alpha\bar{\nu}$. Consequently, $\frac{1}{2}\bar{\nu}(1 - \alpha - \beta) - c$ is the utility to an inequity averse parent if her child is selfish (notice that this quantity is negative since $\alpha + \beta > 1$).

Notice that, the optimal educational effort function for the selfish players is the same for all $p_t \leq p^c$: $\hat{\tau}^e = k\frac{1}{4}\bar{\nu}(1 - p_t)$. By contrast, the optimal educational effort function for $p_t \leq p^c$ to the inequity averse players depend on p_t:

$$\hat{\tau}^a = k\frac{1}{2}\bar{\nu}\left(\beta - \frac{1}{2}\right)p_t \qquad \text{if} \quad p_t < 1 - t^a$$

$$\hat{\tau}^a = k\frac{1}{2}\bar{\nu}\left(\alpha + \beta - \frac{1}{2}\right)p_t \qquad \text{if} \quad p_t \geq 1 - t^a$$

On the other hand, whenever $p_t > p^c$ player 1 will not acquire the testing technology and will always make a general investment. Therefore, it follows that $U^{ee} = U^{ea} = U^{aa} = U^{ae} = 0$. Obviously $\Delta U^e = \Delta U^a = 0$ and therefore, $\tau^e(p_t, G) = \tau^a(p_t, G) = 0$. That is, no type of player 2 has incentives to socialize their children.

The following proposition characterizes the stable steady states of the economy.

Proposition 1. *Let $\bar{D} = \frac{1}{4}\bar{\nu} - t^a(\frac{1}{2}\bar{\nu} - \underline{\nu}) - \frac{1}{8\beta}\bar{\nu} > \underline{D}$, under conditions (A.1), (A.2), (A.3) and $\gamma \geq \hat{\gamma}$,*

(i) Any initial distribution $p_0 > p^c$ is a stable steady state.
(ii) If $D \leq \bar{D}, \tilde{p} = 1/(2\beta)$ is a stable steady state with a basin of attraction $(0, p^c]$, where $\tilde{p}$ is such that $\tau^e(\tilde{p}, \sigma') = \tau^a(\tilde{p}, \sigma')$.
(iii) If $D > \bar{D}, p^c$ is a stable steady state with a basin of attraction $(0, p^c]$, where $p^c < 1 - t^a$.

Proof. See appendix. □

Therefore, from any initial condition smaller than p^c, the economy converges to a heterogeneous distribution of preferences. In this stationary state, player 1 uses the testing technology, credibly conditioning his investment decision to the information provided by the test and resulting in all players making specific investments.

We can distinguish three cases in the general result established in Proposition 1 depending on the severity of the prisoner's dilemma:

1. When the prisoner's dilemma is not so severe, that is, $D \leq \underline{D} = t^a(\underline{\nu} - \frac{1}{4}\bar{\nu})$, the particular value of p^c is given by $p'' = (\frac{1}{4}\bar{\nu} - c)/(\underline{\nu} - \frac{1}{4}\bar{\nu}) > 1 - t^a$. In this case, the three possibilities $p_t < 1 - t^a$, $1 - t^a \leq p_t \leq p''$, and $p_t > p''$ lead to a three branch dynamics under the assumption of backward looking expectations:

$$(A)\ p_{t+1} = p_t + p_t(1-p_t)\left[k\frac{1}{4}\bar{\nu}\,(1-p_t) - k\frac{1}{2}\bar{\nu}\left(\beta - \frac{1}{2}\right)p_t\right] \quad \text{if } p_t < 1 - t^a$$

$$(B)\ p_{t+1} = p_t + p_t(1-p_t)\left[k\frac{1}{4}\bar{\nu}\,(1-p_t) - k\frac{1}{2}\bar{\nu}\left(\alpha + \beta - \frac{1}{2}\right)p_t\right] \quad \text{if } 1 - t^a \leq p_t \leq p''$$

$$(C)\ p_{t+1} = p_t \quad \text{if } p_t > p''$$

The equations come from (8) in Section 2.3. Notice that, there is a discontinuity in $p_t = 1 - t^a = (1+\alpha)/(1+2\alpha)$ and also in $p_t = p''$. The phase diagram in Fig. 1 shows this case. Figure 1 is qualitatively correct for all admissible parameter values.

The dynamics has the following steady states: $p = 0$, $p \in (p'', 1]$ and the interior steady state $\tilde{p} = 1/(2\beta)$, where $\tilde{p}$ is such that both educational effort levels get equalized under dynamics (A). The steady state $p = 0$ is unstable. This steady state is a completely homogeneous distribution of preferences, that is, all players 2 being inequity averse ($p = 0$). If the selfish players 2 are in a minority (that is, p_t is very close to 0), their socialization effort will be very intensive in an attempt to offset the effect of oblique transmission. In this context, $\hat{\tau}^e$ exceeds $\hat{\tau}^a$ and the

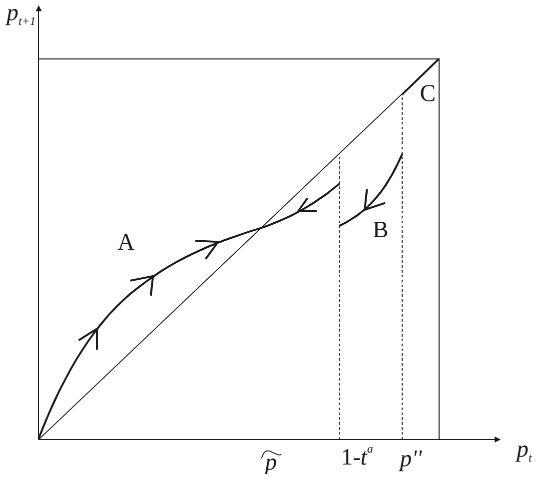

Figure 1

selfish preferences will spread over generations preserving their presence in the society.

It follows from inspection of the phase diagram that for any $p_0 \in (0, p'']$ a unique p_t path results with p_t converging to $\tilde{p} = 1/(2\beta)$. That is, $\tilde{p}$ is a globally stable steady state (on that interval of distributions). The complete and formal analysis of these results is relegated to the appendix.

2. When $\underline{D} < D \leq \bar{D}$, then $p^c = p''' = ((1-t^a)(\frac{1}{2}\bar{\nu} - \underline{\nu}) + \frac{1}{4}\bar{\nu} - c)/\frac{1}{4}\bar{\nu} < 1 - t^a$. In this case, the two possibilities $p_t \leq p'''$ and $p_t > p'''$ lead to a two branch dynamics:

$$(A)\ p_{t+1} = p_t + p_t(1-p_t)\left[k\frac{1}{4}\bar{\nu}(1-p_t) - k\frac{1}{2}\bar{\nu}(\beta - \frac{1}{2})p_t\right] \quad \text{if} \ \ p_t \leq p'''$$

$$(C)\ p_{t+1} = p_t \qquad \text{if} \ \ p_t > p'''$$

Notice that there is a discontinuity in $p_t = p'''$ The phase diagram in Fig. 2 shows this case. It follows from inspection in the phase diagram that for any $p_0 \in (0, p''']$ a unique p_t path results with p_t converging to $\tilde{p} = 1/(2\beta)$. That is, $\tilde{p}$ is a globally stable steady state.

3. When $D > \bar{D}$, $p^c = p'''$ and the two branch dynamics are the same as in case 2. But now, $p''' < \tilde{p}$. The phase diagram in Fig. 3 shows this case. It follows from inspection that for any $p_0 \in (0, p''']$ a unique p_t path results with p_t converging to p'''.

Therefore, the above analysis establishes the success of the strategy σ_A when the two following features are fulfilled: there is a good testing technology and the initial proportion of inequity averse players 2 is greater than a critical value. The first best result is achieved. Notice that with homogeneous selfish preferences the inefficient outcome, where every player makes a general investment, will be the only possible result.

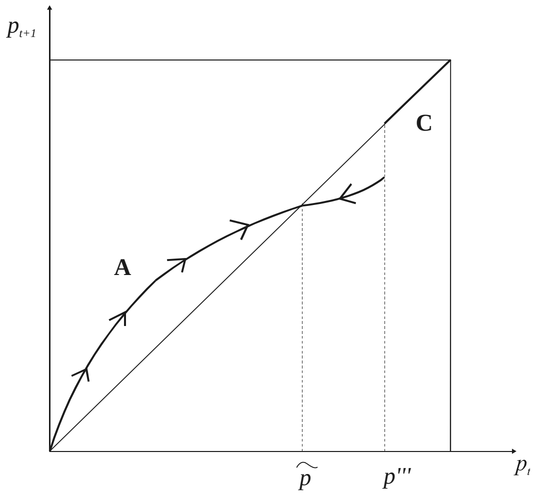

Figure 2

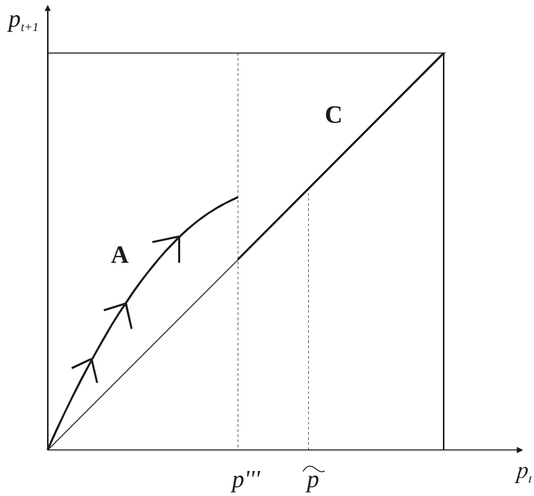

Figure 3

Recall that the testing technology is useless with complete information, that is, when player 1 knows for sure his opponent's type. This is due to the fact that, irrespective of the result of the test, it is a dominant strategy for player 1 to make a general investment when his opponent is selfish and to make a specific investment when his opponent is inequity averse. Accordingly, with complete information the results of the game are the same with or without testing activity.

Therefore, in an incomplete information scenario without testing technology, player 1 will make a specific or a general investment depending on the proportion of both types of player 2 in the population. But players 2 will still make general investments. By contrast, a sufficiently good testing technology changes the behaviour of both types of player 2 enhancing efficiency in the investment decision for any distribution of preferences smaller than a critical value p^c. Both types of player 2 know that if they make a general investment they will be discovered with a non-negligible probability γ obtaining a zero payoff, although with some probability they will go unnoticed and get a high share of the low surplus. But, if γ is high enough it would be better to make a specific investment obtaining for sure at least a substantial share of the high surplus.

Notice that we have assumed that player 1 cannot previously commit to any particular testing policy. In our model, once players 2 have made their specific investments, player 1 according to the strategy σ_A makes a specific investment. This is his best reply given that there are enough inequity averse players 2 in the population. It is easy to prove that the result is even stronger if we allow player 1 to establish *a priori* credible announcements to any policy. In this case, we obtain that the announcement of a commitment to the strategy σ_A is the unique Perfect Bayesian Equilibrium for all p (provided $\gamma \geq \hat{\gamma}$). Interestingly also, for some intermediate values of γ, the equilibrium strategies are again that player 1 announces policy σ_A and the selfish type of player 2 makes a specific investment whereas the inequity averse player 2 makes a general investment.

The first best result is more likely in a society with a big high surplus $\bar{\nu}$, a small low surplus $\underline{\nu}$ and a small cost of specific investment c. The combination of these features yields a low critical value $\hat{\gamma}$ and a high critical value p''. This is because these features diminish the severity of the prisoner's dilemma D, that is, the difference between the individual material gains from both players making a specific investment $(\frac{1}{2}\bar{\nu} - c)$ and the individual material gains from unilaterally defecting $(\underline{\nu})$. Notice that when this difference tends to zero, the critical value p'' tends to one and $\hat{\gamma}$ tends to $(c/\underline{\nu})$ which is always smaller than one half.

Observe that the negotiation policy of player 1 as a proposer is to offer the threshold t^a, this implies that there is also efficiency in the negotiation stage. Whereas, under the negotiation policy consisting of offering zero there would be efficiency in the investment stage but not in the negotiation stage because the inequity averse players would reject this offer.

Finally, another interesting feature of the steady state is that players 2 (workers) get a higher proportion of the surplus with respect to the situation with homogeneous preferences. This proportion increases in the disadvantageous inequity aversion parameter α.

5 Conclusions

The aim of this paper is to analyse whether imperfect monitoring can improve the efficiency when players face a severe hold up problem in the sense that to make inefficient general investments is a dominant strategy. If all players have selfish preferences, as standard economic theory assumes, monitoring is useless in this context. However, there is overwhelming evidence to indicate that a non-negligible proportion of the population cares not only about their own material payoffs but also about reciprocity and fairness. Therefore, a more realistic assumption would be that preferences in the population are heterogeneous. We have presented an overlapping generations model with cultural transmission of preferences where the distribution of preferences in the population and the monitoring and investment policies influence one another and are determined endogenously and simultaneously.

We obtain that in the stable steady state of the economy there is a mixed distribution of preferences where both, selfish and other-regarding preferences are present in the population. Moreover, when a sufficiently good testing technology is available and there is a non-negligible initial proportion of inequity averse players, the economy reaches the first best where all players make specific investments. This result is more likely, that is, the basin of attraction of the steady state is greater, whenever the severity of the prisoner's dilemma diminishes. This occurs for a big value of the high surplus and a small value of the low surplus and of the cost of the specific investment. In summary, the combination of cultural transmission of preferences and imperfect monitoring alleviates post-contractual opportunism and improves efficiency.

Appendix

Proof of Lemma 2

Assume player 1 will make a general investment. In this case, if the inequity averse player 2 plays S, after observing the realized surplus $\underline{\nu}$, player 1 will be the proposer in the second stage and he will offer either 0 or t^a. In both cases, the expected utility to the inequity averse player is $-c$. If instead, the inequity averse player 2 plays G, her expected payoff is zero. So, the inequity averse player 2 will play G. As a consequence, if player 1 observes the low surplus $\underline{\nu}$, he will conclude that his opponent has played S and, therefore, this decision only comes from the selfish player 2, that is, $\mu_t = 1$ and he will offer her 0. So, the latter expected payoff will be $-c$. But, if the selfish player 2 plays G, she obtains a zero payoff. Therefore, the selfish player 2 also plays G. Summarising, the expected payoff to player 1 if he plays G is 0 because both types of player 2 will reply with a general investment.

Assume now that player 1 makes a specific investment. Following a similar argument as the one presented above, if the inequity averse player 2 plays S, her expected payoff will be $\frac{1}{4}\bar{\nu} - c$.[9] On the contrary, by playing G she obtains $\frac{1}{2}\underline{\nu}$. Under condition (A.3) the best reply of an inequity averse player is to play G. Therefore, if player 1 observes $\bar{\nu}$, he will conclude that $\mu_t = 1$. So, if the selfish player 2 plays S, her expected payoff will be $\frac{1}{2}\bar{\nu} - c$.[10] Whereas, if she plays G, she obtains $\underline{\nu}$. Under condition (A.3) the selfish player 2 also plays G. Summarising, the expected payoff to player 1 if he plays S will be $p(-c) + (1-p)(\frac{1}{2}\underline{\nu} - c)$, as playing G is a dominant strategy for both types of player 2. Observe that, if $p_t \leq p' = (\frac{1}{2}\underline{\nu} - c)/\frac{1}{2}\underline{\nu}$ the above payoff is positive and if $p_t > p' = (\frac{1}{2}\underline{\nu} - c)/\frac{1}{2}\underline{\nu}$ the above payoff is negative. □

[9] Given that player 1 and the inequity averse player 2 play S, then when the latter is the proposer, she offers half of the surplus $\bar{\nu}$, but if she is the responder, irrespective of the offer of player 1, she obtains a utility of zero.

[10] Note that with probability $\frac{1}{2}$, player 1 is the proposer and he offers zero to the selfish player 2, and with probability $\frac{1}{2}$, the latter is the proposer and she claims all the surplus.

Proof of Lemma 3

Suppose that player 1 carries out the testing activity and follows the strategy σ_A. If the selfish player 2 plays S, player 1 will never observe G with the testing activity, therefore he also plays S. In the second stage the expected payoff to the selfish player 2 will be $\frac{1}{2}\bar{\nu} - c$ if $\mu_t \geq 1 - t^a$ or $\frac{1}{2}\bar{\nu}(1 + t^a) - c$ if $\mu_t < 1 - t^a$. Whereas if she plays G, when player 1 carries out the testing activity, with probability γ he discovers that the selfish player 2 has played G and, as a consequence, player 1 also plays G, but with probability $1 - \gamma$ the testing activity is not successful and player 1 plays S. Therefore, the expected payoff to the selfish player 2 when she plays G is given by $(1 - \gamma)\underline{\nu} + \gamma 0$.

When $\mu_t \geq 1 - t^a$, to play S is better than to play G if:

$$\gamma \geq \bar{\gamma} = \frac{\underline{\nu} - (\frac{1}{2}\bar{\nu} - c)}{\underline{\nu}}.$$

On the other hand, when $\mu_t < 1 - t^a$, a selfish player 2 plays S if:

$$\gamma \geq \gamma' = \frac{\underline{\nu} - \left(\frac{1}{2}(1 + t^a)\bar{\nu} - c\right)}{\underline{\nu}}.$$

Let us next analyse the behaviour of an inequity averse player when she anticipates the strategy σ_A of player 1. If she plays S, her expected payoff will be $\frac{1}{4}\bar{\nu} - c$. Whereas if she plays G, she obtains $(1 - \gamma)\frac{1}{2}\underline{\nu} + \gamma 0$. Hence, to play S is better than to play G if:

$$\gamma \geq \hat{\gamma} = \frac{\underline{\nu} - \left(\frac{1}{2}\bar{\nu} - 2c\right)}{\underline{\nu}}.$$

Note that $\gamma' < \bar{\gamma} < \hat{\gamma}$. □

Proof of Lemma 4

If $\gamma \geq \hat{\gamma}$ both types of player 2 will play S and the testing activity is not informative. It only remains to be shown that player 1 will reply following the strategy σ_A, that is, playing S. Given that $\mu_t = p_t$, then the expected payoff to player 1 if he plays S will be:

$$\begin{array}{ll} p\left(\frac{1}{2}\bar{\nu} - c\right) + (1 - p)\left(\frac{1}{4}\bar{\nu} - c\right) & \text{if } p_t \geq 1 - t^a \\ p\left(\frac{1}{2}(1 - t^a)\bar{\nu} - c\right) + (1 - p)\left(\frac{1}{2}(1 - t^a)\bar{\nu} + \frac{1}{4}\bar{\nu} - c\right) & \text{if } p_t < 1 - t^a \end{array}$$

On the other hand, if player 1 deviates, playing G obtains:

$$\begin{array}{ll} p\underline{\nu} & \text{if } p_t \geq 1 - t^a \\ (1 - t^a)\underline{\nu} & \text{if } p_t < 1 - t^a \end{array}$$

If $p_t \geq 1 - t^a$, player 1 will prefer to play S when $p \leq p'' = (\frac{1}{4}\bar{\nu} - c)/(\underline{\nu} - \frac{1}{4}\bar{\nu})$. And, if $p_t < 1 - t^a$, player 1 will prefer to play S when $p \leq p''' = ((1 - t^a)(\frac{1}{2}\bar{\nu} - \underline{\nu}) + \frac{1}{4}\bar{\nu} - c)/\frac{1}{4}\bar{\nu}$. It is easy to check that $p'' > p''' > 1 - t^a$ when the prisoner's dilemma is not so severe, that is, when $D \leq \underline{D} = t^a(\underline{\nu} - \frac{1}{4}\bar{\nu})$, where $D = \underline{\nu} - (\frac{1}{2}\bar{\nu} - c)$ is the gain from playing G in place of S when your opponent plays S. Therefore, when $p_t \leq p''$ player 1 obtains the highest payoff with σ_A. In this case, the critical value p^c is given by p''.

When the prisoner's dilemma is more severe, that is, $D > \underline{D} = t^a(\underline{\nu} - \frac{1}{4}\bar{\nu})$, then $p'' < p''' < 1 - t^a$. Therefore, when $p_t \leq p'''$ player 1 obtains the highest payoff with the strategy σ_A. Now, the critical value p^c is given by p'''.

But, in general, in both cases $p^c > p'$, therefore when $p_t > p^c$ player 1 will deviate from the strategy σ_A playing G and both types of player 2 will also play G. □

Proof of Proposition 1

We look for simplicity at the continuous time limit of the dynamics of p_t, by assuming that socialization is instantaneous. In other words, we will consider a discrete time model with periods of length h letting then $h \to 0$. We can distinguish three cases:

Case 1. $D \leq \underline{D} = t^a(\underline{\nu} - \frac{1}{4}\bar{\nu})$. In this case $p^c = p'' > 1 - t^a$ and we have a three branch dynamics (see Fig. 1):

$$(A)\ p_{t+h} - p_t = hp_t(1-p_t)\left[k\frac{1}{4}\bar{\nu}(1-p_t) - k\frac{1}{2}\bar{\nu}\left(\beta - \frac{1}{2}\right)p_t\right] \quad \text{if } p_t < 1 - t^a$$

$$(B)\ p_{t+h} - p_t = hp_t(1-p_t)\left[k\frac{1}{4}\bar{\nu}(1-p_t) - k\frac{1}{2}\bar{\nu}\left(\alpha + \beta - \frac{1}{2}\right)p_t\right] \quad \text{if } 1 - t^a \leq p_t \leq p''$$

$$(D)\ p_{t+h} - p_t = 0 \quad \text{if } p_t > p''$$

Taking the limit $h \to 0$, one gets the differential equations:

$$(A)\ \dot{p}_t = p_t(1-p_t)\left[k\frac{1}{4}\bar{\nu}(1-p_t) - k\frac{1}{2}\bar{\nu}\left(\beta - \frac{1}{2}\right)p_t\right] \quad \text{if } p_t < 1 - t^a$$

$$(B)\ \dot{p}_t = p_t(1-p_t)\left[k\frac{1}{4}\bar{\nu}(1-p_t) - k\frac{1}{2}\bar{\nu}\left(\alpha + \beta - \frac{1}{2}\right)p_t\right] \quad \text{if } 1 - t^a \leq p_t \leq p''$$

$$(C)\ \dot{p}_t = 0 \quad \text{if } p_t > p''$$

Under assumption (2) $\tilde{p} = 1/(2\beta) \leq 1 - t^a$, then dynamics (A) defined in the interval $[0, 1 - t^a)$ has an homogeneous steady state $p = 0$ which is dynamically unstable and an interior steady state $p = \tilde{p} = 1/(2\beta)$ which is dynamically stable.

Concerning dynamics (B), notice that $[k\frac{1}{4}\bar{\nu}(1 - p_t) - k\frac{1}{2}\bar{\nu}(\alpha + \beta - \frac{1}{2})p_t] < 0$ for $p_t \in [1 - t^a, p'']$. In particular, this expression is negative for all $p_t > \hat{p} = 1/(2(\alpha + \beta))$. As $\hat{p} < \frac{1}{2}$, then $\hat{p} < 1 - t^a$, and the result follows. As a consequence, $\dot{p}_t < 0$ for $p_t \in [1 - t^a, p'']$.

All the previous arguments yield that $\tilde{p} = 1/(2\beta)$ is a stable steady state with a basin of attraction $(0, p^c]$ where $\tilde{p}$ is such that $\tau^e(\tilde{p}, \sigma') = \tau^a(\tilde{p}, \sigma')$.

Concerning dynamics (C) as $\dot{p}_t = 0$ for any $p_t \in (p'', 1]$ any initial condition $p_0 \in (p'', 1]$ is maintained over time as a stable stationary point.

Case 2. $\underline{D} < D \leq \bar{D}$. In this case $p^c = p''' < 1 - t^a$ and we have two branch dynamics (see Fig. 2). Taking the limit $h \to 0$, we obtain the following differential equations:

$$(A)\ \dot{p}_t = p_t(1-p_t)\left[k\frac{1}{4}\bar{\nu}(1-p_t) - k\frac{1}{2}\bar{\nu}\left(\beta - \frac{1}{2}\right)p_t\right] \qquad \text{if } \ p_t \leq p'''$$

$$(C)\ \dot{p}_t = 0 \qquad \text{if } \ p_t > p'''$$

Notice that, in this case, $p''' > \tilde{p} = 1/(2\beta)$, then dynamics (A) defined in the interval $[0, p''']$ has an homogeneous steady state $p = 0$ which is dynamically unstable and an interior steady state $p = \tilde{p} = 1/(2\beta)$ which is dynamically stable. Therefore, $\tilde{p} = 1/(2\beta)$ is a stable steady state with a basin of attraction $(0, p^c]$.

The result concerning dynamics (C) is the same as in case 1 for any initial condition $p_0 \in (p''', 1]$.

Case 3. $D > \bar{D}$ then, $p^c = p''' < 1 - t^a$. In this case we have the same two branch dynamics of preferences obtained in the previous case 2 (see Fig. 3) but now $p''' < \tilde{p}$. Notice that, $[k\frac{1}{4}\bar{\nu}(1-p_t) - k\frac{1}{2}\bar{\nu}(\beta - \frac{1}{2})p_t] > 0$ for all $p < \tilde{p}$, therefore as $p''' < \tilde{p}$ the convergence to p''' follows for any initial condition $p_0 \in (0, p''']$. □

References

Bisin, A., Verdier, T. (1998) On the Cultural Transmission of Preferences for Social Status. *Journal of Public Economics* 70: 75–97

Bisin, A., Verdier, T. (2000) Beyond the melting pot: cultural transmission, marriage, and the evolution of ethnic and religious traits. *Quarterly Journal of Economics* 115(3): 955–988

Bisin, A., Verdier, T. (2001) The economics of cultural transmission and the dynamics of preferences. *Journal of Economic Theory* 97(2): 298–319

Dawid, H., MacLeod, W.B. (2001) Hold up and the Evolution of Bargaining Conventions. Mimeo, The University of Southern California

Ellingsen, T., Robles, J. (2002) Does evolution solve the hold-up problem? *Games and Economic Behavior* 39(1): 28–53

Fehr, E., Schmidt, K.M. (1999) A Theory of Fairness, Competition, and Cooperation. *Quarterly Journal of Economics* 114: 817–868

Hauk, E., Saez, M. (2002) On the Cultural Transmission of Corruption. *Journal of Economic Theory* 107(2): 311–335

Olcina, G., Peñarrubia, C. (2002) Specific investments and coordination failures. *Economics Bulletin* 3(2): 1–7

Olcina, G., Peñarrubia, C. (2004) Hold up and Intergenerational Transmission of Preferences. *Journal of Economic Behavior and Organization* 54: 111–132

Tirole, J. (1996) A Theory of Collective Reputations (with applications to the persistence of corruption and to firm quality). *Review of Economic Studies* 63: 1–22

Tröger, T. (2002) Why Sunk Costs Matter for Bargaining Outcomes: An Evolutionary Approach. Journal of Economic Theory 102(2): 375–402

Williamson, O. (1985) The Economic Institutions of Capitalism. New York: Free Press