Cultural transmission as complementarity-building investment

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Abstract

We model cultural transmission as an altruistic investment in another individual's capacity to benefit from synergies between the "transmitter's" and the "receiver's" efforts. Contrary to most models in the literature on altruism, we assume that "culture-transmitting" agents have no direct utility from their giving behavior, ruling out any genuily altruistic component in their utility function stemming from "other-regarding" preferences. Furthermore, we also rule out reputational effects yielding incentives for a more pro-social action in the present in order to favor Pareto superior outcomes in the future. In the general case, isolated consumption of one's own benefits from own efforts is the worst equilibrium ("bad" equilibrium), which unfortunately for the society is globally stable and is shown to exist in all cases. On the contrary extreme there may be an alternative equilibrium in which all agents invest all they can to cultural transmission. This equilibrium ("good" equilibrium), when it exists, is also stable and Pareto dominates the aforementioned "bad", no transmission equilibrium. An intermediate equilibrium which is unstable involves potentially asymmetric and "unfair" configurations in which the agent who invests more in cultural transmission ends up with lower utility. Among other extensions discussed, coordination against the Pareto inferior equilibria can be implemented by sequential play, which is especially relevant in an inter-generational context of cultural transmission.

Keywords: Cultural Transmission, Altruism, Fairness, Strategic Complementarities, Subgame Perfection.

1 Preliminary thoughts

It is increasingly remembered nowadays that Adam Smith in his Theory of Moral Sentiments (1759) had explicitly referred to the pleasure of contemplating others' happiness. This fact alone can explain altruistic behavior. The formalization of this type of altruism has lead to approaches which, the more they comply with the axioms of neoclassical economics, the more they tend to reduce altruism down to the standard story of selfish (own) utility maximization. This is due to the fact that the existing neoclassical approaches to altruism need some (positive) other-regarding components in an individual's utility function to explain why my own actions may benefit the society surrounding me.

Even if we take a person's genuine altruistic motivation as a fact, it is not easy to explain why so much effort is put in cultural transmission from parents to their children, from older to young generations, from the society to "newcomers" like immigrants and students from abroad. On the other hand, some societies are more willing to sacrifice substantial resources in cultural transmission than others. Of course, some conservative attitudes aimed at irrationally preserving the local culture from external inputs and drastic changes could help us explain cultural transmission as an irrational adherence to what "has been there since centuries ago". But modern and progressive cultural messages are also transmitted even in the most advanced societies, in which case a rational approach would be necessary. In this paper, we suggest that cultural transmission is a form of strategic investment by the "transmitter" to the "receiver" in order for the latter to improve her capacity to benefit from synergies emerging due to both agents' efforts. In other words, we envisage cultural transmission as a way of improving the "receiver's" ability to understand, communicate, improve, appreciate and finally directly benefit from the interaction with the "sender", rendering their mutual efforts synergic, in order for a higher effort to be made by each one. We also identify an alternative equilibrium in which no cultural transmission takes place. In that case, individuals enjoy the benefits from their efforts in isolation, choosing lower effort levels and yielding lower levels of social welfare.

Certainly close to the selfish approach to altruistic behavior, our framework does not include any other-regarding component in an agent's utility function, nor does it depend on the repetition of human interactions. The resulting behavior looks more like reciprocity of the type "I transmit you something, in order to increase your effort in a task which is synergic to my actions", with the novel features that the magnitude of strategic complementarity is endogenously determined by agents' actions. Apart from showing the possibility of obtaining such reciprocally altruistic equilibria, we offer a rationale of why altruistic actions are easier to observe when agents act sequentially. This finding is especially relevant in a context of intergenerational transmission of culture, given that parents, teachers, artists, intellectuals, etc. always play a leader's role when acting as "senders" of cultural transmission messages.

2 A model of "altruistic" complementarity-building investments

Two players, $i \in \{1, 2\}$ decide on the level of their effort x_i, which yields them a linear benefit and a quadratic cost. Apart from these effects of effort on own utility, the two players' efforts may interact positively to yield a further benefit to each one of them. However, each player's capacity to benefit from the interaction of efforts depends on the other's fully altruistic decision to undertake a costly investment in the former's synergy-absorbing capacity. This investment is altruistic in the sense that it is costly and has no direct positive effect on the *altruist*'s utility. This is captured by a utility function like the one given by:

$$U_i = x_i + \frac{\beta_j}{1+\beta_j} x_i x_j - \frac{1}{2} x_i^2 - C(\beta_i), \tag{1}$$

where β_i is firm i's investment in j's capacity to benefit from synergies arising due to the two agents' efforts x_i,$x_j \in \Re_+$ and $C(\cdot) \geq 0$ is the investment cost function (the same for both firms), with $C'(\cdot) \geq 0$ and $C''(\cdot) \geq 0$.

It should be noted that the player's investment in the other's synergy-absorbing capacity has solely a negative direct impact on own utility, and a potentially (if efforts are both higher than 0) positive impact on the other's utility. The specification of effort synergies in (1) is similar to the way in which spill-overs are usually modeled in IO models of R&D competition. There, several results show that firms may wish to share with other their technological advances[1], but none of the models has gone as far as to assume that a firm may want to undertake costly actions to increase the other's capacity to absorb the synergies arising from their R&D efforts. Despite the obvious analogies, the literature on spill-overs between firms has not been sufficiently exploited to provide explanations for reciprocal behavior between individuals or social groups. Strangely, Vives' (1990, 2005, 2006) work on strategic complementarities has also remained unexploited by theorists of strategic interaction between humans. In fact, Vives (2006) explicitly refers to the way in which multistage interaction may affect equilibria in the presence of strategic complementarities.[2]

The two players play a two stage game once. In the first stage, players decide simultaneously on their *gift*-investment in each other's synergy-absorbing capacity. In the second stage, they simultaneously decide on their effort levels.

Following backward induction, we first discuss the unique Nash equilibrium of the second stage.

[1] For example, Gil-Moltó et al. (2005) show that firms may deliberately choose to increase their technological similarities in order to increase their mutual benefits from synergies arising from their R&D efforts. More recently, Milliou (2006), in an endogenous spill-over duopoly model, shows that firms would make no costly investment to protect their innovations, which is a minimum requirement for the main result presented here to hold.

[2] In this sense, our model may be seen as a special case of Vives' (2006) framework, although, from a technical point of view some of our assumptions contradict those in Vives (2005). Also, we are more interested in equilibria which are different from the obvious candidate of non investment in others' complementarity-absorbing capacity.

Setting the derivative of (1) with respect to the effort level x_i equal to zero, we obtain the first order conditions:

$$\frac{\partial U_i}{\partial x_i} = 0 \Rightarrow x_i = 1 + \frac{\beta_j}{1+\beta_j} x_j \tag{2}$$

It should be observed that the slope of i's effort-reaction function in (2) positively depends (approaching unity asymptotically from below) on j's altruistic investment in the former's capacity to absorb the synergies from the interaction of efforts. Thus, player i's reaction to j's effort will positively depend on j's investment in the former's synergy-absorbing capacity. Our main result in this paper crucially depends on this property of interaction in the effort-choice stage of the game. It is also worth noting that efforts are strategic complements only for strictly positive values of β. In the absence of effort synergies, strategic interaction in effort levels disappears, yielding effort levels of 1 and equilibrium utilities of 1/2.

Solving the system of reaction functions in (2) with respect to x_i, x_j gives equilibrium effort levels:

$$x_i^*(\beta_i, \beta_j) = \frac{(1+2\beta_j)(1+\beta_i)}{1+\beta_i+\beta_j}, \tag{3}$$

which, when substituted into (1), after some nontrivial but standard re-arrangements, give:

$$U_i^*(\beta_i, \beta_j) = \frac{(1+2\beta_j)^2(1+\beta_i)^2}{2(1+\beta_i+\beta_j)^2} - C(\beta_i), \tag{4}$$

We use this expression to solve the first stage of the game.

Differentiating (4) with respect to β_i gives:

$$\frac{\partial U_i^*(\beta_i, \beta_j)}{\partial \beta_i} = \frac{\beta_j(1+2\beta_j)^2(1+\beta_i)}{(1+\beta_i+\beta_j)^3} - \frac{\partial C(\beta_i)}{\partial \beta_i} \tag{5}$$

Further differentiating the first term of the right hand side expression of (5), we obtain that the equilibrium utility net of altruistic costs is neither convex nor concave as implied by:

$$\frac{\partial\left(\frac{\beta_j(1+2\beta_j)^2(1+\beta_i)}{(1+\beta_i+\beta_j)^2}\right)}{\partial \beta_i} = \frac{\beta_j(1+2\beta_j)^2(\beta_j-2-2\beta_i)}{(1+\beta_i+\beta_j)^4} \geq 0. \tag{6}$$

Thus, having assumed that $C(\cdot)$ is convex, we can see that, generally speaking, the equation:

$$\frac{\beta_j(1+2\beta_j)^2(1+\beta_i)}{(1+\beta_i+\beta_j)^3} = \frac{\partial C}{\partial \beta_i} \tag{7}$$

may not lead to an interior equilibrium in the first stage of the game. We illustrate here the existence of such equilibria and explore their properties adopting the following specification:

$$C(\beta_i) = \frac{1}{2}k_i((1+\beta_i)^2 - 1). \tag{8}$$

Then, equation (7) is rewritten as:

$$\frac{\beta_j(1+2\beta_j)^2(1+\beta_i)}{(1+\beta_i+\beta_j)^3} = k_i(1+\beta_i) \tag{9}$$

or, simplifying:

$$\frac{\beta_j(1+2\beta_j)^2}{(1+\beta_i+\beta_j)^3} = k_i \tag{10}$$

Now, it is easy to derive a unique best response function in altruistic investments on the positive reals, using Descartes' sign rule of a polynomial.

$$\beta_i(\beta_j) = \max\{0, \sqrt[3]{\frac{(1+2\beta_j)^2\beta_j}{k_i}} - \beta_j - 1\} \tag{11}$$

This corresponds to a maximum since $\beta < \beta_i(\beta j)$ implies that:

$$\frac{\partial U_i^*(\beta, \beta_j)}{\partial \beta_i} > 0 \tag{12}$$

and $\beta > \beta_i(\beta_j)$ implies

$$\frac{\partial U_i^*(\beta, \beta_j)}{\partial \beta_i} < 0 \tag{13}$$

Now we study the properties of the best response functions which are graphically represented together with the resulting equilibrium in Figure 6. First, it is easy to show that it is an increasing function of β_j if $k_i \leq 4$ and it is a concave function with independence of the values of k_i (after some computation on the derivatives).

We also derive two interesting values for β_j.

1) If $k_i \leq 4$ then there is a $\underline{\beta_j}$ such that $\beta_i(\underline{\beta_j}) = 0$ and $\beta > \underline{\beta_j}$ implies $\beta_i(\beta) > 0$.

2) If $k_i \geq 1/2$ then $\beta_i(\beta)$ is a function that does not cross the diagonal, otherwise $k_i < 1/2$ implies that $\widehat{\beta} = \frac{k_i}{1-2k_i}$ is the point where the function $\beta_i(\beta)$ crosses the diagonal.

Finally if there is a bound $\overline{\beta} > \widehat{\beta} = \frac{k_i}{1-2k_i}$ on the possible β and $k_i < 1/2$ there is $\overline{\beta_j} \leq \overline{\beta}$ such that $\beta_i(\overline{\beta_j}) = \overline{\beta}$.

Similarly, the best response of agent j satisfies the same properties since the agents are equal except for the gift-production technology expressed in j's gift-cost parameter k_j.

The first result we could derive is that the *bad* equilibrium always exists with independence of the values of k.

Result 1: Existence of a Bad equilibrium $(\beta_i^*, \beta_j^*) = (0, 0)$**.**

Proof: If firm j sets $\beta_j = 0$, the right hand side of (7) is always larger than the left hand side. Thus, firm i's best response will also be $\beta_i = 0$. By symmetry, this implies that this is always an equilibrium.□

Now, depending on the values of k_i we could also find an interior equilibrium and other extreme equilibria. Before exploring the properties of these equilibria, we summarize the conditions under which they may emerge.

CASE 1: If $k_i \geq 1/2$ for all $i = 1, 2$ then no other equilibrium than the *bad* one described above exists since none of the best responses cross the diagonal.

This case is depicted in Figures 1 and 2, which show that such a situation may emerge either in a symmetric or an asymmetric setting. A straightforward proof is also available from the authors of the fact that, when unique, this equilibrium is also globally stable.

CASE 2: If there is a $k_i > 1/2$ and $k_j < 1/2$ then we could find asymmetric situations in which either interior and extreme equilibria coexist, or only the aforementioned bad equilibrium exists. The former of these situations is depicted in Figure 3, while an example of the latter has already been mentioned in Figure 2.

CASE 3: If $k_i \leq 1/2$ for all $i = 1, 2$ then we surely find three equilibria, the *bad* one, an *interior* one and the *good* one, which implies full reciprocity. Figures 4 and 5 present examples of a symmetric and an asymmetric situation in which such equilibria emerge. A proof is available form the authors that, in the case in which good and bad equilibria coexist, they are both locally stable. On the contrary, interior equilibria are, unstable.

Now we characterize the interior and good equilibria of the game.

Result 2: Existence of an Interior equilibrium (β_i^*, β_j^*)**.**

Proof: Given $k_i \leq 1/2$ for all $i = 1, 2$, we know that $\beta(\overline{\beta}) > \overline{\beta}$ and the interior equilibrium is the solution to the following system of equations:

$$\beta_1(\beta_2) = \max\{0, \sqrt[3]{\frac{(1+2\beta_2)^2\beta_2}{k_1}} - \beta_2 - 1\} \tag{14}$$

$$\beta_2(\beta_1) = \max\{0, \sqrt[3]{\frac{(1+2\beta_1)^2\beta_1}{k_2}} - \beta_1 - 1\} \tag{15}$$

Define the following function: $S(\beta) = \beta - \sqrt[3]{\frac{(1+2\beta')^2\beta'}{k_1}} + \beta' + 1$ with $\beta' = \sqrt[3]{\frac{(1+2\beta)^2\beta}{k_2}} - \beta - 1$. $S(0) = \sqrt[3]{\frac{1}{k_1}}$ and $S(\overline{\beta}) < 0$ since β' is increasing in β and $\beta'(\overline{\beta}) > \overline{\beta}$. Then, by continuity there exists a β^* such that $S(\beta^*) = 0$ and $\beta_1^* = \beta^*$ and $\beta_2^* = \beta_2(\beta_1^*)$ □

Result 3: Existence of a Good equilibrium $(\beta_i^*, \beta_j^*) = (\overline{\beta}, \overline{\beta})$**.**

Proof: If there is a bound on the maximal investment $\overline{\beta}$ for each agent, the good equilibrium is characterized by agents investing their full capacity.□

The three aforementioned equilibria can be easily ranked using the Pareto criterion.

It is also interesting to show that if agents differ in their efficiencies to increase each other's synergy-absorbing capacities ($k_i \neq k_j$), asymmetric equilibria arise. For example, if $k_1 = 0.16$ and $k_2 = 0.13$, the resulting interior equilibrium is given by: $(\beta_1^*, \beta_2^*) = (1, 1.1)$. In such an equilibrium, the *efficient* agent invests more in the *inefficient* one's absorptive capacity than does the latter in favor of the former. This leads the efficient agent to enjoy lower levels of utility than does the inefficient one $(1.8858, 1.83)$. Therefore, the interior equilibria obtained here are *unfair*, in the sense that efficient and, thus, generous agents enjoy less utility than their inefficient counterparts.

In a more general model in which fairness considerations are relevant, the fact that interior equilibria are, generally speaking, unfair makes them more difficult to emerge and more vulnerable to opportunistic, non-altruistic behavior. The difficulty of such unfair equilibria to emerge is further enhanced by the fact that they are unstable. An interesting, straightforward and realistic way of implementing the good equilibrium is by sequential play. We show the following result:

Result 4: Sequential play implements the Good equilibrium.
Proof:

We will show that, given $k_i \leq 1/2$ for all $i = 1, 2$ and the best response function of agent 2, the best choice for agent 1 is to choose $\beta_1 = \overline{\beta}$. Furthermore the equilibrium attained is the good one.

Let $U_i^*(\beta_i, \beta_j)$ be the utility attained by agent i with generic β_i, β_j, which is strictly increasing in β_j. Then for any β_i, $U_i^*(\beta_i, \beta_j) \leq U_i^*(\beta_i, \overline{\beta})$ and since the best response of agent i, $\beta_i(\overline{\beta}) = \overline{\beta}$. Finally we conclude that $\max_{\beta_i, \beta_j \in [0, \overline{\beta}]} U_i^*(\beta_i, \beta_j) = U_i^*(\overline{\beta}, \overline{\beta})$.

The equilibrium in the sequential play is given by $\max_{\beta_i \in [0, \overline{\beta}]} U_i^*(\beta_i, \beta_j(\beta_i))$. But the utility attained in this way is always lower than $\max_{\beta_i, \beta_j \in [0, \overline{\beta}]} U_i^*(\beta_i, \beta_j) = U_i^*(\overline{\beta}, \overline{\beta})$. And we know that $\beta_i = \overline{\beta}$ attains this utility. Then we conclude that there may be more than one equilibrium in the sequential play but at least the "fully reciprocal" equilibrium always exists. □

3 Experimental Design

We have 3 treatments, with a between-subject design.

Independent of the treatment, there are three game always played in the following order.

Game 1: risk elicitation game (Holt and Laury) is proposed *once*.

Game 2: other regarding preferences elicitation game is proposed *once*.

Game 3: complementarity-building investment game is proposed *repeatedly*.

Only one over the 25 periods is randomly chosen for payment in phase 3.
Total gains from the experiment are the sum of the gains in the three games.

Phase 3.
The game is repeated for 25 periods according to a stranger-matching design.
The 25 periods are divided in 5 sequences of 5 periods each.
At the beginning of each sequence, each subject chooses his/her own β_i, that is kept constant for the next 5 periods in the sequence.
In each of the five periods of the sequence, he/she is randomly paired with a different subject (with a different β_j chosen at the beginning of the sequence).
In each of the five periods of the sequence, after β_i and β_j are made public information in a pair, x_i and x_j are chosen and uniperiodal profits are revealed within the pair.

Complementarity-building investment game
For each player, the function to maximize is the following:

$$U_i = 10\left(x_i + \frac{\beta_j}{1+\beta_j}x_i x_j - \frac{1}{2}x_i^2 - \frac{1}{2}k_i((1+\beta_i)^2 - 1)\right), \tag{16}$$

with $\beta_i, \beta_j \in [0,2]$ chosen first and $x_i, x_j \in [0,3]$ chosen after with 0.10 grids for both complementary-building investments and efforts.

The only treatment variable is the value we assign to $k_i = k_j$:

- Treatment High-cost, we set $k_i = k_j = 0.6$.
- Treatment Medium-cost, we set $k_i = k_j = 0.4$.
- Treatment Low-cost, we set $k_i = k_j = 0.2$.

Equilibrium predictions:

Equilibrium values	β^*	x^*	U^*
Treatment H	0.00	1.00	5.0
Treatment M	2.00	3.00	29.0
Treatment L	0.33	1.33	9.5

4 Concluding remarks and Extensions

Reciprocity may arise in the absence of any reputation effects or cooperation due to repeated play. In this paper, we show how strategically reciprocal behavior may emerge from a rational individual's interest to increase another's capacity to benefit from his own actions.

We have shown this in a two-person world in which agents' benefits from own effort are enhanced by the effort of the other player. In this context, an agent will altruistically incur a cost, without directly benefitting from it, in order to help the other to benefit from synergies arising due to both agents' efforts. This result is due to the strategic effect arising from such an altruistic behavior, leading to an increase of the two players' interdependence in the effort-choice stage of the game.

Apart from the sequential-move extension discussed above, it would be interesting to investigate whether explicit cooperation in the stage of effort choice (like in organized collective activities) facilitates the emergence of the reciprocal equilibrium and whether increasing the group size affects the reciprocal equilibrium described here. Our conjecture is that, if effort synergies enter into an agent's utility as the sum of bilateral interaction terms, agents may (under specific conditions) prefer to specialize in two-person reciprocal relations, whereas if multilateral synergies appear in an agent's utility as the product of many agents' efforts, global (social) reciprocal equilibria are more likely to emerge. In fact, introducing an assumption of decreasing returns to synergy-developing group size could intuitively help us define an optimal group size within which cultural transmission takes place.

To summarize, our results predict that if human interaction is the result of situations like the ones described here, three types of outcomes should be expected. The good one, in which everyone does everything possible for others to benefit from his own effort, extracting everybody's maximal effort and yielding maximal utility to all. The bad one, in which nobody invests in cultural transmission, extracting minimal, individually optimal effort levels and a positive but minimal equilibrium utility resulting from isolated human action. The unfair ones in which efficient agents contribute more and receive less than inefficient ones, yielding effort levels and utilities lying between the two aforementioned equilibria.

Surprisingly, in many real world situations people find it hard to reach the good equilibrium. So far, this has been explained as a consequence of people's lack of altruism or, alternatively, as dynamic instability of the cooperative outcome in situations of repeated interaction. In our framework, failure to reach the good equilibrium can only be due to lack of synergies arising from interacting agents' efforts. Certainly, a more plausible explanation could be that agents often fail to recognize the benefits from actions which benefit others, if such actions do not have a direct positive impact on their own utility. Then, it would be due to strategic myopia and not to lack of altruism that good equilibria may not be reached as often as they should. Fortunately, some cultures seem to realize the benefits from altruistic transmission of aptitudes and habits, thus rendering culture a healthy self-sustained organism.

Appendix: Figures

Figure 1

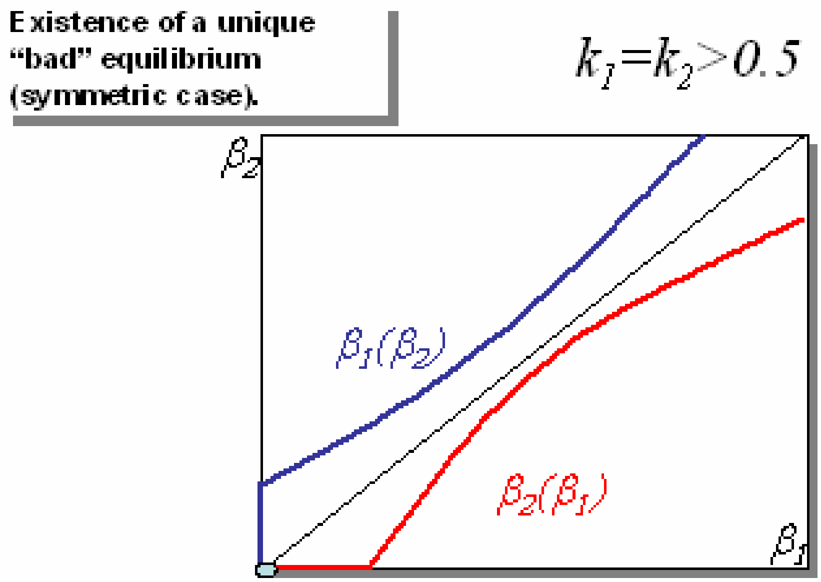


Figure 2

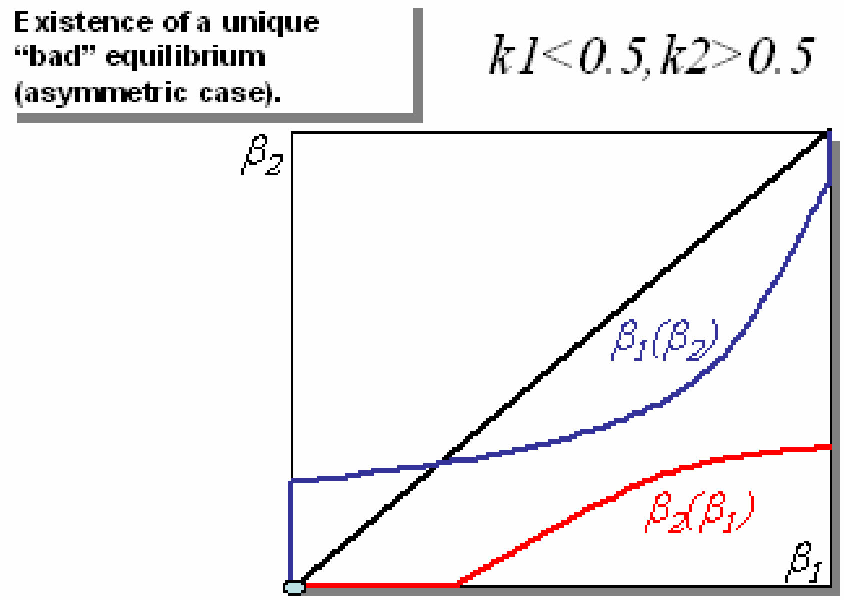
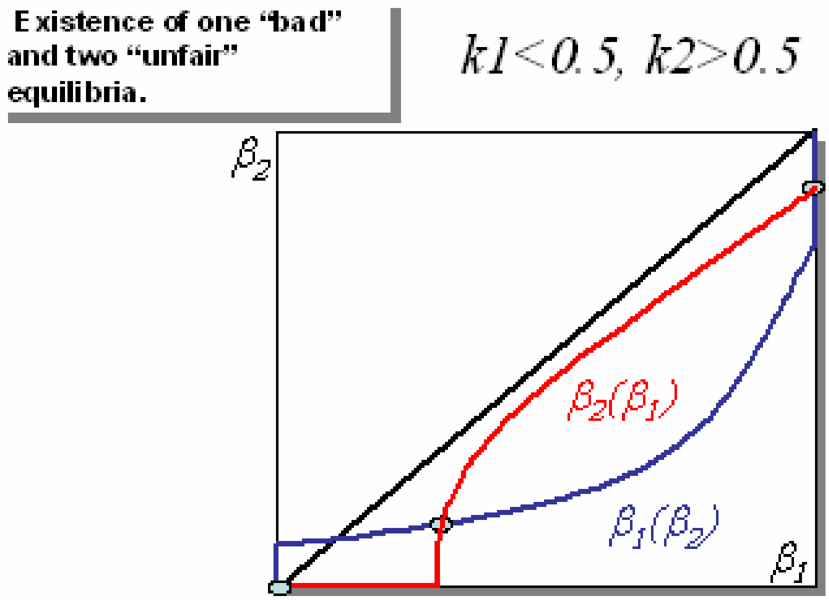
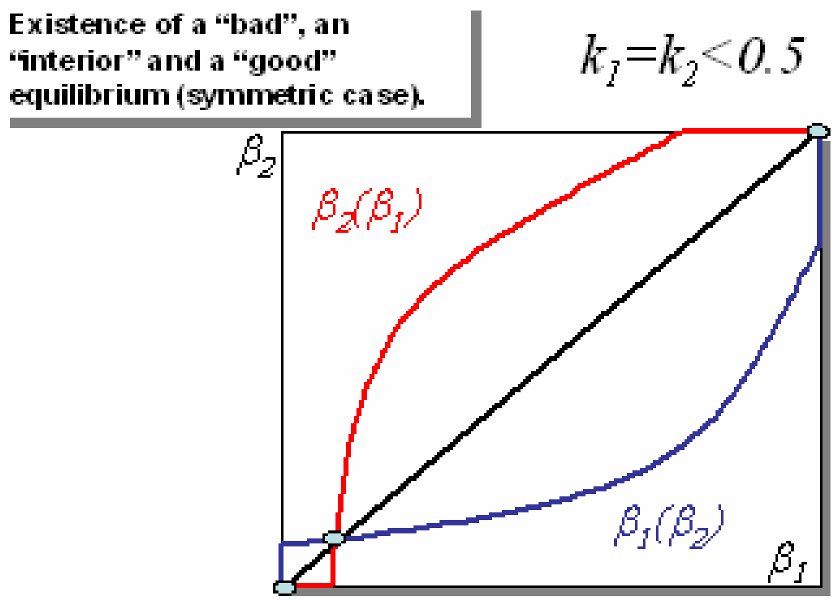

Existence of a unique
"bad" equilibrium
(asymmetric case).
k1<0.5,k2>0.5
β_2
$\beta_1(\beta_2)$
$\beta_2(\beta_1)$
β_1

Figure 3



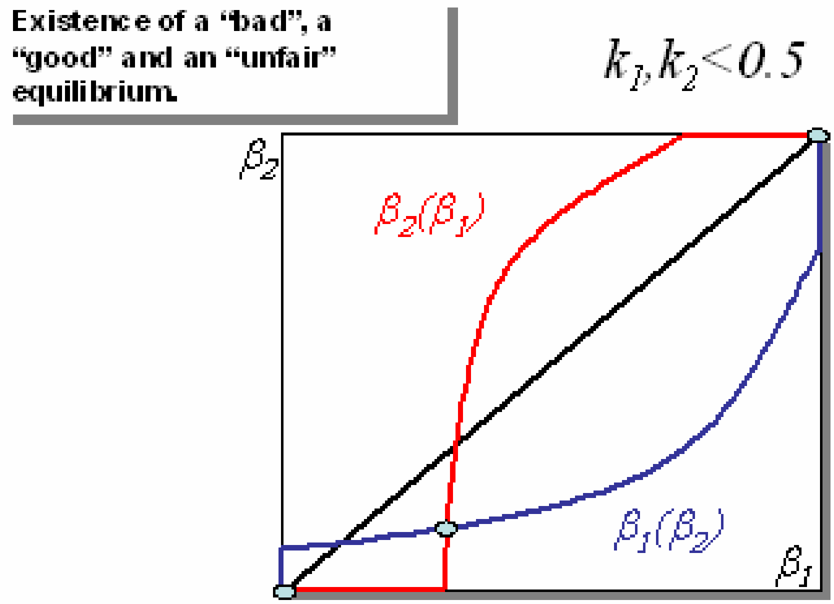
Existence of one "bad" and two "unfair" equilibria.
k1<0.5, k2>0.5
β_2
$\beta_2(\beta_1)$
$\beta_1(\beta_2)$
β_1

Figure 4



Existence of a "bad", an "interior" and a "good" equilibrium (symmetric case).
$k_1=k_2<0.5$
β_2
$\beta_2(\beta_1)$
$\beta_1(\beta_2)$
β_1

Figure 5



Existence of a "bad", a "good" and an "unfair" equilibrium.
$k_1, k_2 < 0.5$
β_2
$\beta_2(\beta_1)$
$\beta_1(\beta_2)$
β_1

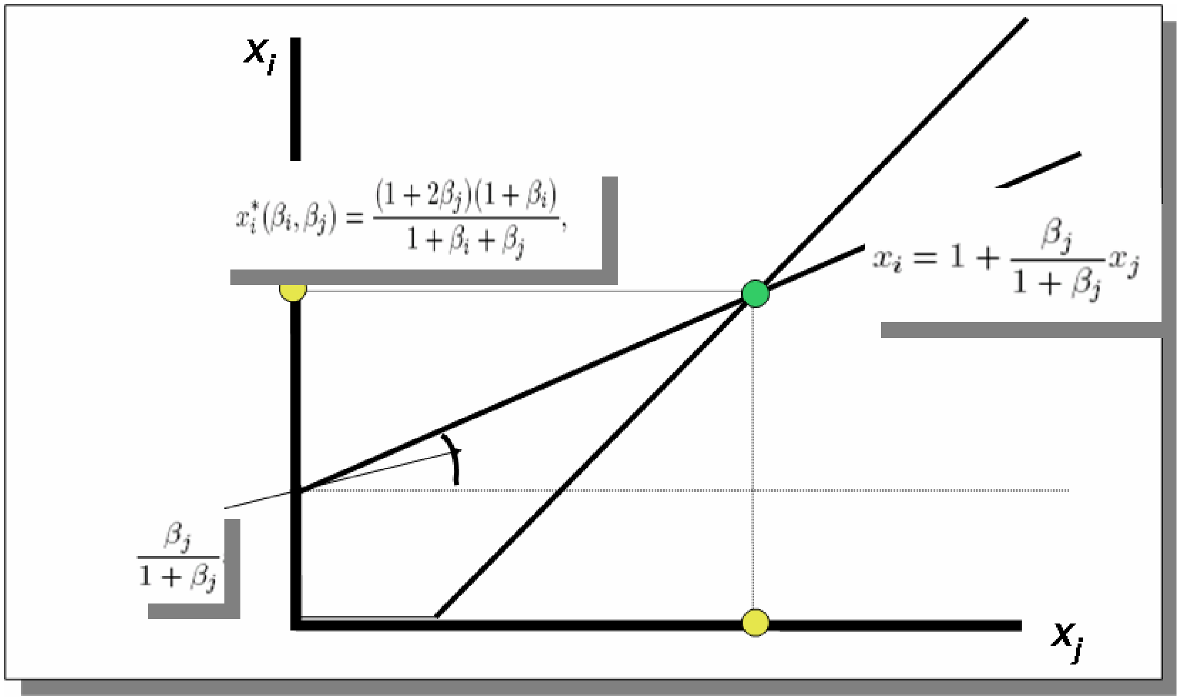


Figure 6: Best response functions and equilibrium in the effort choice stage.

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