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# Social relations and cooperation in organizations

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**Abstract**

This paper addresses the effects of social relations on cooperation (or collusion) in organizations (or communities). Social and production relations are modeled as separate repeated strategic interactions. ''Linking'' them – by employing members of the same community or encouraging social interaction between employees – facilitates cooperation in production: (a) because of available ''social capital,'' the slack of enforcement power present in social relations which may discipline behavior in the workplace; (b) because payoffs from the two relations are substitutes, therefore the linkage endogenously generates social capital; (c) because the linkage generates transfers of ''trust''; and (d) it discloses information about agents' situation. 

*Keywords*: Cooperation; Teams; Social capital; Peer pressure; Peer monitoring; Trust; Reputation spillovers; X-efficiency; Embeddedness; Norms; Community enforcement; Prisoner's Dilemma

*JEL classification*: D20; J50; L23; M12; O17; Q20

> In order to produce, [workers] enter into definite connections and relations with one another and only within these social connections and relations does... production take place. (Karl Marx: *Wage Labour and Capital*) (Marx, 1971)

> Cooperating in this [Prisoner's Dilemma] situation then may get grouped with other activities of cooperation [...]. Hence, non cooperating in this particular Prisoner's Dilemma situation may come to threaten a person's cooperating in those other situations – the line between them may not be so salient [...]. (Robert Nozick: *The Nature of Rationality*) (Nozick, 1993).

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## 1. Introduction

Many organizations, particularly large Japanese firms, offer costly organized leisure time activities to their employees and their families (holiday trips, sport facilities, etc.). This induces employees to interact 'socially,' which seems to encourage commitment to the organization and cooperation in the workplace.

The Grameen Bank – an extremely successful group-lending programme in Bangladesh – requires members of the five-person borrowing teams to be from the same village. Members of the same community are linked by 'social relations,' and this seems to improve on their ability to curbfree riding and sustain cooperation within groups.[1]

Recent work in political science and economics attributes the spread of institutional/organizational efficiency, growth rates, and per capita income between Italian regions to differences in 'social capital,' defined as the additional rule-enforcing power available to communities with an extended network of horizontal social relations (Putnam, 1993, and Helliwell and Putnam, 1995; see also Banfield, 1958).

The idea that cooperative social relations facilitate cooperation in the workplace is well established. However, to our knowledge a satisfactory and rigorous theoretical explanation for why it should be so is still missing.[2] Sociologists as Granovetter (1985) and Baron (1988) have criticized modern economics as blind with respect to the important role played by the network of social relations in which economic transactions are 'embedded.' This criticism bites more when referred to long-term transactions such as employment. Indeed, economists interested in the labor market felt earlier the need to deal with similar issues (e.g. Akerlof, 1984; Lindbeck and Snower, 1988; Solow, 1980, 1990).

In this paper we develop a theory of the influence of social relations on agents' ability to cooperate in the workplace based on 'linkages' between social and production relations. The long-term production relation between members of a team in an organization is modeled as a repeated 'production' Prisoner's Dilemma because of each member's scope for 'cheating' on the others (e.g. Holmstrom, 1982). The central idea of the paper is that long-term social relations between team members are also repeated strategic interactions, which tend to become 'linked' to the production strategic interaction. Our approach, therefore, is analogous to that of the literature on collusion with multimarket contact (e.g. Bernheim and Whinston, 1990; Spagnolo, 1996).

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[1] Members of the Grameen Bank programme are even required to participate in a certain number of 'social' activities, such as joint gymnastic sessions and after-work discussions (similar to 'quality circles'). In credit-for-the-poor programmes social relations are often said to work as a 'social collateral.' For more detailed discussions of the organizational structure of the Grameen Bank's group-lending programme see Besley and Coate (1995); Spagnolo (1995a), or Armendariz de Aghion (1996). It is worth noting here that the strong analogies between the design of modern group-lending programmes (inspired by the Grameen Bank) and the internal organization of large Japanese firms have been largely overlooked in the literatures on both subjects.

[2] Of course, one explanation is that cooperation tends to be 'habit-forming' in the sense that a history of cooperation shapes agents' beliefs and determines 'focal points' (Schelling, 1960). However, this cannot explain why many firms invest valuable resources in order to generate further social relations among employees who already share the same culture and focal points.

The word ‘social’ may have many different meanings. Here we take an agnostic position by defining social relations in opposition to production ones: we denote ‘social’ any activity which agents carry on together which is not strictly related to their work as employees of the organization. We may think of activities as different as helping each other with child care and/or non-market insurance, contributing to the same sport club, organizing and spending holidays together, exchanging invitations for dinner, and so on.

We begin by providing a micro-foundation to Putnam’s (1993) interpretation of the concept of ‘*social capital*’: the ability of a group of agents (a community) linked by horizontal social relations to discipline individual behavior. Here we define social capital as *the slack of enforcing power present in the social relation*, the amount of credible social punishment power available as a threat in excess of that required to maintain cooperation in the social interaction.

Under the standard assumption that agents’ objective functions are linearly separable in the payoffs from the two relations, ‘linking’ these relations – by employing agents from the same social network, or by creating opportunities for employees to interact socially – may either facilitate cooperation in production, or leave employees’ ability to cooperate unchanged, as in Bernheim and Whinston (1990). When members of a production team share social relations, the available social capital can be transferred and profitably ‘invested’ to enforce cooperation in production. If social capital is not sufficient to offset incentives to shirk in the production relation, the linkage will leave agents’ behavior unaffected. Instead, when the linkage is ‘strict’ – in the sense that agents are unable to sustain cooperation in one relation while defecting in the other – the linkage can destroy cooperation in all relations if social capital is too small.

If we relax following Spagnolo (1996), the assumption of linearly separable utilities and let payoffs from social and production relations be substitutes for agents,[3] linking two relations always facilitates cooperation (in both relations), whether or not there is available social capital before the linkage. Furthermore, now the linkage may make cooperation supportable in *all* relations even when cooperation could not be supported in *any* of them otherwise. This is so because when payoffs from the two relations are substitutes, the threat of interrupting cooperation in both relations is relatively stronger, while short-run gains from cheating simultaneously in the two relations are relatively less valuable.

We then consider how linking production to cooperative social relations may lead to ‘transfers of trust’ that facilitate cooperation in the organization.[4] We show that transfers of trust from social to production relations are always in the interest of the organization, but they may not be in the ex ante interest of the agents: these may find the linkage ‘too risky,’ as the transfer tends to reduce trust and undermine cooperation in the social relation.

Finally, we consider the case in which agents can only observe the history of social interactions between other agents from the same community (village). In this case

[3] If an agent is doing well (badly) in production, he will be wealthy (poor), and therefore able (unable) to buy substitutes for non-market insurance, child care, and the other typical ‘products’ of social relations.

[4] Scott (1993) argues that these kind of ‘reputation spillovers’ are the major way in which multi-market contact facilitates tacit collusion in oligopolies.

'weakly linking' production to social relations, by requiring employees to come from the same village, is shown to facilitate cooperation in production by revealing to each team member how the others are doing in social relations. When payoffs from social and production relations are substitutes agents' evaluation of gains from cooperating (and from defecting) in production depends on how they are doing in the social relation. If relations are not linked, cooperation in teams may not be feasible because agents with low net gains from cooperation in production may pool with those with high net gains from cooperation. Weakly linking relations allow agents with high net gains from cooperation in production to separate, to match (or be matched) with each other, and to sustain cooperation in the organization.

Of course, employees may cooperate on different issues: to enhance productivity, but also to support strikes, to enforce low work norms, and to enjoy private benefits. Cooperation and collusion are terms which can be used for the same phenomenon by observers with opposite interests, therefore *all our conclusions on social relations and cooperation also apply to agents' ability to collude against the organization*. Clearly, the degree to which cooperative social relations induce 'productive cooperation' instead of 'counter-productive collusion' depends on how incentives shape the teams' objective functions, on how in line these are with the organization's objectives. Here we have taken an optimistic point of view by focusing on 'productive cooperation' only, because we envisage decentralized participatory organizations where cooperation within teams is crucial (group-lending programmes, Japanese firms, partnerships, etc.).[5] Team performance monitoring and group-incentive schemes such as profit-sharing, gains-sharing, and employees' ownership plans can be (and are) used to align teams' objectives to those of the organization. But these instruments leave teams subject to internal free-riding and sometimes (somewhere) they seem to work well, while some other times (somewhere else) they appear not to work at all (e.g. Blinder, 1990; Kruse, 1993; Spagnolo, 1999). Our results suggest that differences in social background, usually ignored when running regressions, may be behind the ambiguous historical performance of group-incentive schemes.

To conclude, we remind the reader that even 'productive' forms of cooperation, those that help organizations to perform better, can be deleterious for other members of the society (as in the case of criminal organizations; see, e.g. Gambetta, 1993). This is why no general welfare implication can be derived from our analysis.

The rest of the paper is organized as follows. In Section 2 we introduce the model. In Section 3 we consider how pre-existing social capital can be used to enforce cooperation in production. In Section 4 we analyze how social capital is endogenously generated by linking relations. Section 5 addresses transfers of trust. Section 6 deals with the revelation of private information. In Section 7 we discuss related literature and a few applications of the model. Proofs are in the appendix, unless stated otherwise.

[5] In a richer model one may wish to analyze the trade-off between gains from cooperation and losses from collusion between employees, as a function of the organizational design. Presumably, features such as a high degree of participation and decentralization, team work, and group-incentive schemes would show complementarities with cooperative social relations between employees. See chapters in Aoki and Dore (1994) for some work in this direction.

## 2. A model of 'linked relations'

We will work with the simplest possible model composed of two-agent teams and bilateral social relations (most of the results, though, can be readily extended to the $n$-agents multilateral relations case). Consider an organization in need of new employees – a firm, a group-lending institution, etc. – and a population of identical agents, potential employees of the organization. Time is discrete. Each agent discounts future with a factor $\delta < 1$ and interacts with an other agent of the population in a long-term social relation which can be represented by a symmetric infinitely repeated Prisoner's Dilemma.[6] Let $S$ denote the one-shot simultaneous social interaction between two representative agents, and $S^{\infty}$ the long-run social relation, the infinitely repeated interaction which has $S$ as its stage-game. In each period agents can choose between two actions relevant to $S$, cooperate ($c$) and defect ($d$), and – abstracting from other relations in which agents may be involved – the one-shot social interaction has the following payoff matrix:

| | | Agent $i$ | |
|---|---|---|---|
| | | $c$ | $d$ |
| Agent $j$ | $c$ | $\sigma^*, \sigma^*$ | $\underline{\sigma}\bar{\sigma}$ |
| | $d$ | $\bar{\sigma}, \underline{\sigma}$ | $0, 0$ |

Static social interaction $S$

with $\bar{\sigma} > \sigma^* > 0 > \underline{\sigma}$ and $\underline{\sigma} + \bar{\sigma} < 2\sigma^*$.

Within the organization, production is structured in two-persons units, or teams. Because of problems of 'moral hazard in teams' in the static production interaction, the long-term social relation can also be represented by a symmetric infinitely repeated Prisoner's Dilemma. Let $P$ denote the one-shot simultaneous production interaction and $P^{\infty}$ denote their long-run production relation generated by the infinite repeatition of $P$. In each period the two agents of a team can choose between two actions relevant to production, work ($w$) and shirk ($s$), and – abstracting from other relations agents' may be involved in – the one-shot production interaction has the following payoff matrix:

| | | Agent $j$ | |
|---|---|---|---|
| | | $w$ | $s$ |
| Agent $i$ | $w$ | $\omega^*, \omega^*$ | $\underline{\omega}, \bar{\omega}$ |
| | $s$ | $\bar{\omega}, \underline{\omega}$ | $0, 0$ |

Static production interaction $P$

with $\bar{\omega} > \omega^* > 0 > \underline{\omega}$ and $\underline{\omega} + \bar{\omega} < 2\omega^*$.

Both for simplicity and because they imply less problems of coordination, we restrict attention to symmetric stationary equilibria supported by Friedman's (1971) unrelenting trigger strategies, so that cooperating agents strategy is ''stick to cooperation (work) as

[6] Games repeated a finite but uncertain number of times would lead to qualitatively identical results: a constant probability of the game ending in each period could easily be incorporated in the discount factor.

long as your opponent does the same, if a deviation occurs defect (shirk) forever after.'' This is not a restrictive assumption because in the repeated Prisoner's Dilemma unrelenting trigger strategies are an 'optimal punishment' that keeps deviating players at their 'security level' (or minimax; see Abreu, 1986).[7] Agents' choice is then between two stationary subgame perfect Nash equilibria for each long run relation: the 'cooperative' one described above and the non cooperative one 'always defect (shirk).'

We assume throughout that the *organization chooses which agents interact in teams, and gains when agents cooperate in production*. This means that conflicts of interests between teams and the organization are solved ex ante, say, by sharing or franchising contracts: agents have no opportunity to collude against the organization. In this framework, any objective function for the organization which delivers a higher payoff when agents cooperate in production would do, so we don't need to specify it.

We introduce now some definitions.

**Definition 1.** *Social and production relations ($S^\infty$ and $P^\infty$) are 'not linked' when agents face a different agent in each relation.*

**Definition 2.** *Social and production relations are 'linked' if the same two agents face each other in both $S^\infty$ and $P^\infty$.*

**Definition 3.** *Social and production relations are 'strictly linked' if the same two agents face each other in both $S^\infty$ and $P^\infty$, and if in equilibrium agents can not choose different actions in the two relations.*

When relations are linked as in Definition 2, agents consider the two relations as a single repeated strategic interaction, though they are free to support cooperation in one relation while defecting in the other.

In some situation this may not be a sensible assumption. Definition 3 suits these cases in which agents are 'emotionally' unable to treat independently the two long-term relations with an other agent, so that they are not able to cooperate in production with someone who does not cooperate in the social relation, and vice versa.

Finally, we assume that the history of a production relation cannot be observed by agents outside the team. In other words, in our model an agent cannot condition strategies in the social relation on the history of a production relations between other agents.[8]

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[7] Other optimal strategies, such as the renegotiation-proof strategies discussed in van Damme (1989) could have been adopted. The qualitative results of our model would not be affected by the use of these more complex strategies or of suboptimal but more realistic punishments strategies such as ''after a deviation is observed, deviate for a finite number $T$ of periods, then re-start cooperation.''

[8] This assumption is also required – although seldom made explicit – in models of multimarket contact and collusion. Without it one could have a large number of agents (or firms) acting 'as a group,' (e.g. punishing in social relations agents who shirked in production relations with different agents). We would end up in a 'community enforcement' framework and there would be no role for the identity of the agents in a team (for work in this direction see, e.g. Kandori, 1992 and Milgrom et al., 1990).

## 3. Social capital and cooperation in teams

In this section and in the next one we abstract from problems of coordination and asymmetric information, which will be discussed in Sections 5 and 6. We assume that all agents have complete information on the history of all social relations, and that agents are able (perhaps with the help of the organization) to coordinate on the Pareto-dominant subgame-perfect Nash equilibrium of the (repeated) strategic interactions they face. The following assumption (to be relaxed in the next section) keeps us within the standard model collusion with multimarket contact (Bernheim and Whinston, 1990).

**Assumption 1.** *Agents maximize a time-separable utility function with an instantaneous utility function additively separable in payoffs from social and production relations.*

Cooperation is sustainable if short-run gains from deviating unilaterally from the cooperative agreement are smaller than the loss of future gains from cooperation caused by such a deviation. Suppose short-run gains from defecting (shirking) in production exceed expected gains from cooperating (working), while the contrary happens in the social relation:

$$\frac{\omega^*}{1-\delta} < \bar{\omega} \qquad \textit{and} \qquad \frac{\sigma^*}{1-\delta} > \bar{\sigma}.$$

When relations are not linked, cooperation may be sustained in the social relation but not in the production one.

Let $K_s$ denote the slack of enforcing power (net gains from cooperation) present in the social relation, where

$$K_s = \frac{\sigma^*}{1-\delta} - \bar{\sigma}.$$

*We name* '**social capital**' *the surplus of enforcing power $K_s$ available to agents from their social relations.*[9]

Let

$$D_p = \bar{\omega} - \frac{\omega^*}{1-\delta}$$

denote the 'demand,' or lack of gains from cooperation present in production.

Consider first the strict form of linkage of Definition 3.

[9] The term 'social capital' has been used by other economists and many sociologists with several different meanings. The late Coleman (1990) used it in a sense similar to that of this paper, but with regard to individual endowments. Here we are using it for the social enforcing power of a (two-agent) community, as in the work of Putnam (1993). We have thought of choosing another definition, not to make things more messy, but 'social capital' fits too well to this situation: the slack of 'social punishment power' present in a community can really be considered an input for the production process, able to generate cooperation, effort in teams, productivity in organizations, and eventually growth.

**Proposition 1.** *Suppose agents cooperate in social relations ($K_s \geq 0$).*[10] *Then: (i) if $K_s \geq D_p > 0$, strictly linking social and production relations are profitable for both the organization and the agents; (ii) if $K_s < D_p$, strictly linking social and production relations leave the organization indifferent but the agents worse off.*

In case (i) by strictly linking relations the organization uses the slack of expected gains from cooperation present in the social relation as a credible threat to enforce cooperation in production (it pools agents' incentive constraints in the two supergames). The strict linkage automatically transfers available social capital to the production relation. In case (ii) the lack of gains from cooperation in production is larger than the available social capital, and cooperation in both relations is not supportable. In this case the strict linkage makes cooperation impossible in both relations; the start of a production relation with low gains from cooperation destroys preexisting cooperation in the social relation.

Definition 3 might fit better small and/or 'ethically oriented' organizations, such as partnerships or cooperatives, in which agents interact directly in smaller groups and are more interdependent.[11]

Consider instead simple linkages, as in Definition 2. When the relations are linked, agents are free to choose to cooperate (work) in one relation even though they are defecting (shirking) in the other, so the static-linked interaction would have a $4 \times 4$ payoff matrix in which all combinations between actions $c$, $d$, $w$, and $s$ are available to agents. This case is fully analogous to the standard model of collusion with multimarket contact, and we can state without proof.

**Proposition 2.** *Linking social and production relations is weakly welfare improving.*

Neither agents nor the organization can ever lose from linking the relations. The point is still that linking relations pools agents incentives constraints in the two relations allowing to transfer slack enforcing power from one relation to the other. However, in this case, when the slack of enforcing power in the social relation, social capital, is not large enough to complement the lack of gains from cooperation in production, agents can go on cooperating in the social relation only, and therefore can lose nothing from the linkage.

## 4. Endogenous social capital

In this and in the next section we will focus on linked relations. This is because the model with linked relations is more general than with strictly linked relations, and all results derived under Definition 2 either directly apply to Definition 3, or can be easily modified to incorporate that case.

The gains from linking relations discussed in the previous section derive from the possibility to 'invest profitably' available social capital; an organization might want to

[10] This is the interesting case, as the organization gains from linking relations. It is straightforward to show that when $K_s < 0$ the organization cannot gain by strictly linking relations: when $D_p \leq K_s < 0$, agents gain from the linkage while the organization is indifferent; when $K_s < D_p < 0$ agents are indifferent and the organization loses.

[11] We are often recommended not to enter in business relations with friends in order not to spoil the friendship with the problems which may emerge in the business (or vice versa?).

employ agents from the same social network because these may have enough social capital to sustain cooperation in production teams.

Here we will show that even when before the linkage there is no available social capital, an organization may still find it convenient to 'link relations' by choosing agents who share social relations for its teams.

We relax the assumption of preferences linearly separable in the payoffs from the two relations. Following Spagnolo (1996), we keep distinct the 'material payoffs' from the two relations and agent's evaluation of such payoffs. This allows to take into account the possible interdependence between the two relations induced by wealth effects.

We substitute Assumption 1 with the following

**Assumption 2.** *Agents maximize a time-separable utility function with a twice differentiable instantaneous utility function U(.) monotone increasing and concave in payoffs from each relation. Further, payoffs from social and production relations are (perfect or imperfect) substitutes.*[12]

If we let $\sigma^{\tau}$ and $\omega^{\tau}$ respectively denote an agent's payoff from the social and production static interactions in period $\tau$, where $\sigma^{\tau} \in \{\underline{\sigma}, 0, \sigma^*, \bar{\sigma}\}$ and $\omega^{\tau} \in \{\underline{\omega}, 0, \omega^*, \bar{\omega}\}$, Assumption 2 implies that each period $t$ agents maximize $\sum_{\tau=t}^{\infty} \delta^{\tau-t} U(\sigma^{\tau}, \omega^{\tau})$, where $U_{\sigma}, U_{\omega} > 0$, $U_{\sigma\sigma}$, $U_{\omega\omega} \leq 0$, and $U_{\sigma\omega} = U_{\omega\sigma} < 0$.

When material payoffs from the two relations are substitutes agents' marginal utility of payoffs obtained one period in one relation is decreasing in payoffs obtained in the other relation. Assumption 2 seems more realistic than that of a linearly separable utility function. Suppose, for example, of monetary earnings from a production partnership and of gains from cooperating in taking care of children or in providing non-market insurance. When one is doing well in production he can better face low levels of cooperation in these social relations than when production is going bad, as with the earnings from production one can usually buy similar (substitute) services. And vice versa, when an agent has very good (bad) social relations he tends to be less (more) dependent on his own earnings, and values less (more) at the margin payoffs from the production relation.

To simplify exposition we normalise $U$ (without loss of generality) so that $U(0,0) = 0$, and from now on write $U(\sigma)$ for $U(0,\sigma)$, and $U(\omega)$ for $U(\omega,0)$.

The static payoff matrix of the production interaction $P$, when not linked to the social interaction, is then

| | | Agent $j$ | |
|---|---|---|---|
| | | $w$ | $s$ |
| Agent $i$ | $w$ | $U(\omega^*, \sigma_i), U(\omega^*, \sigma_j)$ | $U(\underline{\omega}, \sigma_i), U(\underline{\omega}, \sigma_j)$ |
| | $s$ | $U(\underline{\omega}, \sigma_i), U(\underline{\omega}, \sigma_j)$; | $U(\sigma_i), U(\sigma_j)$ |

[12] In a previous version of this paper we worked with 'monetary payoffs,' the monetary value of the material payoffs from the relations, and we assumed a standard instantaneous utility function with decreasing marginal utility for money (Spagnolo, 1995b). The two formulations are equivalent, as a decreasing marginal utility for money implies that monetary payoffs from the two games are perfect substitutes.

where $\sigma_h$, $h\in \{i,j\}$ are agents' payoffs obtained in that period in the social relation, so that when agent $h$ is cooperating (defecting) in his social relation it is $\sigma_h = \sigma^*(\sigma_h = \underline{\sigma})$. Of course, the payoff matrix of the static social interaction $S$ is also subject to an analogous modification.

Again, if the relations are linked the same two agents meet in both social and production static interactions and the static linked interaction has a $4 \times 4$ payoff matrix in which all combinations of actions $c$, $d$, $w$, and $s$ are available.

**Definition 4.** *We will write 'X facilitates cooperation' with the meaning that 'X relaxes agents' incentive compatibility constraints to support cooperation' (and, consequently, that 'X lowers the minimum discount factor at which agents can support cooperation').*

Suppose that before production starts agents are cooperating in the social relation but there is no free social capital, i.e. that ex ante social capital is:

$$K_s = \frac{U(\sigma^*)}{1-\delta} - U(\bar{\sigma}) = 0.$$

One can state

**Proposition 3.** *Even with no ex ante social capital (with $K_s = 0$), linking production to cooperative social relations facilitates cooperation in organizations.*

As before, when the production relation is linked to a cooperative social relation agents can enforce cooperation in production by threatening to interrupt cooperation in both relations if one agent shirks. Even with $K_s = 0$, when agents' static objective function is not linearly separable this has two effects. On the one hand, after the production relation starts and agents begin to receive its payoffs their evaluation of gains from cooperation in the social relation changes, and with it changes the value of social capital. After production starts, if agents cooperate in production the ex post social capital is

$$K_s' = \frac{U(\sigma^*, \omega^*)}{1-\delta} - U(\bar{\sigma}, \omega^*) - \delta \frac{U(\omega^*)}{1-\delta},$$

and $K_s'$ can be larger or smaller than $K_s$, depending on the specific form of the utility function. On the other hand, when relations are linked and deviations and punishments are simultaneous in the two relations, agents' evaluation of gains from deviations and of losses from punishments in production changes. Proposition 3 shows that the sum of these two effects is always positive for the production relation.

Following Spagnolo (1996), one can also state a more general result.

**Proposition 4.** *Linking production and social relations (always) facilitates cooperation in both relations.*

Behind these results there is the effect of changes in the relative value of gains from deviations and of the relative 'strength' of the punishment in the linked relations. As before (and as in Bernheim and Whinston, 1990) the best a player can achieve through a deviation is obtained by deviating simultaneously in both relations, and the optimal punishment against any deviation from a cooperative equilibrium is a simultaneous interruption of cooperation in both relations. Because payoffs from the two relations are substitutes, the simultaneity of the punishments with linked relations increases their strength; the loss of gains from cooperation in each relation are evaluated at a higher marginal utility when punishments are simultaneous. Conversely, when deviations are simultaneous the short-run gains they generate are less valuable to agents, as they are evaluated at lower levels of marginal utility.[13]

A wealth effect analogous to that behind Proposition 4 allows us to state the following

**Corollary 1.** *Linking social and production relations may allow cooperation to be sustained in both relations even when cooperation could otherwise not be sustained in any relation.*

In other words, when payoffs from different relations are substitutes there can be a kind of 'scale effect,' or 'increasing returns' in cooperation when the number of relations between agents increase. Of course, when this is the case the interruption of one of the linked relations will cause a break down of cooperation in the other.[14]

## 5. Linking relations to transfer 'Trust'

Let us make a step back to Assumption 1 of preferences linearly separable in payoffs from the two relations, and consider an extremely simple case in which there are problems of coordination. Suppose that before being employed the agents are cooperating in $S^{\infty}$ but no social capital is available ($K_s = 0$), and that cooperation could in principle be sustained in $P^{\infty}(D_p \leq 0)$. Suppose also that before starting $P^{\infty}$ agents agree – or are recommended by the organization to coordinate on the Pareto-dominant equilibrium, but that each agent is not completely sure that the other agent with whom he is going to interact in production will follow the agreement/recommendation. Our agents assign some positive probability $(1 - q)$, $0 < q < 1$, to the event that the other agent shirks in the first period of production. We assume that the uncertainty regards the first round of $P^{\infty}$ only: if in the first period agents cooperate, all doubts on each other's behavior in the future are cleared. The probability $q$ can then be interpreted as the level of 'trust'

[13] One obvious interpretation for this effect is in terms of Hirschman's (1970) concepts of 'exit' and 'loyalty.' In our model the linkage is able to make payoffs from exit extremely low, compared to when games are not linked, and this induces higher loyalty and cooperation. When the production game is not linked to the social one, the agent has a better exit option in each of the games: if she breaks cooperation in one game, she will continue to get some substitute payoffs from cooperating in the other one, so that she is insured against reaching the very worst situations.

[14] We wrote that, at the cost of some complications (mainly in notation), these results can be extended to more than two relations. Corollary 1 would then imply that there are cases where agents can sustain cooperation in a set of $n$ linked relations, but are unable to cooperate in any of the remaining $(n - 1)$ relations if one of the $n$ relations ends. This result is particularly important for the explanation of the sudden breakdown in cooperation typically observed in isolated communities when they get in touch with more advanced economic institutions (see Sections 7.3 and 7.4).

between the two agents in the production relation, when this is not linked to the social relation.[15]

For each agent, the expected values of the choices to cooperate ($V(w)$) and not to cooperate ($V(s)$) in the first round of $P^\infty$ are, respectively

$$V(w) = q\frac{\omega^*}{1-\delta} + (1-q)\underline{\omega}, \quad \text{and} \quad V(s) = q\bar{\omega}.$$

The net expected gains from choosing $w$ are

$$V(w) - V(s) = \underline{\omega} + q\left[\frac{\omega^*}{1-\delta} - \bar{\omega} - \underline{\omega}\right],$$

therefore, the minimum level of trust necessary to cooperate in production is

$$q^* = \frac{-\underline{\omega}}{(\omega^*/1-\delta) - \bar{\omega} - \underline{\omega}}.$$

Even though cooperation could in principle be sustained in $P^\infty$ (we assumed $(\omega^*/1-\delta) - \bar{\omega} \geq 0$), too low level of trust $q < q^*$ makes cooperation impossible.

What if the organization chooses agents so that $S^\infty$ and $P^\infty$ are linked? The level of trust in the linked relation – the probability $q^L$ assigned by an agent to the event that the other agent cooperates in both linked relations the first period after the linkage – will be some weighted average of the levels of trust present in the two relations. Let $\alpha$, $0 < \alpha < 1$, denote the relative weight of $S^\infty$, so that the level of trust in the linked relations is $q^L = \alpha 1 + (1-\alpha)q$.[16] The expected value of the choices of cooperating and deviating in the linked relations will be, respectively

$$V(w,c) = q^L\frac{\sigma^* + \omega^*}{1-\delta} + (1-q^L)(\underline{\sigma} + \underline{\omega})$$

and

$$V(s,d) = q^L(\sigma + \bar{\omega}).$$

[15] This ‘reduced form’ can easily be derived from an imperfect information framework. For example, one may assume that a fraction $(1-q)$ of the population of agents is composed of types with a particularly high disutility for effort in production, and that this characteristic (which leads them not to cooperate in production) is not observable.
See Fudenberg and Kreps (1987) for a more general model of ‘transfers of reputation’ between multiple simultaneous (static) strategic interactions.

[16] In the imperfect information framework sketched in the previous footnote this would amount to assume that the characteristic of a high disutility for effort is negatively but imperfectly correlated with that of sustaining cooperation in the social relation.
Also, our assumption that the agents are cooperating in $S^\infty$ while there is no social capital implies that the probability agents assign to the event that the other agent with whom they are interacting in $S^\infty$ deviates is zero. To cooperate when the expected gains are just sufficient to offset the incentive to deviate there must be ‘full trust.’ Nothing changes in the logic of the argument if we assume $K_s > 0$ and a positive probability assigned to the event that the other agent deviates, so that in expected terms no excess of punishment power is available in $S^\infty$.

Agents will cooperate in the linked relations if

$$V(w,c) - V(s,d) = q^L \frac{\sigma^* + \omega^*}{1-\delta} + (1-q^L)(\underline{\sigma} + \underline{\omega}) - q^L(\bar{\sigma} + \bar{\omega}) \geq 0,$$

i.e. if

$$q^L \geq q^{L*} = \frac{-(\underline{\sigma} + \underline{\omega})}{((\sigma^* + \omega^*)/(1-\delta)) - (\bar{\sigma} + \bar{\omega}) - (\underline{\sigma} + \underline{\omega})}$$

and, therefore, if

$$\alpha \geq \alpha^* = \frac{1}{1-q}\left[\frac{-(\underline{\sigma} + \underline{\omega})}{((\sigma^* + \omega^*)/(1-\delta)) - (\bar{\sigma} + \bar{\omega}) - (\underline{\sigma} + \underline{\omega})} - q\right].$$

This means that when $\alpha$ is large enough both agents and the organization will find it profitable to link the relations.

The organization cannot lose anything by linking relations, as even when $\alpha$ is very low the worst that can happen is that no cooperation emerges in production. However, the linkage may leave the agents worse off. To see this, note that if relations are not linked agent's expected utility when $P^\infty$ starts is

$$V(c) + V(s) = \frac{\sigma^*}{1-\delta} + q\bar{\omega}, \qquad \text{when} \qquad q < q^*,$$

$$V(c) + V(w) = \frac{\sigma^*}{1-\delta} + q\frac{\omega^*}{1-\delta} + (1-q)\underline{\omega}, \qquad \text{when} \qquad q \geq q^*.$$

Suppose first $q < q^*$: now if the linkage allows cooperation to be sustained ($\alpha \geq \alpha^*$) both the organization and the agents will profit from it. Instead, suppose $q \geq q^*$. Agents will find ex ante profitable to link relations only if

$$V(w,c) = q^L\frac{\sigma^* + \omega^*}{1-\delta} + (1-q^L)(\underline{\sigma} + \underline{\omega}) > \frac{\sigma^*}{1-\delta} + q\frac{\omega^*}{1-\delta} + (1-q)\underline{\omega} = V(c) + V(w),$$

or, equivalently, if

$$\alpha \geq \underline{\alpha} = \frac{(\sigma^*/1-\delta) - \underline{\sigma}}{((\sigma^* + \omega^*)/(1-\delta)) - \underline{\sigma} - \underline{\omega}} < 1.$$

This means that when $\underline{\alpha} > \alpha^*$ there will be values of the parameter $\underline{\alpha} > \alpha > \alpha^*$ at which the linkage is not in the ex ante interest of the agents. This is because agents are concerned not to spoil cooperation in the social relation, so they may find the linkage 'too risky,' as it reduces trust in such a relation in order to increase it in production.

The organization, instead, will always be willing to risk destabilizing cooperation in the social relation to facilitate cooperation in production, given that it loses nothing when cooperation breaks up in the social relation. In other words, when $\underline{\alpha} > \alpha > \alpha^*$ the organization poses a negative externality on agents by choosing employees in order to link relations and generate transfers of trust.

We can summarize this subsection as follows

**Proposition 5.** *When agents cooperate in social relations and the transfer of trust from such relation to the linked production relation is strong enough ($\alpha > \alpha^*$): (i) linking relations can make cooperation sustainable in production even when no social capital is available; (ii) linking relations is always in the interest of the organization but may leave agents worse off.*[17]

## 6. Linking relations to reveal information

In this section we return to Assumption 2 of substitute payoffs in order to derive endogenously the level of trust in the form of agent's 'extrinsic uncertainty' on their opponents' evaluation of gains from cooperation in production.

To disentangle the effect of information revelation from that of social capital, we modify the model introducing

**Assumption 3.** *The population of agents is divided in N 'villages.' Each agent shares social relations with another agent in the village, and can observe the history of social relations among other agents of his village only. A fraction q, with $0 < q < 1$, of the population of each village is cooperating in social relations. The fraction q and the information structure are common knowledge.*

**Definition 5.** *Social and production relations are 'weakly linked' when team members are from the same village.*

In other words, when relations are weakly linked each agent knows how the other agent in the team is doing in the social relation, while when relations are not linked he does not know. We first state a simple lemma.

**Lemma 1.** *Cooperation in $S^\infty$ facilitates cooperation (makes cooperation more difficult) in $P^\infty$ when $(U(\omega^*, \sigma^*) - U(\sigma^*))/(U(\bar{\omega}, \sigma^*)) - U(\sigma^*) > (<)(U(\omega^*))/(U(\bar{\omega}))$.*

When the condition in Lemma 1 is satisfied, the wealth effect induced by payoffs from cooperation in $S^\infty$ reduces agents' relative evaluation of gains from deviation (relative to losses from punishments) in $P^\infty$, making cooperation in production supportable at lower discount factors.

Suppose the inequality in Lemma 1 is satisfied, so that cooperation in production is more attractive for agents who are cooperating in social relations. Under Assumption 3, when the relations are not linked each agent in the team does not know how his opponent is doing in the social relation. Because of Assumption 3, the imperfect information on the

[17] Some intuition on this can be obtained from a related example: suppose you can decide whether to spend your life in a 'society' in which relations are linked, say Japan, or in one in which they are separate, say the USA. Then, even though in Japan you may be able to cooperate more easily because production and social relations are linked, you still may prefer to live in the USA: if there are some risks for things to get bad, in the USA such risks are not as correlated as in Japan, you are better 'insured' against too bad states. In other words, a trade-off between 'insurance' and cooperation may emerge.

other agent's payoffs in $S^{\infty}$ translates into uncertainty on his evaluation of payoffs in $P^{\infty}$. When relations are not linked an agent employed in the organization will assign a probability $q$ to the event that the other agent with whom he is going to interact (in $P^{\infty}$) is of the 'type' which is cooperating in $S^{\infty}$.

The interesting case is that in which the discount factor is in the range where *cooperation in* $P^{\infty}$ *is supportable only for agents who are cooperating in* $S^{\infty}$. Let us focus on this case.

When relations are not linked, an agent who is cooperating in $S^{\infty}$ will choose to cooperate in $P^{\infty}$ if

$$V(w) - V(s) = q\frac{U(\sigma^*,\omega^*)}{1-\delta} + (1-q)\left[U(\sigma^*,\underline{\omega}) + \frac{\delta U(\sigma^*)}{1-\delta}\right] - \left[qU(\sigma^*,\bar{\omega}) + (1-q)U(\sigma^*) + \frac{\delta U(\sigma^*)}{1-\delta}\right] \geq 0.$$

From this condition we can derive the critical fraction of the population cooperating in $S^{\infty}$, $q'$, such that when $q < q'$ even agents who are cooperating in $S^{\infty}$ would find it too risky to cooperate in $P^{\infty}$ when relations are not linked:

$$q' = \frac{U(\sigma^*) - U(\sigma^*,\underline{\omega})}{((U(\sigma^*,\omega^*))/(1-\delta)) - U(\sigma^*,\bar{\omega}) - ((\delta U(\sigma^*))/(1-\delta)) + U(\sigma^*) - U(\sigma^*,\underline{\omega})} < 1.$$

Suppose first $q < q'$. If relations are not linked no agent will be willing to cooperate in production. If relations are weakly linked (if the organization requires team members to come from the same village) agents who are cooperating in $S^{\infty}$ will be able to cooperate in production when matched with another agent who is also cooperating in $S^{\infty}$.[18] Further, in this case the agents who are not cooperating in $S^{\infty}$ (and therefore prefer to defect in $P^{\infty}$) cannot hope to gain anything from being employed; they will get 0 from the beginning, as whoever they face in production will know that they are of the type that doesn't find it convenient to cooperate in production, and will shirk from the beginning. It follows that when relations are weakly linked, by requiring agents to face any small positive 'employment cost' before starting production the organization can screen out agents who are not cooperating in $S^{\infty}$ and implement cooperation in production.

Suppose instead $q \geq q'$. Agents who are cooperating in $S^{\infty}$ will now find it convenient to cooperate in $P^{\infty}$ even when relations are not linked. This means that if relations are not linked agents who are not cooperating in $S^{\infty}$ (and therefore prefer to defect in $P^{\infty}$) can gain $\bar{\omega}$ if they are employed and matched with an agent who is cooperating in $S^{\infty}$, so that their expected utility from being employed is $qU(\bar{\omega})$. It follows that to screen out agents who do not cooperate in $P^{\infty}$ the organization must require an initial 'employment cost' worth at least $qU(\bar{\omega})$. This is feasible only if paying such cost is convenient for agents who cooperate in $S^{\infty}$, and therefore in production, i.e. if

$$U(\sigma^*) - U(\sigma^*,\omega^* - qU^{-1}(\bar{\omega})) \leq \frac{\delta[U(\sigma^*,\omega^*) - U(\sigma^*)]}{1-\delta},$$

[18] Of course, when agents match in production teams so that relations are linked, and not only weakly linked, cooperation in production will be even more stable (by Propositions 3 and 4).

otherwise no agent would ever accept to be employed. When this condition is satisfied the organization can implement cooperation in the production with certainty without linking relations. However, when the condition is not satisfied and relations are not linked cooperation in a production team will emerge only with (approximate) probability $q^2$. If, instead, the organization requires agents to come from the same village agents who are not cooperating in $S^\infty$ cannot gain anything from being employed and any positive 'employment cost' is sufficient to screen out agents who are not willing to cooperate in $P^\infty$.

This reasoning can be summarized as follows

**Proposition 6.** *When the proportion of agents cooperating in $S^\infty$ (willing to cooperate in $P^\infty$) is small ($q < q$), cooperation in production is not feasible when relations are not linked, while it can always be implemented by weakly linking (or linking) relations. When the proportion of agents cooperating in $S^\infty$ (willing to cooperate in $P^\infty$) is large ($q \geq q$), cooperation in production can be supported with positive probability when relations are not linked, while it can always be implemented with certainty by weakly linking (or linking) relations.*

Note that to implement cooperation by weakly linking relations and screening out the agents who are not cooperating in $S^\infty$ the organization needs only to know which village agents are from, and not with whom each agent is interacting nor how he is doing in the social relation.

A fully analogous line of reasoning applies to the specular case in which the condition in Lemma 1 is satisfied with the inverted inequality sign, so that only agents who are not cooperating in $S^\infty$ find it convenient to cooperate in $P^\infty$.

## 7. Related literature and applications of the model

### *7.1. Peer monitoring and peer pressures*

The model above is strictly related to previous work on peer monitoring and peer pressure in the workplace (e.g. Kandel and Lazear, 1992), in group-lending programmes (e.g. Varian, 1990; Stiglitz, 1990; Besley and Coate, 1995), and within the family (e.g. Arnott and Stiglitz, 1991).

With the exclusion of Kandel and Lazear (1992) and Besley and Coate (1995), previous work has focused mostly on the informational aspects of peer monitoring, implicitly understating the importance of the additional sanctions usually available to peers. Monitoring is composed of both the observation of agents' actions and the sanctioning of agents when their actions are not the ones (implicitly and explicitly) agreed upon. Suppose employees of an organization can exert peer monitoring, or have free information on each other's behavior as a by-product of the team-production process. Peer monitoring will be more fruitful the stronger the sanctions agents can use as credible threats to deter 'cheating.' Our model shows that cooperative social relations provide an additional *credible* threat which makes the information obtained through peer monitoring more valuable.

The role played by social relations in Sections 3 and 4 is close to that of 'peer pressure' in Kandel and Lazear (1992). However, in our model peer pressure is self-enforcing, i.e. social sanctions are effective in that they emerge as 'credible threats' (they are a part of the subgame perfect equilibrium strategy profile), whereas in Kandel and Lazear (1992) agents exert peer pressure because of the form of their utility function. In Besley and Coate (1995) 'social collateral' plays a role very similar to our 'social capital', but social collateral is not at the center of that paper so how exactly social collateral works as an effective enforcing mechanism is not modeled in detail.

### 7.2. *Efficiency wages, insiders–outsiders, unions, and social norms*

Efficiency wage theories which follow the 'sociological' or 'fair wage' approach, such as Akerlof and Yellen (1990), assume some form of irrational behavior on the side of workers. Analogously, in Lindbeck and Snower's (1988) Insider–Outsider theory of unemployment workers willing to undercut rivals are assumed to be subject to revenge and ostracism of workmates, and even to physical harassment. Most of these explanations are appealing (who of us is homo economics?), and Frank (1988) has provided sound evolutionary explanations for similar forms of irrationality. Though, our linked relations approach demonstrates that even 'fully rational' agents (in the sense that they consider 'bygones as bygones') could easily enforce 'fair' work/wage norms within the workplace and deter other workers from accepting lower wages than agreed by the credible threat of a breach of cooperation in social relations.

More generally, social capital can be seen as the enforcing mechanism for any other 'social norm': the threat to revert to the worst Nash equilibrium in some repeated interaction if an agent does not follow the norm in another (repeated or static) interaction is credible; it overcomes what sociologists call the 'second-order free-riding problem' of social norms by satisfying the requirement of subgame-perfection (Selten, 1965). In cooperatives, partnerships, or small participatory firms agents share substantially in firm's profits and we would expect cooperation to emerge in the form of higher effort. In traditional large-scale firms, instead, we would expect agents to use more often social relations to enforce low work-norms, participation to strikes, and so on.

It is worth noting here that one of the social relations linked to production is typically a 'union game.' Our results imply that policies directed to weaken workers' unions may reduce social capital and weaken workers' ability to cooperate in the production teams.

### 7.3. *The emergence and breakdown of trust and cooperation*

The model above helps to figure out how cooperative institutions and trust may develop within a group of agents. One can think of a 'state of nature' in which agents are not cooperating in any relation, with a very low level of trust. In such a situation there will be some issues which present larger gains from cooperation than others (typically, joint defense). These large gains may eventually allow agents to coordinate and sustain cooperation in these 'fundamental' relations only. After some time that cooperation has been sustained in these relations the level of trust will grow higher and some social capital will develop. Then other relations, once linked to the 'fundamental' ones, may lead to cooperative outcomes thanks to the transfers of trust and social capital from the 'fundamental' relations. After some more time trust will grow higher in these linked relations too, more social capital will develop, new relations can be linked to the old ones, and so on...

When to this picture one adds that payoffs from many relations are substitutes, the results in Section 4 apply and the cumulative process of generation of trust and cooperation by sequentially linking relations is further reinforced.

If this story makes sense, then it is also easy to figure out why 'sudden breakdowns' in trust and cooperation may occur. Suppose trust and cooperation developed in a group of linked relations, as described above. If, then, cooperation breaks down in one of the linked relations, or if one of these relations comes to an end, there can be a negative chain effect on the whole of the remaining linked relations. On the one hand, a fall of trust in one relation will negatively influence beliefs in other relations. On the other hand, because payoffs are substitutes, the interruption of cooperation in one of the linked relations will decrease net expected gains from cooperation in the other linked relations. There will be a fall in social capital which, together with the fall in trust, may make cooperation impossible in all the remaining relations.

### 7.4. *Communities, markets, enemies, and cooperation*

The story of the previous section offers an explanation for the observation that cooperation seems to become harder in communities used to living off of their own production, after they get in touch with developed markets. Hirsch (1976) observed that the opening of markets or the availability of state-produced services tend to 'crowd out' cooperative relations. More recently, attention has turned to the breakdown in cooperation on the control of the local resource base in 'local commons,' which often follows improvements in communities' access to developed markets (e.g. Dasgupta, 1993, or Baland and Platteau, 1996).

The situation of a self-sufficient community before it gains access to developed markets can be described as a set of linked social, production, and resources control relations in which community members are cooperating. Access to developed markets brings an increase in freedom which can cause the sudden unravel of cooperation. Each community member becomes free to interrupt some relations, to hire a seasonal helper instead of going on cooperating with neighbors in the plough, to borrow from the credit market instead of continuing to cooperate in the implicit credit relations of the community, and so on. Markets reduce the strength of 'social' punishments, as through the anonymous (labor) markets agents are able to guarantee themselves a higher security level of welfare, whatever happens in the community.[19] Some of the linked relations are truncated and replaced by the anonymous market transactions, and this may reduce social capital to the point that cooperation cannot be sustained in any of the remaining social or

[19] The trade-off between the individual freedom offered by the anonymous markets, and the ability to cooperate in repeated personal interactions is reminiscent, again, of Hirschman's (1970) contrast between 'exit' and 'loyalty' in organizations, and is the other face of the trade-off between insurance cooperation discussed in Footnote 16.

resources control relations. Note that this effect will add to the other two negative effects of markets on cooperation identified by Kranton (1996) and Spagnolo (1997).

A similar argument explains why cooperation is easily sustained when a community is fighting a war, or when a 'dangerous' common enemy is perceived, while it tends to break down when the war ends or when such a perception disappears.[20] The 'defense game' generated by a war or by the presence of a common enemy tends to become linked to the other social and productive relations in the community, and makes the option of defecting in any of the relations particularly unattractive. This way cooperation becomes sustainable in all linked relations. The end of the war or the disappearance of the common enemy brings the end of the defense game. This leads to a loss of social capital, of trust, and to a 'wealth effect' on the net expected gains from cooperation in the rest of the linked relations. By Propositions 1–4 and Corollary 1 these effects may make cooperation impossible to sustain in all the remaining relations, so that the new 'peaceful' situation may even lead to a net loss in social welfare for the community.

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## Appendix

### *A.1. Proof of Proposition 1*

When games are strictly linked each team member can choose between cooperating in both relations and deviating in both relations. By Assumption 1 the static payoff matrix of the strictly linked relations is simply

| | | Agent $j$ | |
|---|---|---|---|
| | | $(c,w)$ | $(d,s)$ |
| Agent $i$ | $(c,w)$ | $\omega^*, \sigma^*, \omega^*, \sigma^*$ | $\underline{\omega} + \underline{\sigma}, \bar{\omega}, \bar{\sigma}$ |
| | $(d,s)$ | $\bar{\omega} + \bar{\sigma}, \underline{\omega}, \underline{\sigma}$; | 0, 0 |

and cooperation is feasible if

$$\bar{\omega} + \bar{\sigma} \leq \frac{\omega^* + \sigma^*}{1-\delta}, \qquad \Leftrightarrow K_{\mathrm{s}} \geq D_{\mathrm{p}}.$$

[20] I am grateful to Tore Ellingsen who suggested this example.

In case (*i*) agents' expected payoffs are $((\omega^* + \sigma^*)/(1-\delta)) > (\sigma^*/(1-\delta))$, and in case (*ii*) they are $0 < (\sigma^*/(1-\delta))$. The statements follows from this and the assumption that the organization gains when agents cooperate in production. □

### A.2. *Proof of Proposition 3*

We assumed that agents cooperate in $S^\infty$ but there is no social capital ex ante, so

$$K_s = \frac{U(\sigma^*)}{1-\delta} - U(\bar{\sigma}) = 0. \tag{1}$$

When $P^\infty$ is not linked to $S^\infty$, cooperation is sustainable in $P^\infty$ if

$$\frac{U(\omega^*, \sigma^*)}{1-\delta} - U(\bar{\omega}, \sigma^*) - \frac{\delta U(\sigma^*)}{1-\delta} \geq 0. \tag{2}$$

If $P^\infty$ is linked to $S^\infty$, cooperation is these relations is sustainable if

$$\frac{U(\omega^*, \sigma^*)}{1-\delta} - U(\bar{\omega}, \bar{\sigma}) \geq 0. \tag{3}$$

Subtracting the RHS of Eq. (2) from that of Eq. (3) we obtain

$$\frac{\delta U(\sigma^*)}{1-\delta} - U(\bar{\omega}, \bar{\sigma}) - U(\bar{\omega}, \sigma^*). \tag{4}$$

If this difference is strictly positive, condition Eq. (3) is strictly less stringent than Eq. (3) (net expected gains from cooperation are larger in Eq. (3) than in Eq. (2)) and the statement is proved. Substituting from Eq. (1)

$$\frac{\delta U(\sigma^*)}{1-\delta} = U(\bar{\sigma}) - U(\sigma^*)$$

into Eq. (4) we obtain

$$[U(\bar{\sigma}) - U(\sigma^*)] - [U(\bar{\omega}, \bar{\sigma}) - U(\bar{\omega}, \sigma^*)]$$

which by inspection is strictly positive when $U_{\sigma\omega} < 0$, as assumed. □

### A.3. *Proof of Proposition 4*

(This Proof follows that of Proposition 2 in Spagnolo, 1996). When the two relations are not linked, cooperation can be sustained in both if conditions

$$\frac{U(\omega^*, \sigma^*)}{1-\delta} - U(\omega^*, \bar{\sigma}) - \frac{\delta U(\omega^*)}{1-\delta} \geq 0 \tag{5}$$

and

$$\frac{U(\omega^*, \sigma^*)}{1-\delta} - U(\bar{\omega}, \sigma^*) - \frac{\delta U(\sigma^*)}{1-\delta} \geq 0 \tag{6}$$

hold simultaneously, which imply that their sum must be positive

$$\frac{\delta[2U(\omega^*,\sigma^*) - U(\sigma^*) - U(\omega^*)]}{1-\delta} - U(\bar{\omega},\sigma^*) + U(\omega^*,\bar{\sigma}) - 2U(\omega^*,\sigma^*) \geq 0. \tag{7}$$

If $P^\infty$ and $S^\infty$ are linked, cooperation will be sustainable in the linked relations if condition Eq. (3) is satisfied. Let us subtract the LHS of Eq. (7) from that of Eq. (3): if the difference is always strictly positive the statement will be proved. Subtracting, we obtain

$$\frac{\delta[U(\sigma^*) + U(\omega^*) - U(\omega^*,\sigma^*)]}{1-\delta} - [U(\bar{\omega},\bar{\sigma}) + U(\omega^*,\sigma^*) - U(\bar{\omega},\sigma^*) - U(\omega^*,\bar{\sigma})],$$

which is positive when

$$\delta[U(\sigma^*) + U(\omega^*) + U(\bar{\omega},\bar{\sigma}) - U(\bar{\omega},\sigma^*) - U(\omega^*,\bar{\sigma})] > U(\bar{\omega},\bar{\sigma}) + U(\omega^*,\sigma^*) - U(\bar{\omega},\sigma^*) - U(\omega^*,\bar{\sigma}). \tag{8}$$

The RHS of Eq. (8) is always negative because $U_{\sigma\omega} < 0$. The term with in squared brackets at the LHS of Eq. (8) may either be positive or negative. When the LHS is positive Eq. (8) is always satisfied. When it is negative, we can multiply Eq. (8) by $-1$ and divide by the terms in squared brackets at the RHS obtaining

$$\delta < \frac{-U(\bar{\omega},\bar{\sigma}) + U(\omega^*,\sigma^*) - U(\bar{\omega},\sigma^*) - U(\omega^*,\bar{\sigma})}{-[U(\sigma^*) + U(\omega^*) + U(\bar{\omega},\bar{\sigma}) - U(\bar{\omega},\sigma^*) - U(\omega^*,\bar{\sigma})}. \tag{9}$$

Given that $U_{\sigma\omega} < 0$ implies $U(\sigma^*) + U(\omega^*) > U(\sigma^*,\omega^*)$, the numerator of Eq. (9) is strictly larger than the denominator, and because $\delta < 1$ Eq. (9) is always satisfied. □

### A.4. Proof of Corollary 1

Cooperation can be sustained neither in $S^\infty$ nor in $P^\infty$ when the two inequalities

$$\frac{U(\sigma^*)}{1-\delta} - U(\bar{\sigma}) < 0 \Leftrightarrow \delta < \delta^S = \frac{U(\bar{\sigma}) - U(\sigma^*)}{U(\bar{\sigma})} \tag{10}$$

and

$$\frac{U(\omega^*)}{1-\delta} - U(\bar{\omega}) < 0 \Leftrightarrow \delta < \delta^P = \frac{U(\bar{\omega}) - U(\omega^*)}{U(\bar{\omega})} \tag{11}$$

hold simultaneously. The statement is proved if we can show that condition Eq. (3) can be less stringent than both Eqs. (1) and (11), i.e. if it can be

$$\frac{U(\omega^*,\sigma^*)}{1-\delta} - U(\bar{\omega},\bar{\sigma}) > \max\left\{\frac{U(\sigma^*)}{1-\delta} - U(\bar{\sigma}), \frac{U(\omega^*)}{1-\delta} - U(\bar{\omega})\right\}$$

or, equivalently

$$\delta^{PS} = \frac{U(\bar{\omega},\bar{\sigma}) - U(\omega^*,\sigma^*)}{U(\bar{\omega},\bar{\sigma})} < \min\{\delta^P, \delta^S\}. \tag{12}$$

When $((U(\sigma^*))/(1-\delta)) - U(\bar{\sigma}) > ((U(\omega^*))/(1-\delta)) - (U(\bar{\omega}))$, or $\delta^P > \delta^S$, the condition becomes

$$\frac{U(\bar{\omega},\bar{\sigma}) - U(\omega^*,\sigma^*)}{U(\bar{\omega},\bar{\sigma})} < \frac{U(\bar{\sigma}) - U(\sigma^*)}{U(\bar{\sigma})},$$

or, equivalently

$$\frac{U(\bar{\sigma})}{U(\sigma^*)} > \frac{U(\bar{\omega},\bar{\sigma})}{U(\omega^*,\sigma^*)},$$

which – by inspection – is satisfied when $U_{\sigma\omega}$ is small enough between $U(\omega^*,\sigma^*)$ and $U(\bar{\omega},\bar{\sigma})$.

A similar argument applies when $((U(\sigma^*))/(1-\delta)) - U(\bar{\sigma}) < ((U(\omega^*))/(1-\delta)) - U(\bar{\omega})$, or $\delta^P < \delta^S$. □

*A.5. On Corollary 1*

We try here to give an idea of the scope of application of Corollary 1. Inequalities Eqs. (1) and (11) imply

$$\frac{U(\sigma^*)}{1-\delta} - U(\bar{\sigma}) + \frac{U(\omega^*)}{1-\delta} - U(\bar{\omega}) < 0, \tag{13}$$

while Eq. (13) implies Eqs. (1) and (11) only for relations with a % *'similar strategic structure'* in the sense that $(U(\sigma^*))/(U(\omega^*)) = (U(\bar{\sigma}))/(U(\omega))$. So, when $(U(\sigma^*))/(U(\omega^*)) = (U(\bar{\sigma}))/(U(\omega))$ Eq. (3) is less stringent than both Eqs. (1) and (11) if it is less stringent than Eq. (13), i.e. if the following system is satisfied:

$$\begin{cases} \dfrac{U(\omega^*,\sigma^*)}{1-\delta} - U(\bar{\omega},\bar{\sigma}) \geq 0 \\ \dfrac{U(\sigma^*)+U(\omega^*)}{1-\delta} - [U(\bar{\sigma}) + U(\bar{\omega})] < 0 \end{cases}$$

Solving for $\delta$, substituting and rearranging we obtain

$$\frac{U(\omega^*,\sigma^*)}{U(\omega^*)+U(\sigma^*)} > \frac{U(\bar{\omega},\bar{\sigma})}{U(\bar{\omega})+U(\bar{\sigma})}. \tag{14}$$

For simplicity consider the case in which payoffs from the two relations are homogeneous (or have a constant marginal rate of substitutions, e.g. because payoffs from both relations can be sold and transformed in money), so that $U(\omega,\sigma) = U(\omega+\sigma), U_{\omega\sigma} = U_{\omega\omega} = U_{\sigma\sigma} < 0$, and $(U(\sigma^*))/(U(\omega^*)) = (U(\bar{\sigma}))/(U(\bar{\omega})) \Leftrightarrow \bar{\omega}/\omega^c = \bar{\sigma}/\sigma^c$.

**Remark 1.** *For social and production relations with homogeneous payoffs and a similar strategic structure all utility functions more frequently used in economics (logarithmic, exponential, quadratic, hyperbolic) satisfy* Eq. (14).

To show this we can reduce the number of variables to one by writing the LHS of condition Eq. (14) as

$$f(x) = \frac{U(x)}{U(ax) + U((1-a)x)},$$

where, $0 < a < 1,\ x = (\omega^c + \sigma^c)$ and $a = \omega^c/x$, and study the behavior of this function when $x$ increases for different explicit forms of the objective function $U$: when $f(x)$ is decreasing in $x$ condition Eq. (14) is satisfied and the scale effect of Corollary 1 applies.

For the **quadratic** function (in its increasing part), $U(x) = bx - cx^2, b, c > 0,$ we obtain

$$f(x) = \frac{bx - cx^2}{b(ax) - c(ax)^2 + b((1-a)x) - c((1-a)x)^2}$$

and

$$\text{sign}\left\{\frac{\partial f(x)}{\partial x}\right\} = \text{sign}\{a(a-1)\},$$

so that, because $a(a-1) < 0$, condition Eq. (14) is always satisfied.

For the **exponential**, $U(x) = -(1/\alpha)\exp(-\alpha x), \alpha > 0$, we obtain

$$\text{sign}\left\{\frac{\partial f(x)}{\partial x}\right\} = \text{sign}\{(a-1)\alpha \exp(-\alpha x(1-a)) - a \exp(-\alpha x(2-a))\},$$

and, because $(a-1)\alpha \exp(-\alpha x(1-a)) < a \exp(-\alpha x(2-a))$ Eq. (14) is, again, always satisfied.

Among macro-economists the **hyperbolic** CRRA function $U(x) = \frac{x^{1-\lambda}}{1-\lambda}$, with a coefficient of relative risk aversion $\lambda$ larger than, or close to one seems to be considered a more realistic specification of real world utility functions (e.g. Blanchard and Fisher, 1989, chap. 2). For $\lambda > 1$ the function is negative, so we use the most general linear transformation which makes it positive in some interval, $U = A + (x^{1-\lambda}/(1-\lambda)), A > 0$. Condition Eq. (14) is, once again, always satisfied: we obtain

$$\text{sign}\left\{\frac{\partial f(x)}{\partial x}\right\} = \text{sign}\left\{A\left[2 - a^{1-\lambda} - (1-a)^{1-\lambda}\right]\right\},$$

while it is always $2 < a^{1-\lambda} + (1-a)^{1-\lambda}$.

For $\lambda \to 1$ the function converges to the **logarithmic**. For $U(x) = \log(x)$ we obtain

$$\text{sign}\left\{\frac{\partial f(x)}{\partial x}\right\} = \text{sign}\{\log[a(1-a)]\},$$

and because $\log[a(1-a)] < 0$, Eq. (14) is always satisfied.

### *A.6. Derivation of Lemma 1*

With complete information, or when relations are weakly linked cooperation in $P^\infty$ between agents who are not cooperating in $S^\infty$ is possible if

$$\frac{U(\omega^*)}{1-\delta} - U(\bar{\omega}) \geq 0 \Leftrightarrow \delta < \delta^P = \frac{U(\bar{\omega}) - U(\omega^*)}{U(\bar{\omega})},$$

while for agents who are cooperating in $S^{\infty}$ cooperation in production is supportable if

$$\frac{U(\omega^*, \sigma^*)}{1-\delta} - U(\bar{\omega}, \sigma^*) - \delta \frac{U(\sigma^*)}{1-\delta} \geq 0,$$

or, equivalently, if

$$\delta \geq \delta' = \frac{U(\bar{\omega}, \sigma^*) - U(\omega^*, \sigma^*)}{U(\bar{\omega}, \sigma^*) - U(\sigma^*)}.$$

Cooperation in $S^{\infty}$ makes cooperation in $P^{\infty}$ more (less) attractive when $\delta^P > \delta'$, inequality which after a few algebraic manipulations leads to

$$\frac{U(\omega^*, \sigma^*) - U(\sigma^*)}{U(\bar{\omega}, \sigma^*) - U(\sigma^*)} > (<) \frac{U(\omega^*)}{U(\bar{\omega})},$$

as in the statement. □

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