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Contracts and Motivations
The Case of Open Source

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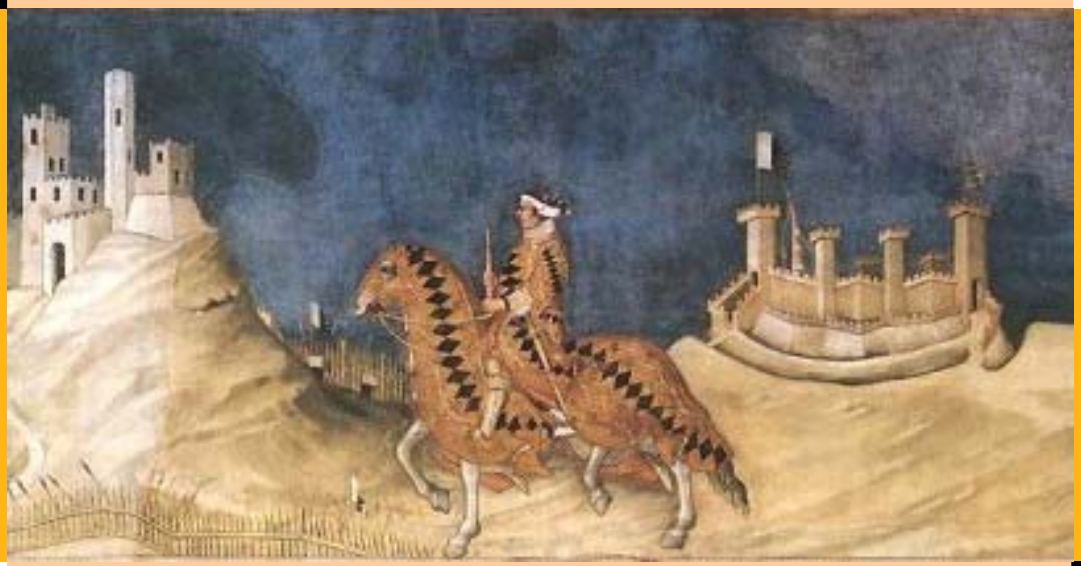

Abstract - The literature on Open Source phenomenon has revealed the crucial role played by both intrinsic and extrinsic motivations. However an analysis attempting to formally explore this interplay is still missing. In this paper, we try to fill the gap by introducing intrinsic motivations in standard principal-agent model, focusing on the case of Open Source Software (OSS). We show that, if developers' intrinsic motivation is sufficiently high, paying developers to work on OSS projects allows the firm to induce a desired level of workers' effort at a lower cost compared to the standard case of monetary incentives and sanctions coupled with costly monitoring.

Keywords: extrinsic and intrisic motivations, agency contracts, open-source software, open-source software developers

JEL Classifications: O32, M52, M54, O33, O31, M12

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1 Introduction

The Open Source Software (OSS) phenomenon has, by now, been explored from many angles (for surveys, see Maurer and Scotchmer, 2006 and Rossi, 2006). The questions that have so far attracted the bulk of the attention have to do with the (at first) puzzling fact that individuals were willing to contribute to a good that was made available for free without any direct monetary compensation and that the combination of this 'anarchic' array of contributions was a set of software products of remarkable quality. The empirical literature on the matter has revealed that both intrinsic and extrinsic developers' motivations play a role and that it is difficult to extract a case for the absolute prevalence of either sort of motivation. To our knowledge, however, no formal analysis of the interplay between intrinsic and extrinsic motivations has been provided.

In this paper, we provide a formalization of the effects of the interaction between intrinsic and extrinsic motivations on a developer's choice of development effort in the context of an OSS firm, namely a firm hiring developers to work on OSS projects. In order to more clearly highlight the relevant effects, we base our analysis on a standard adverse selection model such as the one presented in Laffont and Martimort (2002) but we specify the agent's (developer's) decision problem so as to take into account the interplay between intrinsic and extrinsic motivations.

The formalization we provide allows to shed light on three interrelated questions. What is the role of intrinsic motivation within the firm? Besides technical/market reasons, is there some reason for purely self-interested firms for choosing the OSS form of production for some of their activities (i.e. hiring developers to work on OSS)? When are "OSS contracts" more likely to be observed? The analysis suggests that it is precisely developers' intrinsic motivation that may provide a reason different from technical and market ones why firms may find it in their interest to adopt a OSS production model. To hire developers to work on OSS projects may be rational for a purely self-interested firm because it allows to reduce the cost of providing monetary incentives when developers' behavior is influenced by intrinsic motivation. Moreover, the model shows that paying developers to work on OSS projects allows the firm to induce a desired level of effort on the part of the agent at a cost that might be lower than that incurred by recurring to the use of monitoring and costly sanctions.

The paper is organized as follows. Section 2 introduces the existing literature on the interplay between intrinsic and extrinsic motivation of OSS developers and analyzes some distinctive aspects of developers' intrinsic motivation within the OSS firm. Section 3 introduces the principal-agent model. Section 4 concludes.

2 Intrinsic vs. Extrinsic Motivation and OSS Development

2.1 Previous literature

The empirical evidence so far available on the issue of OSS developers' motivation has revealed a composite landscape in which both intrinsic and extrinsic motivations play a role (Gosh et al., 2002; Hars and Ou, 2001; Hertel et al. 2003; Lakhani and Wolf, 2001). Extrinsic motivations relate to the immediate or delayed benefits accruing to the individual in a mediated form, generally through monetary compensation. Within this category are included the benefits in terms of increased reputation within and outside of the OSS community that are obtainable through OSS contributions (see, for instance, Lerner and Tirole, 2002), the satisfaction of user needs through OSS programming (von Hippel, 2002) and the benefits in terms of learning and skill acquisition made possible by the participation to OSS projects. With the expression intrinsic motivations, by contrast, reference is made to the benefits that accrue the individual from performing an activity because that activity is valued per se, as it is the case, for instance for the play-value and homo-ludens payoffs that derive from the performance of a fun activity. Lindenberg (2001) has proposed a further distinction between enjoyment-based intrinsic motivation, which is closer to the previous definition, and obligation/community-based intrinsic motivation that refers to the intrinsic benefits that may be associated to adherence to social or community norms and has been variously named gift-giving, reciprocal altruism or generalized reciprocity (on intrinsic motivation see also Bitzer et al., 2006).

The 'user needs' sort of extrinsic motivation has been explored particularly by Eric von Hippel and his colleagues at MIT. The main insight offered by this set of papers is that the free revealing of innovations developed in the first place for a personal need might turn out to be in the interest of a rational individual

because the benefit from revelation might be large enough to outweigh the costs of diffusion (kept low by the decreasing costs of digital communication) and the opportunity costs of release in the public domain (that may be low at least for some of the heterogeneous participants to OSS communities).

Another sort of extrinsic motivation that has fared prominently in the literature is the pursuit of reputation. The reputation-maximizing story has been proposed particularly by Lerner and Tirole (2002) who interpret the effort spent in contributing to OSS projects as a signal to both the community of peers and to the labor market. By contributing to OSS projects developers enjoy an immediate benefit in terms of increased reputation among their peers and a delayed benefits in the form of better job offers relative to non-OSS developers. According to Lerner and Tirole, the OSS world constitutes an environment particularly suitable for the reputation mechanism to display its effects for a variety of reasons[1].

As for intrinsic motivations, emphasis has been placed on the so-called 'gift-giving culture'. The expression refers to the fact that OSS developers may share the adherence to community social norms that attribute a positive value to the act of giving a 'gift' to the community in the form of software source code or related documentation. Of course, the prevalence of this sort of community norm makes sense, in particular, in the realm of intangibles for which the non-rivalry property holds (Kollock, 1999).

Gift-giving might be interpreted in two different ways. The first interpretation looks at the gift primarily as a means to acquire status within one's community. The larger the gift, the greater the status acquired within the community. Along these lines, Eric Raymond, one of the most active ethnographers of the OSS community, depicts the OSS culture as a gift culture in which economic scarcity is not an issue and social status is determined "not by what you control but by what you give away" (Raymond, 1998). A similar perspective is adopted by Zeitlyn (2003), who stresses that gift-giving allows the accumula-

[1]Costs are lowered by (a) the 'alumni effect' due to the fact that OSS programs are generally used at universities; (b) the private benefit of solving a programming problem and (c) the enjoyment of programming. Benefits include the fact that (a) openness allows a better performance measurement and increases the visibility of one's own contribution to the relevant audience; (b) each programmer is fully responsible for her contribution; and (c) the labor market is more fluid.

tion of 'symbolic capital' in Bourdieu's terms, and by Bergquist and Ljungberg (2001) who explore in greater detail the way in which the gift economy organizes relationships within OSS communities. This interpretation of gift-giving is thus not very different from the reputation-based explanation for contribution. Yet, it links the acquisition of status and reputation to adherence to a set of shared social norms within the OSS community that include a need for reciprocation that may be key in explaining why contributions may be made even if the cost-benefit balance is more ambiguous by conventional measures.

The second interpretation of gift-giving in OSS communities places the emphasis exactly on this set of social norms and explains gifts not as means of status acquisition, but rather as means to obtain 'behavioral confirmation', i.e. "the feeling of doing or having done 'the right thing' in the eyes of relevant others" (Lindenberg, 2001, p.327). According to this perspective, gift-giving amounts to a form of reciprocal altruism backed by the perception that one's own altruistic behavior is positively valued by the community or to a form of generalized reciprocity according to which gifts may be given on the basis of the expectation that a balance might occur within the group as a whole, given that the whole group shares a similar set of social norms. This aspect of individual motivation is also often referred to as obligation-based intrinsic motivation, because it entails the feeling of an obligation to adopt behavior consistent with community norms, i.e. to publish code. What it is important to note is that the driver of individual motivation is not the pursuit of an external reward (in any form, including status), but rather the perception of the need to act appropriately according to the metric set by the community – a type of behavior that Weber has defined 'value-rational'.

The relevance of motives broadly consistent with this definition of the gift-giving culture finds some support in the empirical literature. Anecdotal evidence confirms that a coherent set of norms, values and shared beliefs informs interactions in the OSS community, although the extent to which the norms and values of the community are internalized differs across participants, with those who subscribe to the views of the Free Software Foundation being at the extreme of the spectrum of ideological commitment. More formal empirical analyses have also substantiated the relevance of the sense of identification with the community as a powerful driver of individual participation to OSS projects. This is true for all the empirical analyses of motivation of which we are aware (Gosh et al.,

2002; Hars and Ou, 2001; Hertel et al. 2003; Lakhani and Wolf, 2001). In Lakhani and Wolf the components of obligation and community based motivation are highly ranked by participants. Similar results appear in the FLOSS survey (Gosh et al., 2002). Hertel et al. (2003) study contributions to the Linux kernel, and find that identification with the Linux community has the strongest influence on participants' engagement, together with the more pragmatic motive of improving own software and with tolerance of time investments.

2.2 Intrinsic motivation within the OSS firm

Most of the economic research conducted in the OSS field focuses on a range of issues concerning independent developers, i.e. developers acting outside of any employment relationship. However, both small firms' and corporate involvement in OSS is significant and on the rise, so that the number of developers working on OSS projects in the context of employment relationships is steadily increasing. At present, at least one third of OSS developers is paid by a commercial firm to make contributions to OSS projects that better address the firms' needs (CED, 2007).

Moreover, the empirical evidence available to date (Hars et al. 2002; Lakhani et al., 2005; Roberts et al., 2006) shows that there seems to be no or very scarce crowding out of intrinsic motivation in OSS, i.e. the intrinsic motivation of developers is not undermined if they are paid to work on OSS projects through completion-contingent rewards or performance-contingent rewards. In other words, developers working for OSS firms, i.e. within firms hiring developers to work on OSS projects, tend to be motivated by both intrinsic and extrinsic drivers. This is puzzling in light of both the psychological literature, which shows that certain types of incentive have a detrimental effect on agents' motivation, and in light of the economic literature on intrinsic motivation, that has highlighted the possibility of crowding out in similar but more general contexts.

Both of these empirical observations – the increasing involvement of commercial firms in OSS projects and the evidence on the absence of crowding-out – motivate the focus of this paper on the issue of motivations within OSS firms and particularly on the interplay between extrinsic and intrinsic motivations. To understand the latter it is important to understand the determinants of intrinsic

motivation within the firm. We assume that intrinsic motivation corresponds to the acquisition of 'Self-Esteem' through the adoption of behavior congruent with community social norms. In so doing, we focus on obligation-based intrinsic motivation, as defined in the previous paragraph. In order to acquire Self-Esteem, the agent must exercise an effort that: (a) benefits the community (because it is released under an OSS license); and (b) exceeds the amount of effort that is considered 'fair' for a given level of monetary compensation from the principal.

As for (a), working for a principal that allows some or all of the software developed under the employment contract to be distributed under OSS licenses means exercising an effort that is congruent with the community social norms of 'generalized reciprocity' (Kollock, 1999) and thus allows the developer to acquire Self-Esteem. Moreover, it is reasonable to posit that the acquisition of Self-Esteem depends not only on reciprocal behavior that directly benefits the community but also on reciprocal behavior towards the principal, which indirectly benefits the community given that the latter contributes to the community by releasing the software developed for her firm under OSS licenses. This implies that reciprocity-oriented developers will tend to reciprocate benevolent behavior by the principal.

As for (b), the amount of effort that is exactly compensated by the principal through a payment that reflects the agent's productivity cannot generate Self-Esteem for at least two reasons. The first is that the fraction of the effort that is exactly compensated by the principal is perceived as serving the specific needs of the firm (not necessarily congruent with community social norms) and/or the corresponding compensation is perceived as 'controlling' in the sense specified by Deci et al. (1999), i.e. shifting the locus of control outside the developer and therefore likely to undermine intrinsic motivation (see also Bénabou and Tirole, 2003)[2]. The second is that, as is well-known in the psychological literature, in order to be a means of 'behavioral confirmation', adherence to social norms should be costly (Lindenberg, 2001). Acting consistently with the norms of the OSS community can only provide Self-Esteem if the act cannot be performed at zero cost, so that the fraction of the effort whose disutility is

[2]Deci et al. (1999) and Staw et al. (1980) underline that the very form in which a reward is presented may affect intrinsic motivation, distinguishing between rewards that are purely informational and do not tend to undermine intrinsic motivation and rewards such as completion-contingent or engagement-contingent rewards that – perceived as controlling by workers – do tend to undermine intrinsic motivation.

exactly compensated in monetary terms may not serve the purpose of increasing Self-Esteem.

The above observations imply that an individual's Self-Esteem positively depends on the amount of development effort she exercises beyond the level of effort she considers 'fair' for a given amount of remuneration, and negatively depends on the amount of remuneration that exceeds her reservation price for a given effort level, i.e. the minimum amount that would induce the agent to offer that level of effort. In other words, we assume that, as the amount of remuneration in excess of the reservation price of effort increases, the individual suffers a loss of Self-Esteem if she refrains from making an adequate effort or if her remuneration is too high as compared to the effort exercised. This assumption is at the heart of the formalization we propose, to which we now turn.

3 The interplay between intrinsic and extrinsic motivation: a formalization

In this section, we introduce a standard adverse selection model (Laffont and Martimort, 2002) where, however, the principal/firm is assumed to be purely self-interested, while the agent/developer is motivated both by a profit mechanism driven by extrinsic motivation and by a 'moral mechanism' driven by (obligation-based) intrinsic motivation following from the fact that she attaches a positive value to the social norms of gift-giving that are often said to characterize OSS communities.

3.1 The developer's decision problem

Let the individual's utility depend on the total amount of goods she may consume (X) and on Self-Esteem (SE). The endogenous variable Self-Esteem is meant to capture the fact that the individual attaches a positive value to her own reciprocal or gift-giving attitude, i.e. to behavior coherent with the social cultural habits of gift-giving prevailing in the OSS community[3]. This implies that the individual's Self-Esteem (and therefore her utility) may decrease as

[3]In other words, the variable Self-Esteem is meant to capture the individual propensity to adopt "value rational" behavior in Weberian terms.

a consequence of behavior inconsistent with social norms[4]. Assume that the price of X is 1. The agent's problem is to choose X and SE to maximize utility, subject to a budget constraint that includes the expenditure to conserve Self-Esteem (opportunity cost).

The developer's decision problem is therefore:

$$\max_{X,SE} U(X, SE) \tag{1}$$

$$s.t.\, X + C(SE) = M \tag{2}$$

$$\begin{aligned} &where \\ &C(SE) = f(e)M, 0 < f(e) \leq 1, f_e(e) > 0,\, M > 0 \\ &\quad U_X > 0\, always \\ &\quad U_e = \frac{dU}{df(e)} \frac{df(e)}{de} > 0 if\, SE \leq SE* \\ &\quad U_e < 0 if\, SE > SE* \end{aligned}$$

Equation [2] indicates the budget constraint and states that the expenditure on X and on production of Self-Esteem $C(SE)$ indeed the net opportunity cost, must equal the monetary amount (M) that indicates the remuneration that exceeds the reservation price of effort since, as explained above, it is only this fraction of the remuneration that may produce-induce Self-Esteem. The function $f(e)$ indicates the amount of Self-Esteem the agent obtains for effort e. The effort e produces a double effect: it increases disutility by unpleasantness of working but also produces a larger utility by increasing Self-Esteem, up to $SE*$. Note that the assumptions on U_e are also meant to capture the fact that, above a subjectively given amount $SE*$ Self-Esteem becomes a bad (excess of a good) since it induces a feeling of subjection and exploitation, meaning that the individual feels she is giving too much in exchange for too limited benefits. Finally the budget constraint is not linear since the shape of $f(e)$ depends on social and cultural habits.

The optimal solution implies that:

[4] A general model is in Basili and Franzini 2007.

$$L = U(X, SE) - \lambda(M - X - C(SE)) \tag{3}$$

$$\begin{aligned} &f.o.c. \\ &\frac{dL}{dX} = U_X + \lambda = 0 \\ &\frac{dL}{de} = U_e + \lambda C_e = 0 \\ &\frac{dL}{d\lambda} = M - X - C(SE) = 0 \end{aligned}$$

From the first order condition it is obtained that:

$$\frac{U_X}{U_e} = \frac{1}{C_e(SE)}$$

that is the optimal solution for the Agent implies that her Marginal Rate of Substitution between Self-Esteem and consumption of conventional goods X equals the 'Technical Rate of Transformation' between Self-Esteem and consumption of conventional goods. It is worth to note that assuming a given M, consumption of conventional goods can only increase by loosing Self-Esteem.

3.2 The Principal's decision problem

The Principal is assumed to be purely self-interested, as in standard Principal-Agent models. The problem of the Principal is that of maximising profit, that is the difference between the value of production and the associated costs. The information asymmetry concerns the productivity of the Agent (the software developer) that could be high or low (Efficient or Inefficient Agent), giving rise to low or high marginal costs, respectively.

Let θ_H be the constant marginal cost of the efficient Agent and θ_L the constant marginal cost of the inefficient Agent. Since the Principal cannot observe θ, he cannot equalise the marginal value of each Agent's production to its marginal cost. Indeed, if he were to offer a contract calling for different compensation levels on the basis of the quantity produced and equal to the respective marginal benefit, the efficient Agent could simulate being inefficient (producing less) with a view to pocketing the information rent. The latter is equal to the difference

between the two marginal costs at the low production level or $\Delta\theta q_L$.

Given information asymmetry, the Principal has thus to establish compensation levels by disregarding the equality between marginal benefit and marginal cost, or he has to define incentive and punishment mechanisms. In both cases he has to bear an additional cost with respect to the first best solution and, consequently, he will choose the less costly solution. Following Laffont and Martimort, let:

q_H, q_L the level of production obtained by the efficient and inefficient Agents, respectively;

$S(q_H), S(q_L)$ the value of production obtained with the efficient and inefficient Agents, respectively;

U_H, U_L the monetary transfer in excess of the compensation of the cost of production to the efficient and inefficient Agents, respectively;

$v, (1-v)$ the probability to come across an efficient or inefficient Agent, respectively.

Assume further that U_i – the monetary transfer in excess of the cost of production – coincides with M_i as defined in section 3.1, i.e. the amount of remuneration that exceeds the agent's reservation price of effort. In other words, assume that the reservation price of each agent's effort in producing q is equal to her cost of producing q,$\theta_i q_i$.
The Principal's maximization problem can be written as follows:

$$\max_{\{U_L, q_L, U_H, q_H\}} v\left[s(q_H) - \theta_H q_H - (1 - f(e_H))U_H\right] + (1-v)\left[s(q_L) - \theta_L q_L - (1 - f(e_L))U_L\right] \tag{4}$$

$s.t.$

$$U_H \geq U_L + \Delta\theta q_L \tag{5}$$

$$U_L \geq U_H - \Delta\theta q_H \tag{6}$$

$$U_H > 0 \tag{7}$$

$$U_L \geq 0 \tag{8}$$

Inequalities (5) and (6) represent the incentive constraints for the high and low productivity Agent, respectively, and inequalities (7) and (8) are participation constraints. As in similar Principal-Agent problems of this sort we can simplify the problem by noting that (7) is redundant because it is trivially satisfied if (5) and (8) hold and that (6) is irrelevant because the inefficient agent does not have incentives to claim that he is efficient. We further note that (5) and (7) must be binding. This leaves us with:

$$U_L = 0 \tag{9}$$

$$U_H = \Delta\theta q_L \tag{10}$$

Substituting the new constraints into the maximization problem we have:

$$\max_{\{q,,q_H\}} v\left[s(q_H) - \theta_H q_H - (1 - f(e_H))\Delta\theta q_L\right] + (1 - v)\left[s(q_L) - \theta_L q_L\right] \tag{11}$$

The choice to hire developers to work on OSS projects by the principal influences the value assumed by the function $f(e_i)$. An OSS development contract guarantees that $0 < f(e_i) \leq 1$ (where the first inequality is strict), while a non-OSS development contract implies that $f(e_i) = 0$ since working for a firm that does not contribute to the OSS community does not allow the developer to acquire Self-Esteem through on-the-job development effort. By choosing to release her products under OSS licenses, the firm is able to "activate" developers' intrinsic motivation: in this case to exert development effort may allow developers to acquire Self-Esteem, given that this choice allows them to abide

by the OSS community social norms. This will not hold if the firm chooses a non-OSS business model and employment contract.

If $0 < f(e_i) \leq 1$, in turn, a fraction $f(e_i)U_i$ of the monetary transfer in excess of the cost of production that the principal gives to the agent will translate into increased effort. This is because a fraction of the monetary transfer in excess of the reservation price of effort (M_i,that in our formulation coincides with U_i) that the developer receives will translate into a loss of their Self-Esteem to the extent that she does not expend an effort considered "fair" with respect to such monetary transfer.

The implications of the choice of an OSS vs. a non-OSS contract are summarized by propositions 1 and 2.

Proposition 1 (non-OSS contract[5]). *The optimal non-OSS contract contemplates an information rent for the efficient agent only. It implies that there is no output distortion with respect to the first best for the efficient agent and a downward output distortion with respect to the first-best solution for the less efficient Agent, such that:*

$$S'(q_L) = \theta_L + \frac{v}{1-v}\Delta\theta \tag{12}$$

The output distortion for the inefficient agent derives from the fact that any increase in the output of the inefficient agent implies an increase in the efficient agent's information rent and a correspondent decrease in the principal's expected payoff.

Proposition 2 (OSS contract). *The optimal OSS contract contemplates an information rent for the efficient Agent only. It implies that there is no output distortion with respect to the first best for the efficient Agent and a downward output distortion with respect to the first-best solution for the less efficient Agent. The extent of output distortion decreases as $f(e_H)$ increases, according to the following relationship:*

[5] Laffont and Martimort, 2001

$$S'(q_L) = \theta_L + \frac{v}{1-v}(1 - f(e_H)\Delta\theta \tag{13}$$

The extent of the output distortion for the inefficient agent depends on the amount of Self-Esteem the efficient agent obtains for a given level of effort. This is because, the higher will be $f(e_H)$, the lower it will be the cost for the Principal of providing incentives to the efficient agent through the information rent, which implies the possibility to increase the output level of the inefficient agent with respect to the level that would be chosen by the principal in absence of intrinsic motivation. The choice of an OSS contract, by allowing to "activate" developers' intrinsic motivation thus induces a second-best solution to which is associated a lower extent of output distortion.

Finally, consider the choice between a OSS contract and a non-OSS contract (such that $f(e_i) = 0$) with an audit mechanism with endogenous punishment. Let:

s_L	the probability of discovering the inefficient Agent's deception;
$c(s_L)$	the cost of auditing the inefficient Agent;
P_H, P_L	the amount of the endogenous punishment for the efficient and inefficient Agents, other things being equal.

Proposition 3 (non-OSS contract with audit). *The solution with endogenous punishment implies that only the inefficient Agent is monitored with a strictly positive probability, the same production as first-best for the efficient Agent and a reduction with respect to first-best production for the inefficient Agent, that is:*

$$S'(q_L) = \theta_L + \frac{v}{1-v}(1 - s_L)\Delta\theta \tag{14}$$

Proposition 4 (OSS contract vs. non-OSS contract with audit). *The OSS contract is chosen (rejected) if the necessary cost of activating altruism*

$(1 - f(e_H))$ *of the more efficient Agent is lower (greater) than the probability* $(1 - s_L)$ *of the loss connected to the non-punishment (exposure) of the less efficient Agent in the event of fraudulent behaviour. This is because:*

$$S'(q_L) = \theta_L + \frac{v}{1-v}(1 - f(e_H)\Delta\theta \leq S'(q_L) = \theta_L + \frac{v}{1-v}(1 - s_L)\Delta\theta \quad (15)$$
$$if\,(1 - f(e_H)) \leq (1 - s_L)$$

4 Discussion

The literature has identified a number of reasons why firms might find in their interest to contribute to OSS projects. Small and Medium Enterprises (SMEs) tend to participate to OSS communities for reasons that are akin to those of individual developers (Bonaccorsi and Rossi, 2003). The prominent reason to contribute seems to be given by the existence of user needs coupled with the low transaction costs involved by the act of contributing back to the community software developed for one's own needs. More generally, OSS offers to small firms the possibility to adopt a business model based on the provision of services such as customization and support rather than on the sale of the software. Corporate players find it in their interest contributing to OSS projects out of four sorts of motivations (FLOSS survey, 2002): (1) standardization; (2) use of OSS software as a low-cost component; (3) strategic considerations; and (4) enabling compatibility[6].

The model presented in the previous section suggests that firms might find in their interest to adopt a OSS business model even setting aside market/technical reasons. It highlights an advantage of the adoption of a OSS business model that has not been formally analyzed before, namely that the choice of an OSS

[6]The first motivation relates to the fact that a OSS platform offers a specific advantage as a common standard because the license under which it is distributed effectively prevents any of the commercial developers adopting the standard from appropriating the software at a later point of time. The second motivation is easy to understand: the fact that F/OSS software is free makes it an ideal candidate for being offered to customers as part of a hardware-software bundle to meet specific needs. Contributions to F/OSS software development may also be motivated by competitive goals, such as the desire to pose a threat to dominant firms in the market (3). Finally, firms might simply be interested in making their software or hardware compatible with F/OSS software and develop plug-ins necessary to do so (4).

contract may reduce the cost of providing monetary incentives (in the form of an information rent) to agents in circumstances in which developers' behavior is influenced by obligation-based intrinsic motivation. These circumstances are highly likely to occur, according to the empirical literature reviewed in section 2. Moreover, the model suggests that, if agents attribute a sufficiently high weight to adopting behavior consistent with intrinsic motivation, choosing a form of production such as OSS that positively influences intrinsic motivation may be less costly than adopting a monitoring/punishment arrangement. This is more likely to hold in contexts such as software development in which agents' creativity is involved to a significant extent so that monitoring is particularly costly.

One aspect of the formalization that it is important to note is that the cost of providing monetary incentives is lower when intrinsic motivation is at play, which implies that the provision of monetary incentives does not crowd out intrinsic motivation. The formalization of the interplay between intrinsic and extrinsic motivations we propose thus provides theoretical support to the empirical evidence showing that the provision of monetary incentives in the OSS world does not tend to crowd out intrinsic motivations (Hars et al. 2002; Lakhani et al., 2005; Roberts et al., 2006). The results of the analysis may be generalized beyond the OSS environment. In particular, the analysis suggests that, whenever intrinsic motivation significantly influences agents' behavior it might be rational for a purely self-interested firm to organise those activities that are likely to exert a positive influence on agents' motivations in a way that is consistent with those motivations.

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