Hierarchy, Information and Effort Observability

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***Abstrac**t: This paper analyzes the choice between a centralized and a decentralized organizational structure focusing on the relationship existing between the allocation of decisional rights and the use of different compensation systems. We assume that a profitable production is realized thanks to good information in the selection of projects and hard work in the implementation stage. Implementation effort is provided by the agent. Selection of projects can be done by the principal (hierarchy) or by the agent (delegation), each using his own information. Under the hierarchical system, the principal participation at the ideation and development of projects allows him to evaluate, even if imperfectly, whether unsatisfactory results are due to the selection of a bad project or to low effort during the implementation stage. This, under hierarchy, permits the use of a compensation systems based not only on output but also on the principal's inference of the agent's effort, while under delegation the payment to the agent can be conditioned only on the final output, since the principal has no independent information on the quality of the selected project. Therefore, a trade-off between agent's better information and less accurate incentive system may emerge.*
JEL: D23, L22, J33)

1. Introduction

An extensive literature has examined the benefits and costs of hierarchical and decentralized organizational forms, showing that the allocation of decisional rights has a crucial role in shaping the use of the available information, the relevance of communication costs and the kind of errors made in the decision process, and – in asymmetric information contexts – it significantly influences agents' incentives to provide unobservable effort.

The organizational form has been viewed as aimed to solve co-ordination problems taking into account the costs of acquisition, processing and communication of information, delays and errors in decision-making, advantages from specialization (Aoki, 1986; Sah and Stiglitz, 1986; Radner, 1993; Van Zandt, 1999; Bolton and Dewatripont, 1994; Garicano, 2001).

The choice between centralization and decentralization has initially been studied focusing on the trade-off between the optimal use of information available to subordinate agents, allowed by a decentralized decision-making process, and the advantages of coordination and control, deriving from a centralized structure.

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This first strand of the literature has not considered incentive problems, which have been dealt with more recently taking into account problems related to the existence of asymmetric information among the members of organizations.

Among this second approach figures prominently Aghion and Tirole (1997) who assume that the principal and the agent have private divergent objectives. The delegation of authority to the agent, which allows him to choose projects that maximize his private benefits, enhances his effort in the acquisition of information concerning projects to be implemented. However, a higher effort can be obtained only suffering a cost in terms of loss of control, since the implemented projects do not maximize the principal's payoff. Aghion and Tirole assume that the agent's opportunistic behavior can be controlled only partially and only by conceding him some decisional rights, because monetary incentive contracts are not available because of the agent's infinite risk aversion.

In Zabojnik (2002), under the centralized system, the agent has the task to implement the project selected by his superior, while in a decentralized firm the agent works on a project selected by himself. The author shows that it might be more costly to induce an employee to work on the project selected by his superior, because if the agent believes that the project has a low probability of success, he will be discouraged in putting high effort in the implementation stage. On the contrary, if the agent is free to choose the project that, in his opinion, has more probability of success, stimulating his effort will be less costly, since his expected payoffs are higher.

De Paola and Scoppa (2006) assume that agent's effort is not observable and that firms use a performance-related pay system to encourage the agent to work hard to select profitable projects. In a hierarchical organization, a screening activity is performed by the principal on projects proposed by the agent. This activity allows to reject some bad projects, but on the other hand, since screening is not perfect, it implies that also some good projects proposed by the agent are discarded. Therefore, the principal's screening activity eliminates either some wage penalties and some wage premium for the agent's behavior. As a consequence, incentives become more costly in hierarchy with respect to delegation.

The model we offer in this paper is related to De Paola and Scoppa (2006). We consider a novel aspect, not yet considered in the literature on organizational forms and incentives: in situations in which the principal carries out some tasks in the firm's production process, he obtains precious information which can be useful in the evaluation of agent's activity and, therefore, in defining his compensation.

In line with some recent papers, we consider that in many circumstances there is a relationship between the allocation of decisional rights and the convenience or feasibility of different compensation systems. Prendergast (2002), Raith (2005), Baker and Jorgenson (2003), starting from a lack of evidence of the negative correlation between uncertainty and strength of

incentives (as should emerge from standard models of agency), build models that explain why the principal has interest to delegate decision power (and to give more incentives) when uncertainty is higher. As argued by Prendergast (2000, p. 9): "firms delegate decision-making power more in uncertain environments but offer output-based contracts in order to constrain the possibility that they use their discretion in harmful ways. By contrast, in more certain environments firms assign tasks to workers and find it more profitable to monitor actions directly".

In examining this aspect, we focus our attention on an objective and some kind of subjective measures of performance, based both on output results and on the principal evaluation. More specifically, the model we propose assumes that a profitable production is realized thanks to the gathering of good information in the selection of projects and hard work in the implementation stage. Selection of projects can be done by the principal (hierarchy or centralization) or by the agent (delegation or decentralization), according to his/her own information. We assume, for the sake of simplicity, that the information necessary for selection of projects is exogenously given. Both the principal and the agent have a given set of information, which could represent their ability. We assume that, in addition to the ex-ante information on which the project selection his based, during the development stage some additional information becomes know, allowing to evaluate, even if imperfectly, whether the project at hand is a successful one.

Once the project has been selected and developed in its details it is implemented thanks to the agent effort (effort has to be provided by the agent in both organizational forms). Since the agent's effort is not observable by the principal a moral hazard problem arises. We show that incentive systems may be different under the two organizational structures, because of the additional information available to the principal under hierarchy: under delegation the compensation system can be conditioned only on the final output since the principal has no independent information on the quality of the selected project, while under hierarchy – in addition to the payment based on output – the principal is able to pay a wage based on his inference (subjective evaluation) of the agent's effort. This leads to better incentives under hierarchy (if the project's quality is observable by the principal without too much noise) since one source of uncertainty can be neutralized in the determination of the agent's compensation.

Through the incentive compatibility constraint, we determine an "efficiency wage" necessary to induce the agent to work hard under the two organizational forms, and compare them showing that while under decentralization the agent effort is strictly related to his own information, under hierarchy a crucial role in shaping the agent's effort is represented by the principal ability in recognizing the effective quality of the selected project. When the principal evaluation is not too noisy, this can lead to a reduction of uncertainty and determine an advantage with respect to delegation.

We weigh this advantage of the hierarchical organization against potentially better information available to the agent, which under the decentralization system translates in a large fraction of good projects. In fact, as suggested by a number of papers (Aoki, 1986; Acemoglu et al. 2006), employees working at direct contact with the production line possess information that is superior to that of the principal.

We then compare profits obtained under the two organizational forms, discussing the effects of the principal's and agent's information availability (ability) and of the principal evaluation activity. Whereas the comparison between centralization and decentralization based on agent's and principal's information availability is common in literature, we add to this comparison the consideration that hierarchy allows for a better monitoring of agent's actions.

The paper is organized as follows. In Section 2 we present the main hypothesis of the analysis and lay out the model dealing with effort as a continuous variable. Since the comparison between centralization and decentralization is very complex with continuous effort, in Section 3 we assume that effort is a discrete variable which can be only high or low: this simplification allows us to proceed with an efficiency comparison of delegation and hierarchy. Section 4 concludes.

2. The model

We consider a principal-agent relationship with a risk neutral owner-manager hiring one risk adverse agent. The economic activity of the firm consists in the selection and implementation of profitable projects.

The profits realized with the projects depend on the combination of two (stochastic) variables: how good is the information obtained by the decision-maker who select the project and how much effort the agent provides in the implementation stage.

The quality of the project can be good (Q^G) or bad (Q^B) and the effort can give rise to a good implementation (E^G) or a bad implementation (E^B).

We assume that the amount of information (i) gathered – by the principal or by the agent, according to the organizational form – represents the probability that the project is good, while the effort level (e) represents the probability that the project implementation is good. Therefore, 4 cases are possible (see Table 1):

1) if the project's quality and implementation are both good (the joint probability is ie), then profits are positive ($G > 0$);
2) if the project's quality is good but the implementation is bad (the joint probability is $i(1-e)$), profits are zero;

3) if the project's quality is bad but the implementation is good (the joint probability is $(1-i)e$), profits are zero;

4) if the project's quality is bad and the implementation is bad too (the joint probability is $(1-i)(1-e)$), profits are negative ($B<0$);

Table 1. Quality of the project, implementation and project's revenue

Quality of the project and of implementation	Probability	Project's revenue
Q^G and E^G	ie	$G>0$
Q^G and E^B	$i(1-e)$	0
Q^B and E^G	$(1-i)e$	0
Q^B and E^B	$(1-i)(1-e)$	$B<0$

To illustrate, think of the production of a innovative good: the good can meet or not the desires of consumers, for example in terms of design, and its production can be accurate or sloppy. Reaching the first objective strictly depends on the product ideation and development, while meeting the second objective depends on the implementation stage. If the new product design is highly appreciated by consumers and its quality is good, the firm makes profits; profits are zero if either the quality is satisfying but the product design is not very appreciated by consumers (in fact, even if the product design does not respond consumers' desires, they may still appreciate its quality) or if production quality is poor but the product design is valued a lot. Finally, profits are negative if consumers do not appreciate the product style and its quality is poor.

Therefore, firm's expected revenue *R* are equal to:

[1] $$R = ieG + (1-i)e(0) + i(1-e)(0) + (1-i)(1-e)B$$

The agent's choice of effort is not observable to the principal: this informational asymmetry gives rise to a moral hazard problem. However, the final result is observable and verifiable. We assume, for the sake of simplicity, that the information available is exogenously given (for example, it could represent the principal's or the agent's ability in gathering useful information).

We consider two different organizational structures. Effort must be provided by the agent in both type of organization, while the task of selecting projects can be done either by the principal (hierarchical organization) or by the agent (delegation).

The worker and the manager have different ability to select good projects, respectively denoted with i_A and i_p, which can be interpreted as type parameters. We assume that i_A and i_p are common knowledge. Therefore, under the decentralized organizational structure projects are chosen by the agent according to his own information (i_A). Under the hierarchical form, projects are chosen according to the principal's information (i_P) and then the agent has the task to put forth effort during the implementation stage.

In the first stage, the principal has to decide which organizational structure to adopt. Once the organizational form has been decided, the project must be selected (by the principal or by the agent) and then the agent provides an unobservable effort in order to implement the project. It follows that under delegation, the project's success probability depends both on the agent's ability in selecting a good project and on his effort, while under the hierarchical system the results obtained depend on the principal's ability and the agent's effort.

The principal is risk neutral and maximizes expected profits, given by the revenues from the project realization minus the wage payment to the agent. The agent is risk-adverse, and, for the sake of simplicity, we assume that his utility function takes the following form: $U = W^{\alpha} - \frac{\gamma e^2}{2}$, where W is the wage received by the agent, α is a parameter that takes into account the worker's risk aversion ($0 < \alpha < 1$, where the degree of relative risk aversion[1] (Arrow-Pratt) is given by $1-\alpha$) and $\gamma e^2/2$ represents the disutility of his effort. The agent's reservation utility level is denoted by $\bar{u}$.

Incentives

Given that effort is unobservable, in order to give to the agent incentives to work hard, a performance related pay must be implemented.

Under delegation, since only the profits are observable by the principal (and verifiable), the principal pays a positive wage *w* when revenues are positive (*R=G*). In order to simplify the analysis, we assume that the firm cannot impose the payment of a fine on its workers ("limited liability constraint"). This means that a wage equal to zero represents the severest punishment for workers in the case of bad performance (R=*B<0*). The exclusion of penalties is quite realistic, since workers are usually liquidity-constrained (because of imperfect capital markets)

[1] The coefficient of relative risk-aversion is given by: $-wu''(w)/u'(w)$

and since legal constraints prevent the possibility of paying a negative wage.[2] In addition, it can be shown (see appendix), that it is optimal for the principal to pay a wage equal to zero also when profits are zero (R=0) (rather than paying a wage w_1 when *R=0* and a w_2 when *R=G*).

Under hierarchy, the principal is able to use the same compensation system based on output, as in delegation, but, in addition, he has the possibility to adopt a different system, using an additional variable to determine the agent's pay. In fact, since the principal in a centralized organization carries out the task to gather information, we assume that once accomplished the project development he becomes able to realize, even if with error, whether the selected project is effectively a good project and as a consequence, once the project pay-off becomes known, he is able to make inference about the implementation results obtained by the agent.

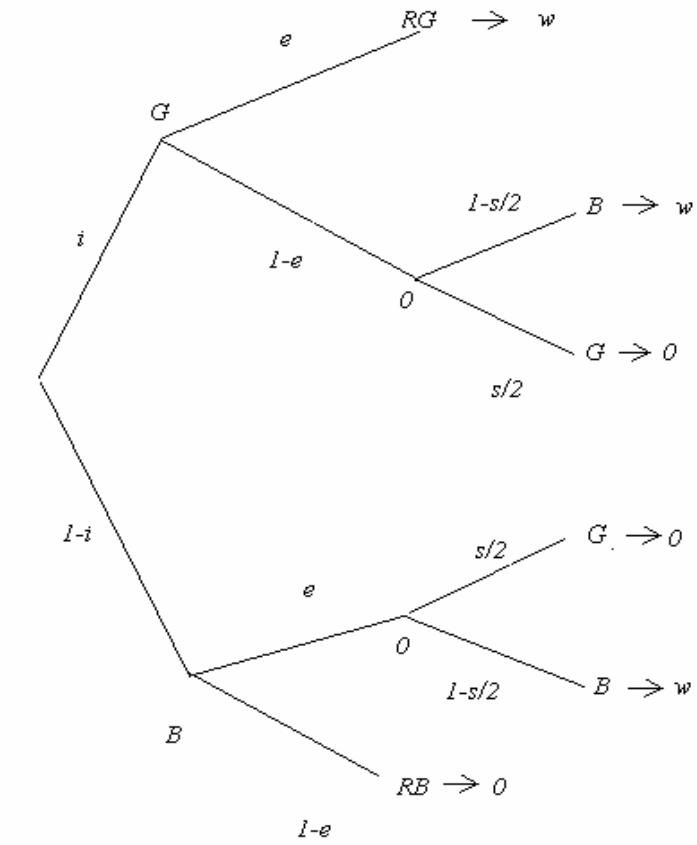
The success probability of project selected by the principal depend on his ability and information availabity, denoted by i_p. However, thanks to his participation at the ideation and development stages, he obtains additional information on the effective nature (bad or good) of the selected project. We assume that in evaluating the quality of the selected project, the principal makes errors of judgement: if the project is good, he is able to realize this with probability $\left(1-\frac{s}{2}\right)$, while he erroneously believes that the project is bad with probability $\left(\frac{s}{2}\right)$. On the other hand, he realizes that the project is bad with probability $\left(1-\frac{s}{2}\right)$ when the project is effectively bad. Therefore, *s* represents the importance of evaluation errors. If $s=0$, the evaluation is accurate, while if $s=1$ the principal is not able to make any useful inference from her observation (good or bad projects are equally probable).[3]

We assume that the quality of the project is observable only ex-post, but it is never verifiable by a Court. In hierarchy, the quality is observable both by the principal (who selects the project) and by the agent (who implements it). In delegation, only the agent is able to observe the project's quality.

Under the hierarchical system, the additional information obtained during the development stage allows the principal, once the project pay-off becomes known, to make inference on the agent effort. This is relevant when the observed pay-off is zero. In fact, the principal pays a positive wage w_H if results are good (*G*) and a wage equal to zero if results are bad (*B*) (as in delegation) (in both cases there is an unambiguous information on the level of effort provided by the agent). On the other hand, when revenues are zero, the principal pays w_H if the project's quality is judged bad (in this case, low revenues are not the agent's fault) while a zero wage is paid if the project's quality is judged good (low revenues are caused by a bad

[2] This assumption is not crucial for our results, but helps in simplifying calculations.
[3] Raith (2005) uses a similar assumption to take into account errors of judgement.

implementation). Figure 1 shows agent's payments in each possible circumstance. We assume that reputational considerations (not modelled explicitly) induce the principal not to renege on wage payment even if quality project is not verifiable.



Therefore, it follows that while under delegation the compensation scheme used by the firm to give incentive to the agent consists of paying him a remuneration related to the outcome realized through the implementation of projects, which is assumed fully verifiable, under hierarchy the principal pays a positive wage even when a pay-off of zero is realized if he infers that the result is due to a project of bad quality. In this way, given certain conditions, the principal, using this additional information, can insure the agent.

In both system, however, since workers are risk adverse and outcomes are stochastic, the performance-related pay system makes it costly to provide incentives and prevents the attainment of first-best solutions.

Delegation

Since under the decentralized organizational system the agent obtains the wage bonus only if a positive performance ($G>0$) is observed, his utility U is given by the benefits deriving from obtaining the bonus w_D, which occurs with probability ei_A (the probability that the projects selected by the agent is good and that the implementation is good), minus the cost deriving from the disutility of effort:

[2] $$U^D = ei_A w^\alpha - \frac{\gamma e^2}{2}$$

The agent decides the optimal level of effort maximizing [2], from which we obtain the following first order condition:

[3] $$\frac{\partial U^H}{\partial e} = i_A w^\alpha - \gamma e = 0$$

The agent reaction function is given by:

[4] $$e_D = \left[\frac{i_A w^\alpha}{\gamma} \right]$$

From the reaction function [4] we can determine the wage the firm has to pay for any given level of effort:

[5] $$w_D = \left[\frac{\gamma e}{i_A} \right]^{\frac{1}{\alpha}}$$

Hierarchy

Under this organizational structure the agent provides effort on projects based on the information available to the principal. As discussed above, during the project realization, the principal observes, even if not perfectly, the quality of the project at hand.

The incentive scheme designed by the firm consists of the payment of a wage w both when a good project is realized (and hence a positive profit is obtained) and when the pay-off obtained is equal to zero but the principal believes that it is due to the bad quality of the selected project. On the other hand, a wage equal to zero is paid when a bad result is observed ($R=B<0$) and when the principal believes that a good project has been damaged by the low effort provided by the agent.

Alternatively, the principal has the possibility of compensating the agent exclusively on the basis of output (as in delegation), that is, paying a positive wage when a profit is realized (G) and zero in the other cases. We analyze below the condition that induces the principal to use

the incentive system based on his subjective evaluation of agent's activity rather than paying him on the basis of output.

The agent's expected utility *U* is given by the utility deriving from obtaining the bonus *w* (see Figure 1), minus the cost deriving from the disutility of effort:

[6] $$U^H = i_P\left(1-\frac{s}{2}\right)ew^\alpha + i_P\left(\frac{s}{2}\right)ew^\alpha + i_P\left(\frac{s}{2}\right)(1-e)w^\alpha + (1-i_P)\left(1-\frac{s}{2}\right)ew^\alpha - \frac{\gamma e^2}{2}$$

which can be written as:

[7] $$U^H = \left[i\frac{s}{2} + e\left(1-\frac{s}{2}\right)\right]w^\alpha - \frac{\gamma e^2}{2}$$

Note that if $s=0$ the principal can pay a wage on the basis of the results of implementation stage, which are directly related to the agent's effort, avoiding that the quality of her job influences the agent's utility.

By maximizing the utility function with respect to the effort *e*, the agent's reaction function can be derived from the following first-order condition:

[8] $$\frac{\partial U^H}{\partial e} = \left(1-\frac{s}{2}\right)w^\alpha - \gamma e = 0$$

which gives the agent's optimal effort given the wage:

[9] $$e_H = \left(1-\frac{s}{2}\right)\frac{w^\alpha}{\gamma}$$

The reaction function [9] can also be expressed in terms of the wage that the firm has to pay for any given level of effort:

[10] $$w_H = \left(\frac{\gamma e}{1-\frac{s}{2}}\right)^{\frac{1}{\alpha}}$$

This wage depends on the probability that the principal incurs in erroneous evaluation, but is not affected by the quality of his information.

If the principal uses the compensation system based on output under hierarchy, it is easy to show that the effort level obtained for a given wage is $\hat{e}_H = \left[\frac{i_P w^\alpha}{\gamma}\right]$. Obviously, the principal finds it optimal to choose the system who insures a higher effort at the same cost. Therefore, a necessary but not sufficient condition for using the first method is that it allows a higher level of effort , which happens when: $e_H = \left(1-\frac{s}{2}\right)\frac{w^\alpha}{\gamma} > \hat{e}_H = \left[\frac{i_P w^\alpha}{\gamma}\right]$, that is:

[11] $$\left(1-\frac{s}{2}\right) > i_P$$

The principal adopts the incentive system based on the subjective evaluation of effort if at least his errors of evaluation (*s*) are not too large with respect to his ability in selecting projects: $s < 2(1-i_P)$. However, it has to be considered, that the higher effort obtained under hierarchy may imply highe costs in terms of wages. Whether it is worth while to sustain these costs is a complex issue and depends, among other thinks, on the revenues obtained thanks to the higher effort provided by the subordinate.

A comparison of effort level under hierarchy and delegation

We have shown that under the two organizational forms different amount of information are available to the principal and, therefore, different compensation methods can be implemented.

In order to evaluate hierarchy and delegation exclusively from the point of view of incentives, we can compare the effort levels determined in the two organizational forms by a given wage (eq. [5] and [10]). A hierarchical organization leads to better incentives if $e_H > e_D$, that is:

[12] $$\left(1-\frac{s}{2}\right) > i_A$$

Delegation can results more efficient in giving incentives if the agent has good information (i_A is high), and therefore the agent provides effort expecting to obtain good results with a high probability, or when the errors of judgement of the principal are high, since this generates high uncertainty for the agent paid according to the compensation system based on the principal's subjective evaluation.

A more *comprehensive* efficiency comparison between delegation and hierarchy is very complex in the continuous framework we have adopted in this section. Since the wage cost necessary to induce the agent to provide effort differs, it follows that optimal effort levels chosen under the two structures differ too, making a comparison unmanageable. In the next section, we assume discrete level of effort in order to simplify the framework and proceed to a comparison, neutralizing the effects arising from the choice of different levels of effort.

3. Discrete levels of effort

In this Section we aim to compare benefits and costs deriving from the two organizational structures, neutralizing the effects arising from the choice of different levels of effort. This can

be done by assuming that the effort is a discrete variable, which can takes only two values: the agent can provide a high effort, e_h, or a low effort, e_l, where $e_h > e_l$.

When effort is e_h, the probability of obtaining a good result in the implementation stage (E^G) is equal to p_h, while with probability $(1-p_h)$ the implementation is unsuccessful (E^B). On the contrary, when effort is low e_l, the probability of obtaining a good result in the implementation stage (E^G) is equal to p_l, while with probability $(1-p_l)$ the implementation is unsuccessful (E^B). Obviously, $p_h > p_l$. The agent's cost of providing high effort is equal to c_h and the cost for low effort is equal to c_l, with $c_h > c_l$.

As in Section 2, we assume that a profitable project (*G*) is obtained if (E^G) matches with (Q^G), and so on, as in Table 1.

Delegation

Under the delegation system the agent receives a bonus w_D only if a good pay-off, *G*, is realized.[4] Then, the incentive compatibility constraint is equal to:

[13] $$p_h i_A {w_D}^{\alpha} - c_h > p_l i_A {w_D}^{\alpha} - c_l$$

where on the left-hand side is represented the expected utility deriving from high effort, while on the right-hand side is indicated the utility deriving from low effort. From [13], the bonus, w_D, paid by the firm is equal to:

[14] $$w_D = \left[\frac{c_h - c_l}{(p_h - p_l) i_A}\right]^{\frac{1}{\alpha}}$$

w_D is increasing in i_A and in the difference between c_h and c_l, decreasing in the difference between $(p_h - p_l)$ (a measure of effort observability), decreasing in α (a more risk-averse agent needs a higher wage).

The firm's profits under delegation are equal to:

[15] $$\Pi^D = p_h i_A (G) + (1-p_h)(1-i_A)B - p_h i_A w_D$$

[4] In the Appendix we show that it is optimal for the firm to pay no wage when the realized pay-off is equal to zero.

substituting in [15] the incentive compatibility constraint, we obtain:

[16] $$\Pi^D = p_h\left[i_A(G+B)-B\right]+(1-i_A)B-p_h i_A\left[\frac{c_h-c_l}{(p_h-p_l)i_A}\right]^{\frac{1}{\alpha}}$$

Hierarchy

Under a hierarchical organization, if the agent provides high effort, he obtains a positive wage *w* when the project gives a profit of *G*, with probability $i_p p_h$. Moreover, the same bonus is obtained when the pay-off reached by the organization is equal to zero, but the principal (correctly or erroneously) believes that it was not imputable to a bad project implementation, which happens with probability $\left[i_p\frac{s}{2}(1-p_h)+(1-i_P)\left(1-\frac{s}{2}\right)p_h\right]$. A similar reasoning can be made when effort is low, substituting p_h with p_l.[5]

The agent will provide the high level of effort only when the utility deriving from a high effort is higher than the utility deriving from a low effort, that is, when the incentive compatibility condition is satisfied::

[17] $$\left[i_P\frac{s}{2}+p_h\left(1-\frac{s}{2}\right)\right]w_h{}^{\alpha}-c_h \geq \left[i_P\frac{s}{2}+p_l\left(1-\frac{s}{2}\right)\right]w_h{}^{\alpha}-c_l$$

The incentive compatibility condition implies that, in order to obtain high effort from the agent, the principal has to pay a bonus w_H equal to:

[18] $$w_H=\left[\frac{c_h-c_l}{(p_h-p_l)\left(1-\frac{s}{2}\right)}\right]^{\frac{1}{\alpha}}$$

The wage is increasing in evaluation errors, s, and it is lower than the optimal wage paid under delegation if $\left(1-\frac{s}{2}\right)>i_A$, that is if the principal's probability of observing the agent's effort is higher that the agent's probability of selecting a good project.

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[5] As discussed in the previous section, under the hierarchical system this kind of compensation system is used instead of an output related pay, as that used under delegation, only if at least $\left(1-\frac{s}{2}\right)>i_p$. This condition is necessary but not sufficient.

We suppose that, given the impossibility to impose a negative wage, the utility the individual obtains providing a high effort is higher than his reservation utility. This means that the participation constraint is not binding.

The profits obtained by the firm, under the hierarchical structure, are equal to:

$$[19] \qquad \Pi^H = p_h i_P G + (1-p_h)(1-i_P)B - \left[i_P \frac{s}{2} + p_h \left(1 - \frac{s}{2} \right) \right] w_h$$

substituting [18] in [19], we obtain:

$$[20] \qquad \Pi^H = p_h i_P G + (1-p_h)(1-i_P)B - \left[i_P \frac{s}{2} + p_h \left(1 - \frac{s}{2} \right) \right] \left[\frac{c_h - c_l}{(p_h - p_l)\left(1 - \frac{s}{2} \right)} \right]^{\frac{1}{\alpha}}$$

In the following sections we will compare the two systems taking in mind that this comparison represents an interesting case especially when $i_p < i_A < 1 - \frac{s}{2}$. In fact, if $i_p > 1 - \frac{s}{2}$, the hierarchical system will use the same compensation system used under delegation and the relative advantage of an organizational system respect to the other will exclusively depend on i_A and i_p. On the other hand, if $i_p < 1 - \frac{s}{2}$, but $i_A > 1 - \frac{s}{2}$, the delegation system will always prevail. A special case emerges when $i_p = i_A < 1 - \frac{s}{2}$.

3.1. A comparison of firm's expected wage costs

Wage premium are paid with different probabilities under the two organizational forms. Therefore, the expected wage costs can be different from wage bonus.

The expected wage costs results higher under the delegation system than under hierarchy, when:

$$[21] \qquad i_A p_h \left[\frac{c_h - c_l}{(p_h - p_l) i_A} \right]^{\frac{1}{\alpha}} > \left[i_P \frac{s}{2} + p_h \left(1 - \frac{s}{2} \right) \right] \left[\frac{c_h - c_l}{(p_h - p_l)\left(1 - \frac{s}{2} \right)} \right]^{\frac{1}{\alpha}}$$

that is when:

[22] $$i_A p_h \left[\frac{1-\frac{s}{2}}{i_A}\right]^{\frac{1}{\alpha}} > \left[i_P \frac{s}{2} + p_h\left(1-\frac{s}{2}\right)\right]$$

This inequality is more likely to be true, that is wage costs for the firm are relatively higher under delegation when:

1) i_A decreases (since the Left-Hand Side (LHS) is decreasing in i_A). Delegation is worse as regards to wage costs when agent's information is lower. This because it becomes more difficult to provide incentives to the agent if the probability of success is lower (he will obtain less frequently the wage bonus);

2) i_P decreases (since the Right-Hand Side (RHS) is increasing in i_P). Wage costs under hierarchy are lower when i_P is lower. The reason is clear, even if this can appear surprising: since the principal can make errors, these are more costly when projects are of good quality, because the principal has to pay a positive bonus in spite of a bad project implementation by the agent. However, if s=0 then an increase in the principal's abilities will produce no negative effect on the wage costs in hierarchy.

3) α is lower (that is, when agent's risk aversion increases) under the condition that $1-\frac{s}{2} > i_A$. In fact, in this case the LHS is decreasing in α:

[23] $$\frac{\partial LHS}{\partial \alpha} = -\frac{1}{\alpha^2}\left[\frac{1-\frac{s}{2}}{i_A}\right]^{\frac{1}{\alpha}} \log\left[\frac{1-\frac{s}{2}}{i_A}\right] < 0$$

If the principal's evaluation in hierarchy is not too noisy, hierarchy performs better the higher the agent's risk aversion: the principal can insure the agent against risk thank to her subjective evaluation of agent's effort. When the degree of risk aversion increases, the decentralized system has to pay higher wages to compensate the agent for the higher risk he suffers compared to the hierarchical system which allows wages to be less affected by uncertainty.

4) *s* decreases. This can be seen writing the inequality [22] as: $i_A p_H \left[\frac{1}{i_A}\right]^{\frac{1}{\alpha}} > \frac{\left[i_P \frac{s}{2} + p_H\left(1-\frac{s}{2}\right)\right]}{\left[1-\frac{s}{2}\right]^{\frac{1}{\alpha}}}$ and deriving the RHS with respect to *s*:

[24] $$\frac{\partial RHS}{\partial s}=\frac{\left(1-\frac{s}{2}\right)^{-\frac{1}{\alpha}}\frac{1}{2}\left[i_P+\frac{1}{\alpha}i_P s\left(1-\frac{s}{2}\right)^{-1}+p_H\left(\frac{1-\alpha}{\alpha}\right)\right]}{\left[1-\frac{s}{2}\right]^{\frac{2}{\alpha}}}>0$$

An higher probability of incurring in errors increases the wage bill paid under hierarchy.

3.2. Determinant factors in the choice between hierarchy and delegation

The principal will choose the hierarchical structure when $\Pi^H > \Pi^D$ and instead she will adopt the decentralized structure if the opposite holds.

Defining the profits differential between hierarchy and delegation as $\Delta\Pi_{H-D}=\Pi_H-\Pi_D$ and substituting in it equations [20] and [16], we obtain:

[25]

$$\Delta\Pi_{H-D}=(i_P-i_A)[p_h(G+B)-B]-\left\{\left[i_P\frac{s}{2}+p_h\left(1-\frac{s}{2}\right)\right]\left(1-\frac{s}{2}\right)^{-\frac{1}{\alpha}}-\frac{p_h}{i_A^{\frac{1-\alpha}{\alpha}}}\right\}\left[\frac{c_h-c_l}{p_h-p_l}\right]^{\frac{1}{\alpha}}$$

where the first term on the RHS is the difference in expected revenues and the second term represent differences in expected wage costs. The key comparative static results are obtained analysing how this differential is affected by changes in the relevant variables.

The relative advantages of hierarchy reduces when the agent's ability i_A, increases:

[26] $$\frac{\partial\Delta\Pi_{H-D}}{\partial i_A}=-[p_h(G+B)-B]-\left(\frac{1-\alpha}{\alpha}\right)i_A^{-\frac{1}{\alpha}}p_h\left[\frac{c_h-c_l}{p_h-p_l}\right]^{\frac{1}{\alpha}}<0$$

This happens both because of a better selection of projects and because the agent's effort becomes less costly. It follows that better educated workers, who are more apt at gathering and elaborating information for the selection of good projects, are more likely to obtain delegation.

An increase in the principal abilities i_P produces a more complex effect and the sign of derivative is ambiguous:

[27] $$\frac{\partial\Delta\Pi_{H-D}}{\partial i_p}=[p_h(G+B)-B]-\frac{s}{2}\left[\frac{\frac{c_h-c_l}{p_h-p_l}}{\left(1-\frac{s}{2}\right)}\right]^{\frac{1}{\alpha}}$$

On the one hand, a higher i_P increases revenues for hierarchy deriving from the implementation of good projects, while, on the other hand, as we have seen above, it produces an increase in the total wage paid to the agent independently of his effort. Being able to select good projects does not allow the provision of better incentives, at least if this does not produce a reduction in the probability of incurring in errors in the evaluation of each single project. It simply increases the cost of the insurance that the principal provides to the agent: when the evaluation error in which incurs the principal is lower compared to the agent probability of selecting a good project, hierarchy provides better incentives but at a cost in terms of total wage paid to the worker.

Since the relative advantage of the hierarchical system is its ability to allow a better evaluation of the agent's effort, thanks to the principal's ability of evaluating subjectively the agent's effort, the performance of the hierarchical system worsens when the probability of erroneous evaluations *s* increases:

[29]

$$\frac{\partial \Delta\Pi_{H-D}}{\partial s} = -\left(1-\frac{s}{2}\right)^{-\frac{1}{\alpha}} \frac{1}{2}\left[i_P + \frac{1}{\alpha} i_P s \left(1-\frac{s}{2}\right)^{-1} + p_h\left(\frac{1-\alpha}{\alpha}\right)\right]\left[\frac{c_h - c_l}{p_h - p_l}\right]^{\frac{1}{\alpha}} < 0$$

This results corresponds to the result on the difference in expected wage costs (eq. [24]).

Assuming that the agent's information is better that the information available to the principal $(i_P - i_A) < 0$, the relative advantage of hierarchy decreases when positive payoffs G increase:

[29] $$\frac{\partial \Delta\Pi_{H-D}}{\partial G} = (i_P - i_A) p_H < 0$$

and when negative pay-offs B increase in absolute value:

[30] $$\frac{\partial \Delta\Pi_{H-D}}{\partial B} = (i_P - i_A)(p_H - 1) > 0$$

Two special cases worth to examine are when the principal does not make errors of evaluation $(s = 0)$ and when the information available to principal and agent are equal $(i_P = i_A)$.

When $s = 0$, hierarchy as an advantage in terms of wage costs (the second term on the RHS of [25] is positive) and this has to be compared with the difference in the expected revenues due to different information:

[31] $$\Delta\Pi_{H-D} = (i_P - i_A)[p_h(G+B) - B] - p_h\left\{1 - \frac{1}{i_A^{\frac{1-\alpha}{\alpha}}}\right\}\left[\frac{c_h - c_l}{p_h - p_l}\right]^{\frac{1}{\alpha}}$$

When $i_P = i_A$, the profits differential is equal to:

$$[32] \qquad \Delta\Pi_{H-D} = -\left\{ i\frac{s}{2}\left(1-\frac{s}{2}\right)^{-\frac{1}{\alpha}} + p_H\left[\frac{1}{\left(1-\frac{s}{2}\right)^{\frac{1-\alpha}{\alpha}}} - \frac{1}{i^{\frac{1-\alpha}{\alpha}}}\right]\right\}\left[\frac{c_H - c_L}{p_H - p_L}\right]^{\frac{1}{\alpha}}$$

and it results positive only if the following condition is respected:

$$[33] \qquad p_h > -\frac{i\frac{s}{2}}{\left(1-\frac{s}{2}\right)\left[1-\frac{1}{\left[\left(1-\frac{s}{2}\right)i\right]^{\frac{1-\alpha}{\alpha}}}\right]}$$

which is less likely to be respected when i increases, since the RHT increases when i increases.

$$[34] \qquad \frac{\partial RHS}{\partial i} = \frac{\frac{s}{2}\left(1-\frac{s}{2}\right)\left[1-\frac{1}{\left[\left(1-\frac{s}{2}\right)i\right]^{\frac{1-\alpha}{\alpha}}}\right] - \frac{is}{2}\frac{(1-\alpha)}{\alpha}\left[\frac{i^{-\frac{1}{\alpha}}}{\left[\left(1-\frac{s}{2}\right)\right]^{\frac{1-\alpha}{\alpha}}}\right]}{\left\{\left(1-\frac{s}{2}\right)\left[1-\frac{1}{\left[\left(1-\frac{s}{2}\right)i\right]^{\frac{1-\alpha}{\alpha}}}\right]\right\}^2} < 0$$

which is negative since the first term at the numerator is negative.

4. Concluding remarks

In this paper we have compared two different organizational structures: one in which projects are selected according to the principal information and implemented thanks to the agent effort (hierarchy) and another in which both the ideation and the implementation stage are assigned to the agent.

As widely recognized by the existing literature, we show that the choice between the two systems is strictly related to the amount and quality of the information available respectively to

the agent and to the principal. However, in this comparison we introduce a new element: independently from the availability of good information, the hierarchical system, thanks to the principal participation at the project ideation and development, allows for additional information compared to the delegation system, which can be used to evaluate the agent effort during the implementation stage. For example, the principal having observed a number of signals that denote difficulties in the development stage may be able to recognize that an unsatisfactory result is not due to a poor implementation, but instead to problems in the project development.

Whether these signals allow for a more or less precise evaluation may depend on the relative importance that factors related to the project development have for obtaining successful results compared to external factors, which are out of the principal's control. In a very uncertain context even well developed projects may determine negative pay-off and viceversa. In this case, the principal ability to evaluate the project quality may result undermined.

Thanks to the additional information available to the principal, under the hierarchical system it is possible to adopt a compensation scheme that induces higher effort compared to delegation even if the agent is endowed with better information compared to the principal. In fact, we show that when the principal evaluation is sufficiently precise (the probability of recognizing the effective quality of selected projects, is higher than the agent probability of selecting a good project), the hierarchical system induces a higher level of effort. We show that this advantage results particularly relevant when the agent risk-aversion increases.

However, for a more comprehensive efficiency comparison we need to compare the profits obtained under the two organizational systems. We show that the relative advantage of the hierarchical system reduces when the agent ability increases, both because of a better selection of projects and because the agent's effort becomes less costly. It follows that better educated workers, who are more apt at gathering and elaborating information for the selection of good projects, are more likely to obtain delegation. An increase in the principal ability produces a more complex effect: on the one hand, a higher i_P increases revenues for hierarchy deriving from the implementation of good projects, while, on the other hand, it produces an increase in the total wage paid to the agent independently of his effort.

Finally, the relative advantage of hierarchy increases when the principal evaluation errors decrease.

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APPENDIX

Throughout the paper we have made the assumption that under the delegation system, the agent receives a bonus only when a good result, *G*, is observed, while when the pay-off is zero or negative he receives a wage equal to zero.

Since under our assumptions the wage is equal to zero both in case of zero and negative pay-offs, it emerges as a natural question whether this compensation system is optimal or whether it would be better to pay different wages in these two cases. In this appendix we aim to show that paying zero both in case of a zero and a negative payoff represents a optimal strategy for the firm.

Let us suppose that the firm, under delegation, pays two different bonuses: w_1 is paid when the pay-off G is observed, while the bonus w_0 is paid when the pay-off is equal to zero, with $w_1 > w_0$. We continue to assume that in case of a negative pay-off, B, the worker obtains zero because of a limited liability constraint.

In the discrete framework, under these assumptions, the utility the agent gets when provides a high level of effort can be represented by the following equation:

[A.1] $$U_{e_h} = i_A p_h (w_1)^{\frac{1}{\alpha}} + \left[i_A (1 - p_h) + (1 - i_A) p_h \right] w_0^{\frac{1}{\alpha}} - c_h$$

With probability $i_A p_h$ a good result is obtained and the agent gains w_1, while when the pay-off is equal to zero his wage reduces to w_0 and vanishes when the pay-off reached by the organization is negative. The utility obtained by the agent is reduced by the cost of his effort.

A similar equation can be written for the agent's utility when he provides a low level of effort:

[A.2] $$U_{el} = i_A p_l (w_1)^{\alpha} + \left[i_A (1 - p_l) + (1 - i_A) p_l \right] (w_0)^{\alpha} - c_l$$

The incentive compatibility constraint (ICC) requires that $U_{e_h} > U_{el}$ from which we obtain the combination of wages w_1 and w_0 that insures the respect of this constraint:

[A.3] $$w_1 \geq \left[\frac{c_h - c_l}{(p_h - p_l) i_A} + \frac{(2 i_A - 1) w_0^{\alpha}}{i_A} \right]^{\frac{1}{\alpha}}$$

Assuming that $i_A > \frac{1}{2}$ (otherwise we would have the implausible result that the agent selects bad projects more often than good projects), the ICC is increasing and has a positive intercept in the plane with w_1 and w_0 (Figure 1).

The firm decides the optimal level of w_1 and w_0, maximizing profits, which are equal to:

[A.4] $$\Pi = i_A p_h (G - w_1) + (1 - p_h)(1 - i_A)B - [i_A(1 - p_h) + (1 - i_A)p_h]w_0$$

We can represent this choice graphically in the plane w_1 and w_0, representing in the plane with w_1 and w_0 the isoprofit curves obtained from each given level of profit $\overline{\Pi}$ and expressed as:

[A.5] $$w_1 = \frac{[i_A p_h G + (1 - p_h)(1 - i_A)B - \overline{\Pi}]}{i_A p_h} - \frac{[i_A(1 - p_h) + (1 - i_A)p_h]}{i_A p_h} w_0$$

The isoprofit curves are clearly decreasing in w_0 and higher profits are associated to lines near the origin of the axis.

Since the ICC is increasing, it is immediate that the firm will always choose to set $w_0 = 0$ (point A in Figure 1), since with this wage it is possible to reach a lower isoprofit curve, corresponding to higher profits.

It follows that under the delegation system it is always an optimal strategy for the firm to set $w_0 = 0$, consistently with the assumption made throughout the paper.