Escola de Pós-Graduação em Economia - EPGE
Fundação Getulio Vargas

Organizational Design and Incentive Provision

Dissertação submetida à Escola de Pós-Graduação em Economia da Fundação Getulio Vargas como requisito para obtenção do Título de Mestre em Economia

Aluno: Cristiano Machado Costa

Orientador: Humberto Luiz Ataíde Moreira

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(Stockholm School of Economics)

Rio de Janeiro
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Contents

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Abstract

We model the trade-off between the balance and the strength of incentives implicit in the choice between hierarchical and matrix organizational structures. We show that managerial biases determine which structure is optimal: hierarchical forms are preferred when biases are low, while matrix structures are preferred when biases are high. Moreover, the results show that there is always a level of bias for which matrix design can achieve the expected profit obtained by shareholders if they could directly control the firm. We also show that the main trade-off, i.e., hierarchical versus matrix structure is preserved under asymmetric levels of bias among managers and when low-level workers perceive activities with complementary efforts.

1 Introduction

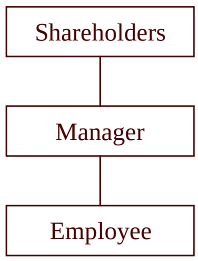
One of the most studied topics in microeconomic theory is the existence of the firm and its internal interactions. Coase (1937) argues that intra-firm relations substitute the price system when transaction costs within organizations are lower. In the same context, Arrow (1974) defined an organization as “a mean of achieving the benefits of collective action in situations in which the price system fails”. Behind these two statements is the idea that firms are constituted when the market does not provide the efficient response to the needs of an entrepreneur. However, many difficulties may arise when transactions are implemented inside a firm. More precisely, constituting a firm to reduce transaction costs or because markets are not efficient does not mean that it will work perfectly.

There are many ways to organize tasks among workers in a firm and these options may interfere directly with a firm’s performance. In practice, when choosing the organizational design of a firm, owners decide how the labor will be divided, what kind of relationships will exist among workers (including coordination, authority and agency aspects), and how information will flow within the firm. The choice of an optimal design for a firm must take into account all the sources of inefficiency that may arise from the fact that transactions are now evaluated inside an organization. Examples of problems related to the optimal firms’ design are: the choice of optimal mechanisms of rewards, the distribution of tasks among employees, the share of risk implied by contracts, the information flows and the motivational issues. Therefore, the choice of the internal organization is fundamental to achieve the firm’s main objectives, and it is an important aspect concerning the provision of incentives.

Firms should not believe that workers have their interest aligned to the owners’ objectives or that it will occur without any cost. The design of internal structures and the use of efficient reward mechanisms constitute important ways to provide these incentives. In fact, organizations’ internal design and incentive schemes could be used together for this purpose. On one hand, organizations’ design defines the nature of the agency problems within a firm and provides workers with the information, coordination, and incentives needed to properly implement the owners’ objective. On the other hand, reward systems determine the power and the direction of the workers’ effort. In summary, we can deduce that one of the aims of organizational design - together with the use of reward mechanisms - should be to obtain the alignment between the purposes for the firm existence and the workers’ interests.

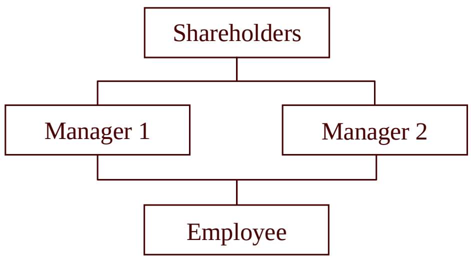
Observing the structures used by large organizations we can find many different organizational forms[1]. For example, it is not rare to observe two firms adopting different internal structures even when engaging in the production of identical goods. In a very simplified way, we can divide all the possible forms of internal organization into two large groups. The first one includes all structures where each employee is subordinated to just another employee. This kind of internal design is called *hierarchical structure*. This first group includes, for example, flat, multidivisional (M-forms), and the unitary functional structures (U-forms). The simplest structure that can be used to illustrate this group is a shareholders-manager-employee organization (Figure 1).

Figure 1: Hierarchical Internal Design



The second group includes the structures in form of a matrix, where one employee may be subordinated to two or more supervisors. This internal organization design is called *matrix structure*. A simple example of a matrix structure is given below (Figure 2).

Figure 2: Matrix Internal Design



[1] This issue is well known in the economics and business administration literature. Chandler (1962) developed an important study of the different forms of internal organizations implemented by four American corporations (Du Pont, General Motors, Standar Oil and Sears) in the beginning of the last century. He emphasizes the differences between the use of functional and multidivisional structures. After his work, many others authors have dedicated their research hours to study the many aspects of each form of structure. Nowadays, the main internal structures used by firms include the multidivisional, functional, flat, matrix and network forms. For a brief discussion of these forms see Besanko et al. (2000, ch. 16)

The existence of different forms of internal organization does not mean that one firm can not use a combination of structures. For example, a firm may use a hierarchical structure in the initial nodes of interaction and after a determinate level it may use a matrix structure. This is perfectly possible and vastly observed in larger organizations. Therefore, one of the most important questions in the study of organizations is what determines the use of different structures and what are its consequences.

Using the agency theory approach, this work seeks to add a new element to this discussion. We model a situation where a group of shareholders wants to implement a strategy based on the outputs produced by the firm. If one views subordinates as agents and superiors as principals, the choice between hierarchical and matrix structures can also be seen as a choice between one or multiple principals. The main objective is to model the choice between hierarchical and matrix structures when these two structures provide different incentives for lower-level agents.

We adopt the same setup as in Dixit (1996), which is actually a multiprincipal version of the well-known Holmström and Milgrom (1991) linear contracts model. The model considers a situation in which the employee (the agent) must exert effort into many different activities and this effort is not observable, constituting a moral hazard problem in the lower-level. There might be either one or many managers (the principals) who may benefit from the outcome generated by the agent's effort. Dixit (1996) is concerned with comparing a situation in which many principals compete with each other by offering incentive contracts to the agent, each one caring about only one of the activities, with a situation in which the same principals collude and offer a single contract to the agent. This modeling strategy is well suited for Dixit's purpose, i.e., to explain the perceived low power of incentives provided to government agencies, taking the multiprincipal nature of political representation as given. However, this approach does not appear to be useful in explaining organizational design, because the outcome under collusion always dominates the case in which principals compete, implying that there is no trade-off between the two cases. Thus, in order for this approach to have any explanatory power for organizational design, collusion among principals can not be possible. Actually, the collusion solution is obtained when we suppose that shareholders are directly managing the firm[2].

[2] When shareholders directly manage the firm the collusion solution is obtained. However, this result is a second-best solution due to the hidden action problem in the lower level of the structure.

We modify Dixit's setup in the following manner: we assume that the organizational designer's task is to choose the number of principals for a given agent, but principals are unable to collude and write binding agreements with each other. We then show that the choice between hierarchical (one principal) and matrix (many principals) structures depends crucially on the *biases* of the potential principals (managers). We will say that a manager is *biased* when his preferences are not fully aligned with shareholders' ones. In our model, it means that a *biased manager* will give less weight to one of the activities than shareholders do. Moreover, it means that the manager attributes more weight to the activity that he is biased to, relatively to the other. It implies an unbalanced weight of activities for different types of managers. Our definition of bias can be interpreted as a relative measure. It is simply the level of conflict between the manager and the shareholders objectives.

If principals' preferences are such that they are heavily biased towards some activities, the hierarchical structure performs poorly because the single principal's bias will distort the incentive schedule offered to the agent towards his preferred activity, leading to an unbalanced distribution of incentives across activities. In such a case, the matrix structure might be preferable, because competition among principals partially offsets the effect of their individual biases on the incentive structure as perceived by the agent. However, the matrix structure leads to the traditional kind of distortions associated with common agency problems: the power of incentives might be too small under many principals, an effect emphasized by Martimort (1996) and Dixit (1996), or it might also be too large, as we will show below. In either case, common agency generically leads to incentives that are either too weak or too strong. We conclude by arguing that our approach can be used to describe the choice between hierarchical and matrix structures as a trade-off between *strength* and *balance* of incentives they provide to lower-level workers.

The remainder of the article is organized as follows. Section 2 presents a brief review of the literature in organizational design theory. In Section 3, the basic principal-agent problem is described and the possible solutions (shareholders control, hierarchical design and matrix design) are explored. The choice of an optimal organizational form is characterized in Section 4. Finally, Section 5 presents some interesting extensions of the basic model and Section 6 concludes.

2 Relation to the Literature

The economic theory of organizational design has tried to explain the choice of internal structure from different approaches. Chandler (1962) argued that the choice of an internal design must follow strategic decisions. The main idea behind Chandler's statement is that, implementing a specific strategy, the internal structure will affect workers in three important ways: information flow, coordination among tasks and provision of incentives. All these links between strategy (or performance) and structure have been explored in the literature.

The information system approach analyzes the relationship between the internal design of firms and the flow of information among workers. It attempts to investigate how these informational transactions may affect the performance of the firm. In this approach, the internal design problem is viewed as the optimal choice of channels through which information flows.

Sah and Stiglitz (1986) argue that the internal design of a firm "describes how the decision-making authority and ability are distributed within a system, who gathers what information, and who communicates what with whom". The authors focus the analysis on the quality of decision-making. The costs of acquiring and communicating information, the distribution of available projects, and decision rules are the core of the argument. Sah and Stiglitz (1986) conclude that the "architecture" of an organization affects the errors made by individuals and the form that these errors are aggregated, and it leads to a trade-off between hierarchies and polyarchies. Radner (1993) interprets managers as information processors with limited capability. The efficiency of the system is measured in terms of the number of processors and the delays between the reception of information and the decision implementation. The main conclusion is that, in certain cases, efficiency in the class of all architectures can be obtained by structures in form of trees (hierarchical and matrix). Bolton and Dewatripont (1994) analyze how the internal structure can minimize the costs of processing and communicating information. The main idea of the article is that the benefits of specialization achieved by having many agents processing information are offset by the cost of communication among agents. The authors show that an efficient network involves some degree of centralization.

The choice of the internal structure also affects the problems of coordination between activities and agents. Garicano (2000) studies how knowledge is acquired in the relationships among individuals inside an organization. The author shows that a hierarchy, based on knowledge, is a natural way to organize a firm when matching

problems with those who know how to solve them are costly. Harris and Haviv (2002) try to explain the choice of an organization structure based on the optimal coordination of interactions among activities. They suppose that managers can coordinate interactions only in their area of expertise while the CEO can coordinate company-wide interactions. The different configurations of internal structure lead to different costs and benefits. The authors classify when the optimal design is hierarchical (functional, divisional or flat) or a matrix structure depending on these coordination expertises.

The relationship between the provision of incentive and optimal organizational structure has also been explored. Besanko, Regibeau and Rockett (1988) model the relationship between internal structure and incentives and generally support the value of the hierarchical divisional form. Maskin, Qian and Xu (2000) argue that different organizational forms lead to different performances because they differ in how incentives are provided. The authors show that, under certain assumptions, the multi-divisional form is preferable to the unitary form because it promotes yardstick competition more effectively. However, these works do not compare this two hierarchical structures (multi-divisional and unitary) with an alternative matrix structure.

This paper seeks to add a new element to this discussion using the agency theory literature as the basic framework. Holmström (1979) describes a situation where a principal can not observe the effort done by an agent, but only the output of this effort, characterizing a moral hazard problem. He showed that this situation may be solved using an optimal linear contract where the agent agrees to do the effort required by the principal when he receives a payment based on outcomes that can be observed. Holmström and Milgrom (1991) extend the model for the multitask case whereas Bernheim and Whinston (1986) consider a situation where several principals attempt to influence a common agent. Dixit (1996) links these two problems. He considers a common agency relationship where each principal has preferences for only one of the many outputs resulting from the efforts done by the agent. In our framework, we make use of this Dixit's approach to show that the choice between hierarchical (one principal) and matrix (many principals) structures depends crucially on the level of conflict between the potential managers and the shareholders objectives.

3 The Model

The firm can produce two different outputs: x_1 and x_2. These outputs result from tasks done by an employee (the agent). The agent can choose the level and how to distribute his effort between the two tasks, t_1 and t_2. The outcome can be modelled in a simple way as the effort done by the agent in the specific task plus an error term

$$x = t + e$$

where $x = [\ x_1,x_2]$, $t = [t_1, t_2]$, and $e = [e_1, e_2]$ are 2-dimensional vectors. We are assuming also that errors are normally distributed with mean zero and diagonal variance matrix Ω. Moreover, assume that errors are not correlated and have the same[3] finite variance σ.

The shareholders of the firm observe these two outcomes, but they do not observe the amount of effort done by the agent, characterizing the moral hazard problem. Shareholders are risk-neutral (their benefit functions are linear) and they assign the same weight to each outcome produced in the firm. Then, let ι denote the shareholders vector of marginal benefits. Without loss of generality we normalize $\iota = [1, 1]$, a vector of ones. Therefore, each good produced in the firm gives the same amount of benefit to shareholders. Furthermore, the shareholders have to groan with the cost of inducing the employee to work hard (w). The total shareholders' benefit is given by

$$L = \iota' x - w.$$

The agent's utility function has the property of constant absolute risk-aversion (CARA) and it is given by

$$u(w, t) = -\exp(-r\,[w - c\,(t)])$$

where w is the wage received by the agent, $c\,(t) = \frac{1}{2} t' C t$ is the cost of the effort done by the agent and r is the agent's absolute risk-aversion coefficient.

[3] Different from the original multi-task problem, we are assuming that the tasks done by the agent have the same variance. We are imposing this assumption because we do not want to create more sources of asymmetries from the model except the differences on the managers' preferences.

Hypothesis 1 *The cost of effort has a quadratic form where the matrix C is assumed to be positive definite and with cross-terms positives.*

That is, we will assume that the cost matrix has "ones" in the main diagonal and the elements of the secondary diagonal (denoted by s) are positives. This hypothesis means that the two efforts are substitutes and this substitution-effect is given by $s \in (0, 1)$ [4].

We will also assume that shareholders can not manage the firm directly. This assumption can be justified in a context where shareholders exercise many activities and do not have much time to control the agent. Our intuition says that it is not a strong assumption. For example, it is just the case where shareholders have a high opportunity cost or the control of the firm is diffused among small groups of shareholders. In a more general context, this hypothesis may justify also the existence of a board of directors in many big companies.

Hypothesis 2 *Shareholders can not directly manage the firm.*

Therefore, the firm must contract one manager (or more) to control the activities done by the agent. Managers may have different preferences in relation to the benefits of each activity. We will assume that managers can be of two different types or styles. Let $v \in [0, 1]$ denote how much the manager evaluates one of the activities.

Definition 1 (Type) *The type-1 manager has a vector of benefits given by $b_1 = [\,1 \;\; v\,]$, whereas the type-2 manager has a vector of benefits given by $b_2 = [\,v \;\; 1\,]$.*

We are concerned about the situation where managers are biased towards one of the two activities. This preference can be motivated by many sources. For example, a manager can appreciate more quality aspects whereas the other kind of manager may evaluate more the speed of the production. Or, in a more interesting case, managers may evaluate differently the short and long run periods. One kind of manager may give more value to short-run results, while the other kind of manager may give more credence to long-run outcomes. This unbalance in the managers' preferences can be defined as follow:

Definition 2 (Bias) *The bias of the manager is given by $\theta = 1 - v$. We will say that the manager is "biased towards activity i" if he is "type i" and $v < 1$.*

[4] In the section 5, we will relax this assumption and consider the case where efforts are complementaries, i.e., $s \in (-1, 0)$.

It means that a biased manager gives less weight to one of the activities than shareholders do. Moreover, it means that the manager attributes more weight to the activity that he is biased to, relatively to the other. It implies an unbalanced weight of activities for each type of the managers. The level of bias can be interpreted as a relative measure. It is simply the level of conflict between the manager and the shareholders objectives.

Finally, we can assume that there is a market for managers and the firm observes returns to scale when contracting managers. We are assuming that contracting one or two managers has the same zero cost[5]. In this setup, the shareholders can choose between two forms of organizational design. When the shareholders decide to contract only one manager we say that the firm has an *Hierarchical Design* and when they contract two managers we say that the firm has an *Matrix Design*. The shareholders' problem is to decide which internal design to use, given the managers available in the market. The choice of the optimal internal design will be the only instrument that shareholders can use to reduce the effect of the conflict of interests between them and the managers[6].

3.1 Shareholders Control

In this second-best solution[7] we assume that the shareholders can directly manage the firm. The shareholders can not observe the effort done by the agent, so they can not write a contract conditioned on agent's effort. The incentive scheme must be written in terms of the outcome of the agent's effort, which is observable. Holmström and Milgrom (1987) show that, in this setup presented above (CARA utility function, quadratic costs of effort, etc), we can restrict our analysis to a linear reward scheme. When the outcome is x, the linear contract can be represented by $w = \alpha' x + \beta$, where α is a 2-dimensional vector and β is a fixed transfer.

[5] This hypothesis clearly does not change the results. For example, consider the case where there is a constant and positive cost to hire each manager. In this case, the cost to hire managers under matrix design will be two times the cost under hierarchical design. Therefore, all results remain valid except for the fact that if these costs were too high, then the hierarchical design would be preferable.

[6] Someone may argue that we should regard the use of incentive contracts between shareholders and managers, or simply the case when shareholders sell the firm to the manager. We are assuming that it cannot happen. On really, it may not work in some cases. For example, we can argue that managers have zero initial wealth, there is limited liability and there are non-verifiable private benefits. This hypothesis is well used in this literature, see for example Burkart, Gromb and Panuzi (1997). In fact, we are trying to use only one instrument to solve this problem of unaligment of interests. Moreover, the use of more than one instrument may be unnecessary, as will be shown. Therefore, the case that we should use as a second-best is the case where shareholders directly manage the firm.

[7] The first-best solution is achieved only when the shareholders can observe and contract the effort done by the agent. This solution is characterized by the fact that the agent will receive, in each dimension, exactly the marginal contribution of his effort.

When the agent exerts effort t his expected utility is given by

$$u(t) = -\exp\left\{-r\left(\alpha' x + \beta - \frac{1}{2}t' Ct\right)\right\}.$$

This expected utility can be easily represented by the following certainty-equivalent income[8]

$$y = \alpha' t + \beta - \frac{1}{2}r\alpha'\Omega\alpha - \frac{1}{2}t' Ct.$$

The problem faced by the agent is, given the incentive scheme proposed by shareholder, to choose the optimal level of effort. The agent's problem is

$$\max_{t\geq 0}\left\{\alpha' t + \beta - \frac{1}{2}r\alpha'\Omega\alpha - \frac{1}{2}t' Ct\right\}.$$

The first-order condition for this problem is

$$t = \Gamma\alpha \tag{1}$$

where, $\Gamma = C^{-1}$. Note that since C is positive definite, then Γ is also positive definite but with negative off-diagonal terms. The intuition of this first-order condition is that, for each task, the agent will choose an amount of effort that equates his marginal cost of effort to the linear reward proposed by shareholders.

Substituting this optimal efforts in the certainty-equivalent income we get

$$y = \beta - \frac{1}{2}r\alpha'\Omega\alpha + \frac{1}{2}\alpha'\Gamma\alpha. \tag{2}$$

The shareholders (the principal) will maximize their expect profit

$$\begin{aligned} E\left[\iota' x - \alpha' x - \beta\right] &= (\iota - \alpha)' t - \beta \\ &= (\iota - \alpha)' \Gamma\alpha - \beta. \end{aligned} \tag{3}$$

[8] We used the formula for the expectation of the exponential of a normally distributed variable. The moment generating function is $M_x(z) = \exp\left(\mu z + \frac{1}{2}\sigma^2 z^2\right) = E_x\left[\exp(zx)\right]$. Hence, $\mathrm{E}_x\left[\exp\left\{-r\left(\acute{\alpha x} + \beta - \frac{1}{2}t' Ct\right)\right\}\right] = \exp\left\{-r\left(\acute{\alpha t} + \beta - \frac{1}{2}t' Ct\right) + \frac{1}{2}r^2\alpha'\Omega\alpha\right\} = \exp\left\{-r\left(\acute{\alpha t} + \beta - \frac{1}{2}t' Ct - \frac{1}{2}r\alpha'\Omega\alpha\right)\right\}$. Therefore, the term in parenthesis is the certaint-equivalent of the agent.

Isolating β in (2) and substituting in (3), the shareholders will choose the incentive scheme that solves

$$\max_{\alpha,y}\left\{(\iota-\alpha)'\,\Gamma\alpha-\frac{1}{2}r\alpha'\Omega\alpha+\frac{1}{2}\alpha'\Gamma\alpha-y\right\}$$
$$\text{s.t.}\qquad -\exp\left(-ry\right)\geq\bar{u}$$

where $\bar{u}$ is the reservation utility of the agent. The agent will accept to work only if his expected utility dominates the minimum utility level (reserve utility). The first-order conditions for the shareholders problem are

$$\Gamma\iota-\left(\Gamma+r\Omega\right)\alpha_s = 0 \tag{4}$$

$$-\exp\left(-ry_s\right) = \bar{u} \tag{5}$$

Equation (4) defines the optimal incentive scheme α_s. After some algebra we get

$$\alpha_s=\left(I+rC\Omega\right)^{-1}\iota \tag{6}$$

where I is the 2 x 2 identity matrix. Equation (5) says that shareholders will choose the β_s that leaves the agent with his reservation utility. Without loss of generality we can assume that $\bar{u}=-1$. In this case $y_s=0$ and so we get

$$\beta_s=\frac{1}{2}r\alpha_s'\Omega\alpha_s-\frac{1}{2}\alpha_s'\Gamma\alpha_s. \tag{7}$$

Therefore, equation (3) gives the total expected profit under shareholders' control

$$L_s=\left(\iota-\alpha_s\right)'\Gamma\alpha_s-\beta_s. \tag{8}$$

This is the standard solution of the multi-task moral hazard model derived by Holmström & Milgrom (1991). Note that if the agent is risk-neutral $(r=0)$, then $\alpha_s=\iota$. In this case the first-best solution can be obtained. From (1) we get

$$t=\Gamma\iota. \tag{9}$$

The expression (9) says that the agent will receive, in each dimension, exactly the marginal contribution of his effort. But, if the agent is risk-averse ($r > 0$), then (for positive values of t) we obtain that $\alpha_s > 0$. Remembering that C is positive definite with all entries positives and that Ω is diagonal we obtain the following result

$$\iota - \alpha_s = rC\Omega\alpha_s > 0$$

or $\alpha_s < \iota$. Therefore, the incentive scheme is not first-best anymore because the agent is receiving less than his marginal contribution in each of the two dimensions. Receiving less, the agent will reduce the optimal level of effort and the total expected profit will be lower. This result reflects the inefficiency cost that arises from the moral hazard problem. The shareholders' control is the best structure that could be chosen, given the asymmetric information problem, but our main assumption is that this design is not available.

3.2 Hierarchical Design

In the hierarchical design, suppose that shareholders decided to contract only one manager to coordinate the activities done by the agent. The solution for this structure is similar to the shareholders control, except for the fact that the manager may be biased. The manager can be of "*type i*", for $i = 1, 2$. Using definition 2, we can rewrite the managers' vector of marginal benefits as a function of the level of bias θ. The optimal incentive scheme chosen by the manager (the principal) will be

$$\alpha_h = (I + rC\Omega)^{-1} b_i(\theta) \tag{10}$$

where $b_i(\theta)$ is the benefits vector of the manager if he is "biased on activity i and has bias θ" and α_h is the solution for the hierarchical structure.

The solution for the constant payment is given by

$$\beta_h = \frac{1}{2} r\alpha_h{}'\Omega\alpha_h - \alpha_h{}'\frac{1}{2}\Gamma\alpha_h \tag{11}$$

where β_h is the constant payment in the hierarchical structure.

Finally, the total expected profit must be calculated from the shareholders' point of view. The solution is

$$L_h = (\iota - \alpha_h)' \, \Gamma \alpha_h - \beta_h \tag{12}$$

where L_h is the expected profit in hierarchical structures.

Some interesting results arise from the introduction of the bias. Suppose that shareholders have contracted a manager "*type i*".[9] Studying the power of the incentive scheme we observe that the higher the level of the manager bias, the less powered is the mechanism in the low weighted task (j) and the more powered in the task that the manager is biased (i). Furthermore, the incentive reward attributed to the less weighted task (j) may be negative, implying that the employee may have to pay to the manager if the result of his effort in this task were positive. Proposition 1 summarizes these results.

Proposition 1 *Suppose that the manager hired is of type i. Therefore, under the Hierarchical Design, the power of the incentive scheme increases with the level of bias in the activity that the manager is biased (i) and decreases in the less weighted activity (j).*

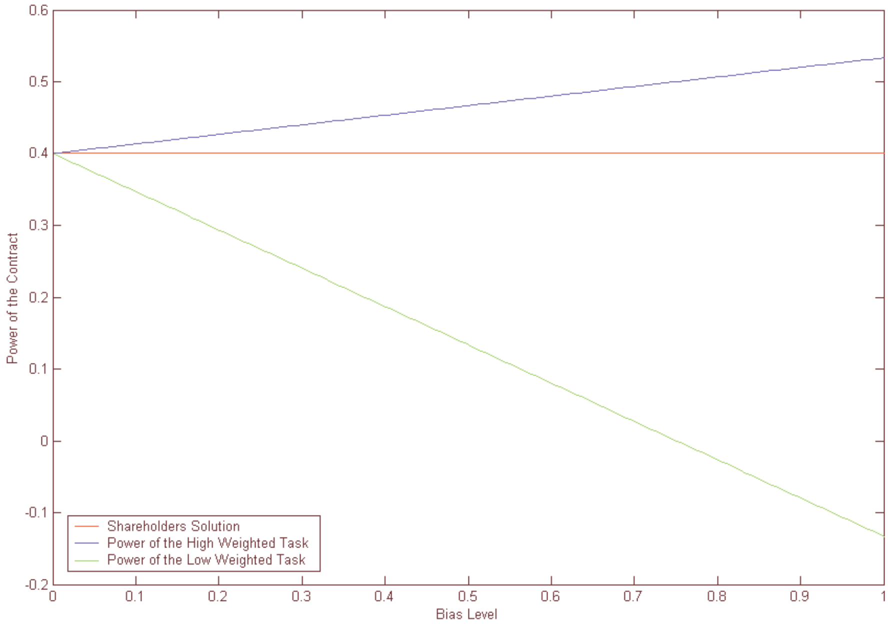
Proof. Define $\alpha_h(i)$ as the power of the incentive scheme in the activity that the manager is biased and $\alpha_h(j)$ the power of the incentive scheme in the other activity. Using equation (10) it is straightforward to show that $\frac{\partial \alpha_h(i)}{\partial \theta} = \frac{rs\sigma}{1+2r\sigma+r^2\sigma^2-r^2s^2\sigma^2} > 0$ and that $\frac{\partial \alpha_h(j)}{\partial \theta} = -\frac{1+r\sigma}{1+2r\sigma+r^2\sigma^2-r^2s^2\sigma^2} < 0$. ■

Furthermore, it is easy to notice that if the manager is not biased ($\theta = 0$, or $b_i = \iota$), then $\alpha_h = \alpha_s$. Therefore, Proposition 1 implies that, if the manager is biased, the power of the incentive scheme is higher than the efficient level in the biased activity and lower in the less weighted outcome. Because the manager evaluates one outcome more than the other, he will offer an incentive contract that is more attractive in the product that he evaluates more (see Figure 3). Therefore, in the Hierarchical Design, if the manager is biased, the optimal incentive scheme is excessively powered in the biased activity (i) and low powered in the less weighted activity (j) relatively to the contract that would be implemented by shareholder if they could manage the firm.

A second result is that the constant payment (β_h) can assume any value (positive or negative) and its relation (with the level of bias of the manager) depends on independent coefficients. This result is intuitive. For small

[9] We can restrict our attention only to one type of manager because the analysis for the other manager is identical.

Figure 3: Power of the Incentive Scheme (r=1, s=0.5 and σ=1)



levels of risk version of the agent and high levels of bias (what means high power in the biased activity), it is natural to imagine that the agent will be disposed to work even if the constant payment is negative (and in this case the constant payment may be decreasing in the level of bias). For high levels of risk aversion the agent will work only if the constant payment is positive, a standard result.

Finally, equation (12) gives a profit function that is strictly decreasing in the bias of the manager. The more unaligned the interests of the manager in relation to the shareholders, smaller the shareholders profits. This result reflects exactly the shareholders' cost of leave the control of the firm to a manager that is not fully aligned with the shareholders interests. The next proposition resumes this result.

Proposition 2 *Under the Hierarchical Design the shareholders' profit is strictly decreasing (and concave) in the level of manager bias.*

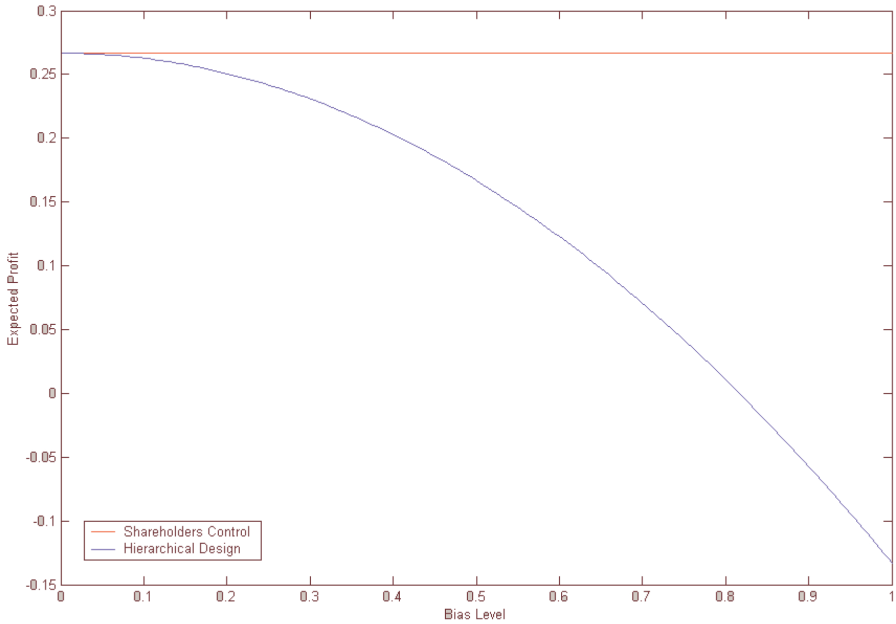
Proof. Using equation (12) it is straightforward to show that

$\frac{\partial L_h}{\partial \theta} = \frac{(rs^2\sigma+1+r\sigma)\theta}{(1+2r\sigma+r^2\sigma^2-r^2s^2\sigma^2)(-1+s^2)} < 0$ for $\theta \in (0,1]$ and that

$\frac{\partial^2 L_h}{\partial \theta^2} = \frac{(rs^2\sigma+1+r\sigma)}{(1+2r\sigma+r^2\sigma^2-r^2s^2\sigma^2)(-1+s^2)} < 0.$ ■

We also know that if the manager is not biased, then the expected shareholders' profit under a hierarchical design is equal to the profit obtained under the shareholders control ($L_s = L_h$). Therefore, the last proposition implies that the expected shareholders' profit will be lower than the efficient level when the manager is biased (Figure 4). Therefore, if the manager is biased, then the shareholders' expected organizational profit, under a Hierarchical Design, is always below the efficient level (L_s).

Figure 4: Expected Organizational Profits (r=1, s=0.5 and σ=1)



These results imply that shareholders should be interested in solving (or in mitigating) this inefficiency problem. We will show that one way to do this may be choosing another internal design for the firm. The next section describes the results obtained under a matrix design.

3.3 Matrix Design

Now we are interested in the case where shareholders decided to contract two managers and these two managers are of different types. Initially, suppose that the managers are symmetric[10]. Each manager will supervise one of the two tasks. The managers can observe the results of both activities and can contract based on these results. We are also assuming that the managers can not act cooperatively, that is, they act only in their own interests.

[10] In Section 5 we allow for assymetric levels of bias among managers.

The agent will report to both managers, characterizing a matrix structure. Furthermore, this internal design characterizes, in terms of the agency theory, a common agency situation where each manager is a principal. In this common agency situation Holmström & Milgrom (1988) showed that each principal's best response to a linear contract is to offer a linear contract. Thus, we can restrict our attention to this equilibrium where linear contracts are offered. There may exist other equilibria where more complex incentive schemes are chosen, but we are assuming that the incentive mechanism is based on linear schemes. Dixit (1996) shows that the optimal incentive scheme for the standard common agency model (that is equivalent to $\theta = 1$ for both types in our definition) is given by

$$\alpha = (I + nrC\Omega)^{-1}\,\iota$$

where n is the number of principals in the relationship. However, we are in a special case where the two managers are biased. So, our solution is given by

$$\alpha_m = (I + 2rC\Omega)^{-1}\,(b_1(\theta) + b_2(\theta)) \tag{13}$$

where α_m is the optimal aggregate incentive scheme for the matrix structure. The most important difference is that in our model the sum of the managers' benefits do not need to be equal to the shareholders' benefits. This will occur only if the managers are totally biased ($\theta = 1$).

The constant payment term is given by

$$\beta_m = \frac{1}{2} r\alpha_m' \Omega \alpha_m - \frac{1}{2}\alpha_m' \Gamma \alpha_m \tag{14}$$

and the total expected shareholders profit is

$$L_m = (\iota - \alpha_m)' \,\Gamma \alpha_m - \beta_m. \tag{15}$$

In this matrix design we obtain new results. Initially, under the matrix design, the power of the optimal incentive scheme is strictly decreasing with the level of managers bias in both tasks[11]. For low levels of bias the sum of the managers' marginal benefits implies an overvaluation of the outcomes (relative to shareholders' objectives) and it leads to high powered mechanism. For high values of bias, the conflict of objectives among managers leads to final low powered incentive mechanism.

Proposition 3 *Under the Matrix Design, the power of the incentive scheme decreases strictly (and symmetrically) with the level of bias in both activities. If the managers are not biased, the power of the incentive contract is above the optimal level and, if the managers are fully biased, the power is below the optimal level.*

Proof. Using equation (13) is straightforward to show that $\frac{\partial \alpha_m(i)}{\partial \theta} = \frac{-1}{2rs\sigma+2r\sigma+1} < 0$ for $i = 1, 2$. Moreover it is easy to see that $\alpha_m(i)\,|_{\theta=0} = \frac{2}{2rs\sigma+2r\sigma+1} > \frac{1}{rs\sigma+r\sigma+1} = \alpha_s(i)$ and that $\alpha_m(i)\,|_{\theta=1} = \frac{1}{2rs\sigma+2r\sigma+1} < \frac{1}{rs\sigma+r\sigma+1} = \alpha_s(i)$ for $i = 1, 2$. ■

Given these properties of this optimal incentive scheme, under a matrix design, we obtain the interesting result that there is always a level of manager bias for which the power of the incentive scheme equates the one that would be offered for the agent if the shareholders were controlling the firm (Figure 5).

Analyzing the optimal fixed payment, we observe that it has some interesting properties. First of all, for high values of agent's risk-aversion or output variability, the constant payment is positive and decreases with level of bias. Moreover, for low values of agent's risk-aversion or output variability the constant payment is negative and increases with the bias of the managers. This result is intuitive: if the agent is highly risk-averse then the manager will have to pay a positive constant, but when the bias increases the conflict of interests between the managers also increases leading to low powered incentives (less risk sharing) which allows a lower constant payment.

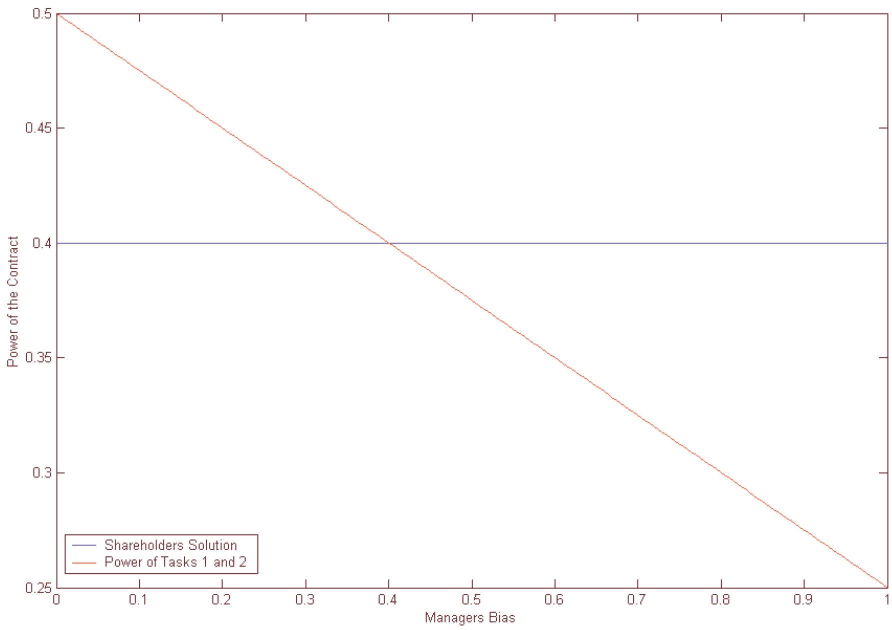
Notice also that, under a matrix design, we again obtain the result that, there is always a level of manager bias for which the constant payment equates the power of the incentive scheme that would be chosen by shareholders if they were controlling the firm.

[11] The symmetric result comes from the symmetry of the managers types imposed when shareholders contract the managers. In the next section we allow for assymmetric degrees of bias on the managers contracting.

Proposition 4 *Under the Matrix Design, there is a level of bias (θ^*) for which the managers offer the same incentive contract that would be offered if the shareholders were directly controlling the firm. Moreover, this level is unique.*

Proof. We know that, under the Matrix Design, $\alpha_m(i) = \frac{2-\theta}{2rs\sigma+2r\sigma+1}$ for $i = 1, 2$ and that if the shareholders could directly manage the firm $\alpha_s(i) = \frac{1}{rs\sigma+r\sigma+1}$ for $i = 1, 2$. Therefore $\alpha_m(i) = \alpha_s(i) \Rightarrow \theta^* = \frac{1}{rs\sigma+r\sigma+1} \in (0, 1)$. The optimal constant payment, under a matrix design, is $\beta_m = \frac{(\theta-2)^2(r\sigma(1+s)-1)}{(s+1)(2rs\sigma+2r\sigma+1)^2}$ and under shareholders' control $\beta_s = \frac{rs\sigma+r\sigma-1}{(rs\sigma+r\sigma+1)(s+1)}$. If $r\sigma(1+s) = 1$, then $\beta_m = \beta_s$ for all $\theta \in [0, 1]$. If $r\sigma(1+s) \neq 1$, then $\beta_m = \beta_s \Rightarrow (\theta-2)^2 = \left(\frac{2rs\sigma+2r\sigma+1}{rs\sigma+r\sigma+1}\right)^2 \Rightarrow (\theta-2)^2 = \left(2 - \frac{1}{rs\sigma+r\sigma+1}\right)^2 \Rightarrow \theta \in \left\{\frac{1}{rs\sigma+r\sigma+1}; 4 - \frac{1}{rs\sigma+r\sigma+1}\right\}$, but the second value is greater than 1. Therefore, $\theta^* = \frac{1}{rs\sigma+r\sigma+1}$ ■

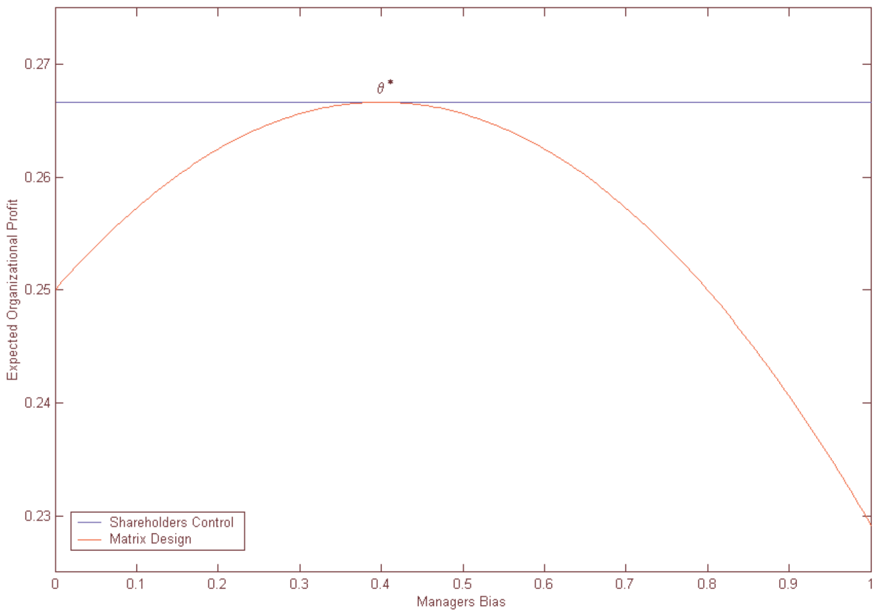
Figure 5: Power of the Incentive Scheme (r=1, s=0.5 and σ=1)



This result is important because it implies that there is an *"optimal level of bias"* (θ^*) such that the aggregate incentive scheme is equal to the shareholders control scheme. Therefore, there is always a unique level of bias for which the matrix design can mimic the incentive contract obtained under the shareholders.

Finally, in this matrix design, the expected shareholders profit function is strictly concave in the bias of the managers. The function also has the interesting property of one global maximum point which gives to shareholders the same expected profit as if they were controlling the firm. This means that under certain conditions the matrix design can provide the same results that would be obtained if the shareholders could directly control the agent. This result is illustrated in Figure 6.

Figure 6: Expected Organizational Profits (r=1, s=0.5 and σ=1)



Proposition 5 *Under the Matrix Design, there is a unique level of bias (θ^*) for which the shareholders obtain the same expected profit as if they were directly controlling the firm . For all others levels of bias the expected profit is below this level.*

Proof. The expected profit function, under the Matrix Design, is given by $L_m = -\frac{(\theta-2)(rs\sigma\theta+2rs\sigma+\theta+r\sigma\theta+2r\sigma)}{(s+1)(2rs\sigma+2r\sigma+1)^2}$. It is easy to see that L_m can be represented as a quadratic function $a\theta^2 + b\theta + c$ where $a < 0, b > 0$ and $c > 0$. $\frac{\partial L_m}{\partial \theta} = -2\frac{\theta(rs\sigma+1+r\sigma)-1}{(s+1)(2rs\sigma+2r\sigma+1)^2}$, therefore if $\theta(rs\sigma+1+r\sigma) < 1$, then $\frac{\partial L_m}{\partial \theta} > 0$; if $\theta(rs\sigma+1+r\sigma) > 1$, then $\frac{\partial L_m}{\partial \theta} < 0$; and if $\theta(rs\sigma+1+r\sigma) = 1$, then $\frac{\partial L_m}{\partial \theta} = 0$ and $\theta = \theta^*$. Moreover, $\frac{\partial L_m^2}{\partial \theta^2} = -2\frac{(rs\sigma+1+r\sigma)}{(s+1)(2rs\sigma+2r\sigma+1)^2} < 0$ for all $\theta \in [0, 1]$.

■

4 Choosing the Optimal Organizational Design

We have already described the structure of the reward scheme and the expected shareholders' profits for each organizational form and levels of managers' bias. Shareholders are interested in determining when one specific organizational design is preferred to the other for each degree of bias on managers' preferences. With this, they can choose the optimal organizational design given the types of managers available in the market.

Suppose initially that an unbiased type of manager is available in the market. Therefore, shareholders can contract a manager with preferences exactly equal to theirs. It is intuitive to imagine that in this situation the hierarchical design must be preferable to the matrix design, because there is no apparent reason to organize the firm in the form of a matrix. If the manager is not biased the hierarchical design generates an expected profit that is exactly equal to the second-best solution (shareholders' control). Under the matrix design, the expected profit can not be higher than the second-best profit, otherwise the shareholders would have offered the matrix design incentive scheme.

Similarly, if managers are fully biased, in the sense that each type of manager has preferences on one of the outputs, then the conflict of interests between two symmetric managers can lead to a balanced reward scheme, resulting in a more profitable scheme. We should expect that, in this specific case, the shareholders will prefer to design the firm in the form of a matrix, rather than in a hierarchical form.

These two extreme cases related above (zero bias and full bias) do not describe all the possible situations faced by the firm when contracting managers. Moreover, imagining that there are managers who have preferences aligned with shareholders ones or that managers just care about one of the two tasks is not a natural situation expected to be faced by the firm. The shareholders want to know what kind of organizational design must be implemented at each degree of the managers' bias faced in the market for managers. The next proposition characterizes the optimal organizational design as a function of the managers' bias.

Proposition 6 *There is an unique level of bias $\overline{\theta} \in [0, 1]$ such that :*

- *if $\theta > \overline{\theta}$, the shareholders prefer the Matrix Design and*
- *if $\theta < \overline{\theta}$, the shareholders prefer the Hierarchical Design*

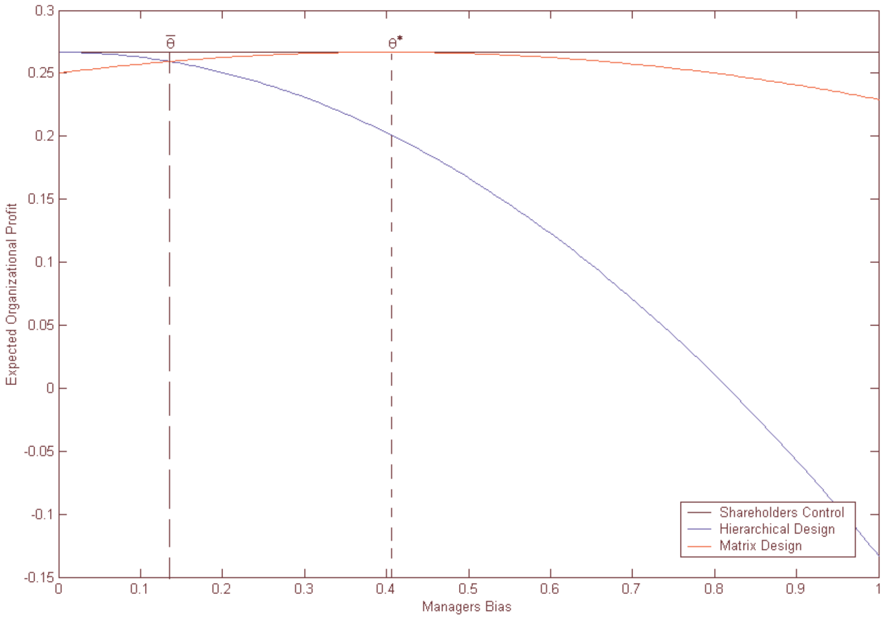
Proof. Define $Y(\theta) = L_h(\theta) - L_m(\theta)$ and set $\theta = 0$. Therefore, $Y(0) = \frac{1}{(2rsg+2rg+1)^2(s+1)(rsg+rg+1)} > 0$

Now, set $\theta = 1$. In this case $Y(1) = -\frac{1}{2}\left(\frac{2r^3\sigma^3(s^4+4s^3+6s^2+4s+1)+2r^2\sigma^2(3s^3+5s^2+5s+3)+r\sigma(s^2+4s+5)+1}{(1+2r\sigma+r^2\sigma^2-r^2s^2\sigma^2)(2rs\sigma+2r\sigma+1)^2(1-s^2)}\right) < 0$.

The Intermediate Value Theorem guarantees the existence of a $\overline{\theta}$, where $\overline{\theta}$ is the point where $Y(\theta) = 0$. Moreover, we guarantee that there are at most two points satisfying this condition. We need to show that only one of these points belongs to the interval $[0,1]$. It is easy to show that $\frac{\partial Y(\theta)}{\partial \theta} = -\frac{(A\theta+B)}{C}$, where $B = (2+4r\sigma)(1-s)+2r^2\sigma^2(1+s^3-s^2-s) > 0$, $C = (2rs\sigma+2r\sigma+1)^2(-1-2r\sigma-r^2\sigma^2+r^2\sigma^2 s)(s^2-1) > 0$ and $A=(2r^2s^3\sigma^2+14r^2s\sigma^2+12r^3s^2\sigma^3+8r^3s\sigma^3+2r^3s^4\sigma^3+3rs^2\sigma+8r^3s^3\sigma^3+2r^2\sigma^2-r\sigma+2r^3\sigma^3+2s+8rs\sigma+14r^2s^2\sigma^2-1)$ which may be positive or negative. But it is straightforward to show that $(A\theta+B) > 0$ for all $\theta \in [0,1]$. Therefore, we obtain that $\frac{\partial Y(\theta)}{\partial \theta} < 0$ for all $\theta \in [0,1]$. This property assures that only one of the roots belong to the interval $[0,1]$ and the unicity result is obtained. ■

Therefore, we showed that shareholders can use the organizational design to mitigate the effects of the conflict of interests among the firms' main objectives and managers' interests. The choice of an optimal incentive scheme will depend on the level of bias. The result is illustrated in Figure 7.

Figure 7: Expected Organizational Profits (r=1, s=0.5 and σ=1)



In this section it was shown that if principals' preferences are such that they are heavily biased towards some activities, the hierarchical structure performs poorly because the single principal's bias will distort the incentive schedule offered to the agent towards his preferred activity, leading to an unbalanced distribution of incentives across activities and, therefore, the matrix structure is better. The competition among principals partially offsets the effect of their individual biases on the incentive structure as perceived by the agent. On the other hand, choosing a matrix design leads to the traditional kind of distortions associated with common agency problems: the power of incentives is too small or it is too large.

In summary, it is possible to argue that our approach can be used to describe the choice between hierarchical and matrix structures as a trade-off between the *strength* and *balance* of the incentives they provide to lower-level workers.

5 Some Extensions

In this section we provide two interesting extensions of the basic model presented in last section. First, we show that under asymmetry the main intuition of our results is preserved, i.e., trade-off between the *strength* and *balance* still holds under asymmetric bias levels. Second, we extend the basic model to the case where the efforts are complementary.

5.1 Asymmetric Bias

In the basic model we assume that managers have symmetric levels of bias. Here we are interested in the case where shareholders could contract managers and these managers are of different types, but they do not need to have the same level of bias.

Definition 3 *Let* $v_i \in [0,1]$ *, for* $i = \{1,2\}$ *denote how the manager evaluates an activity done by the agent. A manager is said to be of "type 1" if he has a vector of benefits given by* $b_1 = [\ 1 \quad v_1\ ]$ *and he is said to be "type 2" when the vector of benefits is given by* $b_2 = [\ v_2 \quad 1\ ]$

Definition 4 *The bias of the manager is given by* $\theta_i = 1 - v_i$ *, for* $i = \{1,2\}$*. We will say that the manager is "biased towards activity i" if he is "type i" and* $v_i < 1$*.*

The result obtained for the hierarchical design is obviously the same. However, for the matrix design, we obtain some interesting results. Initially, it is easy to show that if the bias levels are different, the power of the incentive scheme will not be equal for both tasks anymore.

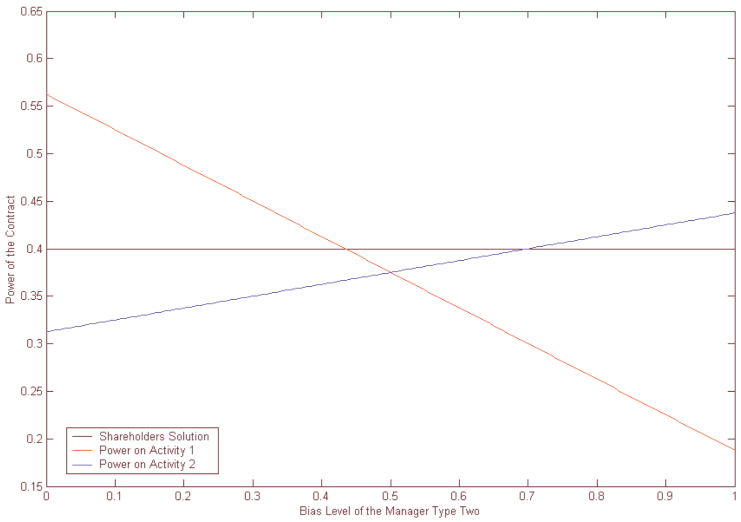
Proposition 7 *If managers have different bias levels, the power of the incentive scheme will be different across activities. The power of the incentive contract will be higher in the activity that the more biased manager is biased.*

Proof. We can directly use equation (13) to obtain the optimal levels of power. Suppose that $\theta_1 \neq \theta_2$. The difference between the power of the incentive contract is given by $\alpha_1(\theta_1, \theta_2) - \alpha_2(\theta_1, \theta_2) = \frac{\theta_1 - \theta_2}{1+2r\sigma(1-s)} \neq 0$. Note that if $\theta_1 > \theta_2$ then $\alpha_1(\theta_1, \theta_2) > \alpha_2(\theta_1, \theta_2)$. ■

Contrary to the symmetric case, we now obtain that the power of the incentive scheme is increasing (and linear) with the level of bias, but it will be true only for the level of bias in favor of the proper activity. That is, the power of activity 1 will be increasing with the bias of the manager type 1 and decreasing in the level of bias of the manager type 2. The next proposition summarizes this result and Figure 8 illustrates it.

Proposition 8 *For each activity, the power of the incentive scheme is strictly increasing with the level of bias of the manager biased in this activity and decreasing with the level of bias of the other manager.*

Figure 8: Power of the Incentive Scheme (r=1, s=0.5, σ=1, and θ_1=0.5)



Proof. It is easy to show that $\frac{\partial \alpha_i(\theta_i,\theta_j)}{\partial \theta_i} = \frac{2rs\sigma}{1+4r\sigma+4r^2\sigma^2(1-s^2)} > 0$ and that $\frac{\partial \alpha_i(\theta_i,\theta_j)}{\partial \theta_j} = -\frac{1+2r\sigma}{1+4r\sigma+4r^2\sigma^2(1-s^2)} < 0$.
■

Obviously, the power of the incentive scheme depends on both managers' bias level. It implies that the constant payment will also depend on the relationship between these levels. As before, the behavior of the constant payment will be indeterminate. Moreover, it depends on the difference between managers biases.

However, one interesting property can be explored. The expected profit function under matrix design is strictly concave in the levels of bias.

Proposition 9 *The expected profit function under matrix design is strictly concave in its levels of bias.*

Proof. Taking derivatives we obtain

$\frac{\partial^2 Lm(\theta_1,\theta_2)}{\partial \theta_1^2} = \frac{\partial^2 Lm(\theta_1,\theta_2)}{\partial \theta_2^2} = -\frac{-4r^3\sigma^3(1-s^4)-3rs^2\sigma-8r^2s^2\sigma^2-1-5r\sigma-8r^2\sigma^2}{(-1-4r\sigma-4r^2\sigma^2+4r^2s^2\sigma^2)^2(-1+s^2)} < 0$, and

$\frac{\partial^2 Lm(\theta_1,\theta_2)}{\partial \theta_1 \partial \theta_2} = \frac{\partial^2 Lm(\theta_1,\theta_2)}{\partial \theta_2 \partial \theta_1} = \frac{s(-1-8r^3\sigma^3(1-s^2)-8r\sigma-16r^2\sigma^2)}{(-1-4r\sigma-4r^2\sigma^2+4r^2s^2\sigma^2)^2(-1+s^2)} > 0$. With this the Hessian $D^2 Lm(\theta_1,\theta_2)$ is negative definite because the second order principal minor gives

$det(D^2 Lm(\theta_1,\theta_2)) = \frac{-r^2\sigma^2(1-s^2)-2r\sigma-8r^2\sigma^2-1}{(-1-4r\sigma-4r^2\sigma^2+4r^2s^2\sigma^2)^2(-1+s^2)} > 0$ ■

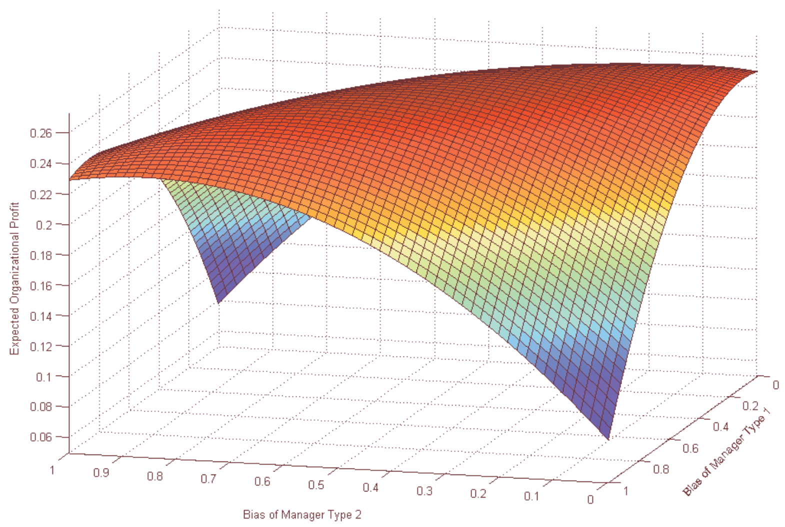
Expected organizational profit under matrix design has exactly one maximum point (see Figure 9). This point is the symmetric one obtained in the previous section. Therefore, the main intuition is preserved, i.e., our approach can be used to describe the choice between hierarchical and matrix structures as a trade-off between the *strength* and *balance* of the incentives they provide to lower-level workers, even when managers have different bias levels.

5.2 Complementary Efforts

This section explores the base model considering the case where efforts are complementary among activities. The main results continue to hold, but some interesting properties arise in this context. Suppose now that efforts are complementary, that is $s \in (-1, 0)$.

When shareholders decide to implement an hierarchical design, with complementary efforts, some incentive issues change. In this context, the single manager can not greatly reduce the incentive in the activity he is not

Figure 9: Expected Organizational Profit (r=1, s=0.5, and σ=1)



biased because it increases the agents' cost of exercising the activity he is biased. On the other hand, he must preserve the relative difference between the powers to induce the effort toward the activity he is biased. The result is a low powered scheme, relatively to the shareholders optimal scheme. This result comes from Proposition 1.

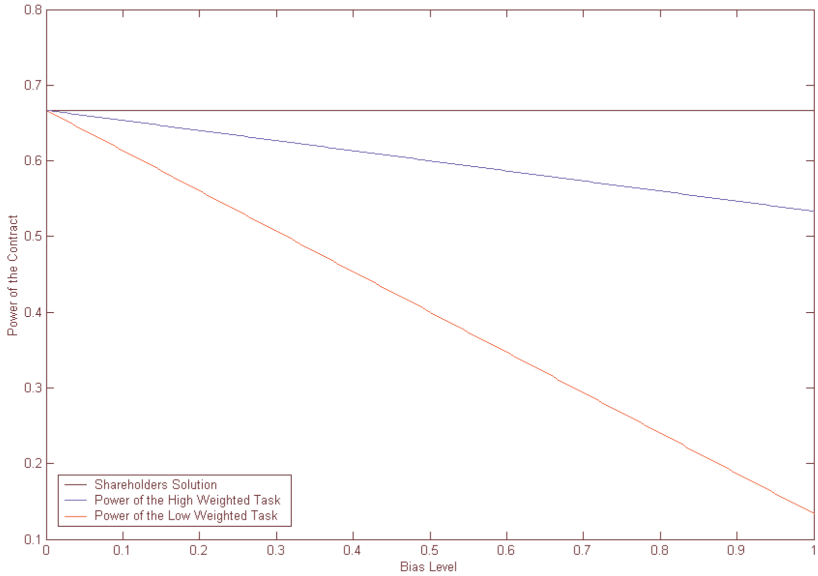
Corollary 1 *Suppose that the manager contracted is of type i. Therefore, in the Hierarchical Design with complementary efforts, the power of the incentive scheme decreases with the level of bias in both activities, but it decreases more in the activity that he is not biased (j).*

This result implies that when we have complementary efforts the power of the incentive scheme, as a whole, will be lower relatively to the case where shareholders manage the firm directly (see Figure 10).

Corollary 2 *If the manager is biased and the organizational design is hierarchical, the optimal incentive scheme is low powered in both activities.*

The remaining results under the hierarchical design are preserved, that is: under the hierarchical design the shareholders profit is strictly decreasing (and concave) with the bias level, and is always below the efficient level. Therefore, shareholders may be again interested in solving this inefficiency problem using a different organizational design.

Figure 10: Power of the Incentive Scheme (r=1,s= - 0.5, and σ=1)



It is easy to show that under the matrix design all results remain the same. Moreover, it is simple to check that all propositions in section 4 are also valid. Consequently, the core of the model remains the same under complementary efforts.

6 Concluding Remarks

One of the most important topics in organizational theory literature is the study of the different internal designs that companies adopt to organize tasks among employees. This paper tries to add a new element to this discussion. The model presented above suggests that *conflict* of interests may be part of the story. It was shown, using a simple three level structured firm, that when the interests of the shareholders and top managers are not fully aligned, the company can mitigate this distortion adopting different organizational forms. We assume that the organizational designer's task is to choose the number of principals for a given agent, but principals are unable to collude and write binding agreements with each other. We then show that the choice between hierarchical (one principal) and matrix (many principals) structures depends crucially on the *biases* of the potential principals (managers).

We show that if the level of conflict is low the hierarchical design is preferred, but if the conflict is high the matrix design is chosen. In fact, this simple approach can be used to describe the choice between hierarchical and matrix structures as a trade-off between the *strength* and the *balance* of the incentives they provide to lower-level workers. It was also shown that this interpretation is preserved under asymmetric levels of bias among managers and when low-level workers have complementary costs of effort.

This model was based on the assumption that shareholders may infer precisely the level of managers' bias. However, this assumption is clearly strong. The next step in this research is to abandon the perfect information hypothesis, using a mechanism design model to solve the shareholders' problem. Another possible extension is to modify this framework attempting to explain the configuration of boards of directors in companies.

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