

Theilen, Bernd

**Working Paper**

## Market competition and lower tier incentives

CESifo Working Paper, No. 2453

**Provided in Cooperation with:**

Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

*Suggested Citation:* Theilen, Bernd (2008) : Market competition and lower tier incentives, CESifo Working Paper, No. 2453, Center for Economic Studies and ifo Institute (CESifo), Munich

This Version is available at:

<https://hdl.handle.net/10419/26498>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# Market Competition and Lower Tier Incentives

BERND THEILEN

CESIFO WORKING PAPER NO. 2453  
CATEGORY 9: INDUSTRIAL ORGANISATION  
NOVEMBER 2008

PRESENTED AT CESIFO VENICE SUMMER INSTITUTE 2008,  
WORKSHOP ON EXECUTIVE PAY

*An electronic version of the paper may be downloaded*

- *from the SSRN website:* [www.SSRN.com](http://www.SSRN.com)
- *from the RePEc website:* [www.RePEc.org](http://www.RePEc.org)
- *from the CESifo website:* [www.CESifo-group.org/wp](http://www.CESifo-group.org/wp)

# Market Competition and Lower Tier Incentives

## Abstract

The relationship between competition and performance-related pay has been analyzed in single-principal-single-agent models. While this approach yields good predictions for managerial pay schemes, the predictions fail to apply for employees at lower tiers of a firm's hierarchy. In this paper, a principal-multi-agent model of incentive pay is developed which makes it possible to analyze the effect of changes in the competitiveness of markets on lower tier incentive payment schemes. The results explain why the payment schemes of agents located at low and mid tiers are less sensitive to changes in competition when aggregated firm data is used.

JEL Code: D82, J21, L13, L22.

Keywords: Cournot competition, contract delegation, moral hazard, entry, market size, wage cost.

*Bernd Theilen*  
*Department of Economics*  
*University Rovira i Virgili*  
*Avinguda de la Universitat 1*  
*43204 Reus*  
*Spain*  
*bt@urv.net*

October 2008

I would like to thank Carolina Manzano, Antonio Quesada, Cori Vilella and the participants of the 2007 EARIE conference in Valencia and the CESifo Venice Summer Institute 2008 Workshop on "Executive Pay" for their valuable comments and suggestions. Financial support from CESifo, the Spanish "Ministerio de Ciencia e Innovación" under projects SEJ2004-07477 and SEJ2007-67580-C02-01 and the "Departament d'Universitats, Recerca i Societat de la Informació de la Generalitat de Catalunya" under project 2005SGR 00949 is gratefully acknowledged.

# 1 Introduction

During the last two decades the relationship between competition and performance-related-pay (PRP) has been investigated both from the theoretical and the empirical perspective. However, most of the literature has focused on the incentive pay of CEOs and little attention has been paid to lower layer employees. An exception in the empirical literature is Cuñat and Guadalupe (2005), who also analyze the effect of changes in competition on worker compensation. However, in the theoretical literature, attention has been paid exclusively to the question of how the design of adequate *individual* incentives is affected by changes in the competitive environment. This has given valuable insights into the relation between a firm's CEO and its owners. However, for low-tier employees the individual-based approach is expected to be too narrow and to give only incomplete insights. Therefore, the purpose of this paper is to develop a simple model which yields testable predictions of how changes in competition affect incentive pay at different layers of a firm's hierarchy.

Most of the results in the empirical literature on executive compensation are summarized in Murphy (1999). The main results are that (1) incentive compensation increases with firm size, though the relation between CEO pay and firm size has weakened over time, (2) pay-performance sensitivities vary across industries, and are particularly low in regulated industries, (3) pay-performance sensitivities have become larger in recent years because of the trend towards more competition due to the spread of information technologies, the reduction of barriers to entry, waves of deregulation and the reduction in transport costs. The theoretical literature mainly supports these findings. Schmidt (1997), Raith (2003) and Vives (2004) analyze a two-stage game in which firms consisting of a principal and an agent compete in an imperfect market. The principal uses incentive payments to incite agents to choose an unobservable effort level to reduce production costs. They show that there are two counteracting effects on incentive provision when competition increases. On the one hand, there is a business-stealing effect which induces firms to provide higher powered incentive schemes because with more competition any cost advantage more easily attracts business from rival firms. On the other hand, there is a scale effect which induces firms to reduce incentives because with more competition market shares decrease and firms have less to gain from possible cost advantages. Which of the two effects dominates is generally ambiguous, though Vives (2004) finds that for most of the different competitive specifications used in the literature the first effect dominates the second one. Therefore, the theoretical prediction is that more competition increases the steepness of performance-related pay.

Cuñat and Guadalupe (2005) analyze the effect of increasing competition not only on CEO pay but also on the compensation schemes of executives and workers in the UK in the late nineties. They confirm the results for CEO's and find that more competition increases the steepness of performance-related-pay in all layers. However, the effect weakens and is mostly not significant for lower layers in the firm. With the theoretical results concerning the relationship between competition and PRP at hand, this is a surprising result for two reasons. First, Burgess and Metcalfe (2000) show, also for a large sample of UK firms, that the adoption of

PRP is greater, especially for low-tier employees, in firms in environments with a low degree of competition than in those operating under a high degree of competition. For example, the number of firms that apply PRP for occupations like sales, skilled manual clerical/secretary and unskilled manual multiplies by eight, five, four and a half and four, respectively, while it only multiplies by three for managers. Second, there is a vast amount of empirical evidence to suggest that PRP at lower layers yields considerable productivity gains.<sup>1</sup> More competition should be expected to increase the pressure to realize potential productivity gains and therefore accelerate the adoption of PRP schemes. Consequently, without further theoretical explanation the results of Cuñat and Guadalupe (2005) can be seen to support the wide-spread view that executive compensation is not intended to be incentive efficient but used by CEOs as a means of self-enrichment where changes in competition serve as a pretext to increase PRP. As a result, the PRP of CEOs increases more than proportionally compared to the PRP of low-tier employees.<sup>2</sup>

The theoretical models on PRP do not specify the kind of agent the principal contracts. Thus, one might expect that the predictions can be applied to employees at any firm layer.<sup>3</sup> However, there are two reasons why the results cannot be applied directly to lower layers of the firm. First, at lower layers team work is a pervasive feature (c.f. Ichniowski and Shaw, 2003). The reward for participating in teams is likely to be some form of group-based pay or joint performance evaluation which has different characteristics to the individual-based schemes we find for CEOs. One major difference is that group-based incentives can be undermined by free riders. Though the free-rider problem can be mitigated by peer pressure (Kandel and Lazear, 1992), decentralized decision making (Baker, 1992) and long-term relationships (Che and Yoo, 2001) it usually results in lower powered incentive schemes than those of individual-based PRP.<sup>4</sup> Therefore, changes in competition should also be expected to have different impacts on low-tier PRP schemes compared to those of CEOs. Especially the question of how changes in competition affect free-riding should be addressed here. Second, in single-principal-single-agent models changes in competition have no employment effects but these effects might be considerable for agents at lower layers. For example, Griffith, Harrison and Macartney (2006) find that increased product market competition reduced unemployment in OECD countries in the 1980s and 1990s. Of course, changes in employment might also be expected to affect the wage setting process and thereby the structure of incentive schemes. Therefore, again, the results from single-principal-single-agent models should not be applied straightforwardly to incentive pay at lower layers.

The aim of this paper is to extend former models which analyze the relationship between performance-related-pay and market competition by explicitly including employment effects which changes in competition may cause. It thereby aims to close the gap between studies

---

<sup>1</sup>An excellent overview on the results of case studies, intra-industry analyses and national cross-industry studies is Ichniowski and Shaw (2003).

<sup>2</sup>See also Bolton et al. (2006) who develop a model that provides a different perspective on this view.

<sup>3</sup>See, for example, Cuñat and Gaudalupe (2005, p.1060).

<sup>4</sup>See, for example, Jensen and Murphy (1990), Holmstrom and Milgrom (1991, 1994) and Che and Yoo (2001).

that analyze the effect of competition on individual-based PRP like Schmidt (1997), Raith (2003) and Vives (2004) and those that analyze group-based PRP from an organizational perspective that excludes explicit modelling of changes in the product market (see Holmstrom and Milgrom (1990), Varian (1990), Ramakrishnan and Thakor (1991), Itoh (1991, 1992, 1993) and Macho-Stadler and Pérez-Castrillo (1993) as examples for this approach). In this paper, product market competition and incentive payments are the result of a multi-stage game in which firms are modeled as a three-tier hierarchy. At the top tier the principal designs contracts of second and third tier employees. Contract design is complicated by the unobservability of subordinates' effort choices. That is, principals in each firm must solve moral hazard problems. It is assumed that the unique commonly observable and verifiable variable is firm output. Thus, all contracts must be based on this variable. The advantage of the model is that it allows to analyze the effect of changes in competition on different layers of a hierarchy using the *same* unit of incentive measure. This enables us to see if the hierarchical level is responsible for differences in the effect of changes in competition and not the specific choice of the incentive measure.

The main difference between the group-based approach and the single-principal single-agent models is that firms can react to changes in competition not only by changing employees' effort but also by adapting the number of employees to new market conditions. However, if the labor inputs of third-tier employees are substitutable and if PRP is group-based this will affect the free-riding of third-tier employees. Therefore, any change in competition which affects firm size will affect third-tier and mid-tier employees differently. For mid-tier employees we assume that labor inputs are not substitutable and that free-riding therefore is a minor issue. Firm size (the number of employees) itself is determined by the costs of entry and labor market conditions. The paper shows that this gives rise to two kinds of heterogeneities. First, PRP sensitivities differ between employees at different hierarchical levels of the firm, or more generally, between employees whose labor inputs are substitutable and whose performance cannot be measured individually and those whose labor inputs are either difficult to substitute or whose performance can be measured individually. Second, PRP sensitivities of third-tier agents differ between firms which react to changes in competition by changing their employees' efforts and those which also change employment, or between firms that operate in closed markets and those that operate in markets with low barriers to entry. Taken together, the results explain the discrepancy between empirical studies that use aggregate firm data and those that are based on individual or firm data. The former find that incentive pay-performance sensitivities have significantly increased in recent years for CEO's while they have remained nearly unchanged at lower tiers. This is because the aggregation of heterogeneous firm data means that different responses to changes in competition at lower tiers compensate each other while they work in the same direction at mid and top tiers. Firm or case studies however, confirm that firms in many circumstances have substantially increased PRP at lower tiers after a change in the competitive environment. However, the handicap of these studies is that their findings cannot be generalized. Therefore, one of the main insights of the model is that future studies should take into account the kind of heterogeneities which have been identified when firm and individual data is aggregated.

The paper is organized as follows. Section 2 presents the model. Section 3 shows the market equilibrium values. Section 4 analyzes the effects of changes in the competitiveness of markets under alternative assumptions concerning the endogeneity of different variables. Finally, Section 5 concludes. All proofs are confined to the Appendix.

## 2 The model

### 2.1 The framework

1. *The firm.* There are  $n$  identical firms. Each firm  $i$  is represented as a three-tier hierarchy. The hierarchy consists of one principal ( $P_i$ ) at the top of the hierarchy or at layer 1, one agent ( $A_{2i}$ ) at layer 2 and a team of  $K_i$  agents ( $A_{3ik}$ ,  $k = 1, \dots, K_i$ ) at layer 3. The agents in each firm jointly produce a marketable output  $q_i$  for the principal. The principal makes all entry, personnel (she chooses the value of  $K_i$ ), and production decisions. The mid-tier agent, also called supervisor, controls the agents at tier 3, also called workers.

2. *Production.* The agents contribute to production by choosing two levels of effort, one that is observable to the principal and that is non-observable to her. Denote agent  $A_{2i}$ 's unobservable effort choice by  $e_{2i} \in \mathfrak{R}^+$  and normalize the observable effort to unity. Similarly, agent  $A_{3ik}$ 's observable effort choice is denoted by  $e_{3ik} \in \mathfrak{R}^+$  and his observable effort choice is normalized to unity. The general production technology is linear homogenous in capital and total labor output. The units of capital employed in production are also normalized to unity. The total worker's unobservable labor output is  $\sum_{k=1}^{K_i} e_{3ik}$  and their total observable labor output is  $K_i$ , that is, a worker's effort is perfectly substitutable, which implies that we assume that workers perform essentially the same tasks without any synergy effects. Supervisors produce "supervision", "control" and "coordination" of the workers' tasks. We assume that total labor output increases with more coordination for any given level of workers' labor output. Concretely, we assume the following production function:

$$q_i(K_i, e_{2i}, e_{3i}) = K_i^{\alpha_1} e_{2i}^{\alpha_2} \left( \sum_{k=1}^{K_i} e_{3ik} \right)^{\alpha_3},$$

where  $e_{3i} = e_{3i1}, \dots, e_{3ik}, \dots, e_{3iK_i}$ ,  $\alpha_1 > 0$ ,  $\alpha_2 \geq 0$ , and  $\alpha_3 \geq 0$ .<sup>5</sup> Notice that when there is no unobservable effort ( $\alpha_2 = \alpha_3 = 0$ ), we have a traditional Cobb-Douglas production function (with capital inputs normalized to unity). To simplify the exposition of the results we make:

**Definition 1**  $\delta = \alpha_1 + \frac{\alpha_3}{2}$ ,  $\varepsilon = \frac{\alpha_2 + \alpha_3}{2}$  and  $A = [2^{\alpha_2} (2 - \alpha_3)^{-\alpha_2} \alpha_2^{\alpha_2 - \alpha_3} \alpha_3^{2\alpha_3}]^{\frac{1}{2(1-\varepsilon)}}$

Finally, the production function displays non-increasing returns to scale:

---

<sup>5</sup>Similar team production functions have been applied by Beckmann (1977), or more recently, by Ferrall and Shearer (1999).

**Assumption 1**  $\alpha_1 + \alpha_2 + \alpha_3 \leq 1$ .

3. *Utility and contracts.* The fact that individual effort is non-observable to the principal, implies that she faces a moral hazard problem.<sup>6</sup> Furthermore, because individual performance measures are unavailable, this problem can only be solved by designing an appropriate group-incentive scheme. All agents are paid with an incentive scheme that has the form of a linear transfer. For agent  $A_{3ik}$  the transfer is  $t_{3ik} = \beta_{3i}q_i + \gamma_{3i}$ . and for agent  $A_{2i}$  the transfer is  $t_{2i} = \beta_{2i}q_i + \gamma_{2i}$ . That is, the contract includes a fixed payment and a variable payment that depends on output.<sup>7</sup> The transfers are chosen by the principal under the restriction that  $\gamma_{2i} \geq \gamma_2$  and  $\gamma_{3i} \geq \gamma_3$ .  $\gamma_2$  and  $\gamma_3$  represent industry wage levels which are determined by the bargaining power of workers, supervisors and principals and includes compensation for observable effort. Furthermore, notice that contracts are identical. Because agents are identical this can be interpreted as a non-discrimination restriction imposed by workers.<sup>8</sup> Agent  $A_{3ik}$  chooses his effort to maximize his utility  $U_{3ik} = t_{3i} - \frac{1}{2}e_{3ik}^2$ . Similarly, agent  $A_{2i}$  chooses his effort to maximize  $U_{2i} = t_{2i} - \frac{1}{2}e_{2i}^2$ .<sup>9</sup> Notice that the supervisor's effort cost increases with the number of subordinates and the effort level chosen. Furthermore, marginal effort increases with the number of subordinates taking into account the fact that coordination and control of tasks become more difficult as the number of subordinates grows. The principal's objective is the maximization of the firm's net profits  $\pi_i = pq_i - t_{2i} - K_i t_{3i} - F$ , where  $p$  is the market price and  $F$  is fixed costs or entry costs.

4. *Competition and demand.* Competition is for a homogeneous good with inverse demand function  $p = a - bq$ ,  $a > 0$ ,  $b > 0$ , where  $q$  is aggregate output.  $n$  identical firms enter the market. For simplicity we assume that  $n$  is a continuous variable. With free entry firms enter until profits are zero. The objective of the paper is to analyze how incentive payments vary for different tiers when the size of the market changes. Market changes are analyzed by changes in the slope parameter  $b$ . A decrease in  $b$  means that the market becomes larger and an increase of  $b$  means that the market shrinks.

5. *Timing.* Competition and contracting are defined to be a multi-stage game in which the

---

<sup>6</sup>Notice that unlike single-principal-single-agent models, we have not included a random term. However, with team production the moral hazard problem stems from the fact that the principal cannot identify individual effort from the observation of output though production is non-random (cf. Espinosa and Macho-Stadler, 2003).

<sup>7</sup>Lazear (2000) shows that this is a realistic assumption concerning the payment schemes applied for low-tier employees in enterprises in industrial sectors. McAfee and McMillan (1991) analyze the conditions under which it is optimal to use linear team contracts.

<sup>8</sup>In fact,  $\beta_{3i}$  is also determined by a bargaining process. However, this process mostly takes place inside the firm. Thus, while the fixed wage is assumed to be the same throughout the industry, performance-related-pay can differ between firms but not between employees of the same firm.

<sup>9</sup>A major difference in models that analyze managerial incentives is that agents are assumed to be risk-neutral. Consequently, there is no trade-off between risk and incentives like in Prendergast (2000) or Raith (2003). However, due to the assumption of limited liability and the fact that the fixed wage is determined exogenously, employees at lower tiers do not support much risk. Therefore, here, incentive pay is basically used to stimulate production and the trade-off is between productivity gains and wage costs.



sequence of events is as follows: At stage 1 the principals of all firms simultaneously decide the size of their firm ( $K_i$ ) and the remunerations ( $t_{2i}$  and  $t_{3i}$ ) of her employees. At stage 2, the supervisors choose their effort ( $e_{2i}$ ). At stage 3 agents  $A_{3ik}$  observe their supervisor's effort and, simultaneously, make their own effort choice ( $e_{3ik}$ ). Then, firms' output and market price are realized, the agents are paid and the principals obtain their profits.

## 2.2 Effort choice

The market game is solved by backward induction. At *stage 3* of the game, when agents  $A_{3ik}$  simultaneously choose their efforts, they know the effort choice of their supervisors and the number of workers in their firm. Thus, optimal effort is given as the solution to

$$\max_{e_{3ik}} U_{3ik} = \beta_{3i} q_i(K_i, e_{2i}, e_{3i}) + \gamma_{3i} - \frac{1}{2} e_{3ik}^2. \quad (1)$$

We obtain that for a given incentive rate  $\beta_{3i}$ , given supervisor effort  $e_{2i}$  and given firm size  $K_i$  in every subgame perfect Nash equilibrium agent  $A_{3ik}$  in each firm chooses effort

$$e_{3ik} = (\alpha_3 \beta_{3i} e_{2i}^{\alpha_2})^{\frac{1}{2-\alpha_3}} K_i^{\frac{\alpha_1 + \alpha_3 - 1}{2-\alpha_3}}. \quad (2)$$

So, firm  $i$ 's third stage equilibrium output is

$$q_i(K_i, e_{2i}, \beta_{3i}) = (\alpha_3 \beta_{3i})^{\frac{\alpha_3}{2-\alpha_3}} K_i^{\frac{2\alpha_1 + \alpha_3}{2-\alpha_3}} e_{2i}^{\frac{2\alpha_2}{2-\alpha_3}} \quad (3)$$

and agent  $U_{3ik}$ 's utility is given by

$$U_{3ik} = \left(1 - \frac{\alpha_3}{2K_i}\right) \beta_{3i} q_i + \gamma_{3i}. \quad (4)$$

Equations (2) and (3) imply that  $A_{3ik}$ 's effort increases as the incentive rate increases which in turn increases firm  $i$ 's output. From (4) we see that a worker's utility is strictly positive. This is the consequence of the limited liability assumption which implies that agents receive an informational rent. Furthermore, a worker's utility increases with the incentive rate of his contract. Thus, *ceteris paribus*, agents at tier 3 prefer higher powered incentives. Notice that workers cannot observe the effort choice of other workers in the firm. Thus, when deciding their own effort choice they face a free-rider problem. More effort yields higher output and therefore higher wages. However, while a worker only receives part of his own effort contribution through a wage increase, his wage also increases when other workers work more without any cost to him. If workers could cooperatively implement their effort choices within a coalition, the effort choice for each individual would be  $K_i^{\frac{1}{2-\alpha_3}}$  higher than the effort choice in (2).<sup>10</sup> Therefore, as expected, the efficiency loss due to free-riding increases with firm size.

<sup>10</sup>In this case the coalition would solve  $\max_{e_{3i}} \sum_{k=1}^{K_i} U_{3ik} = K_i \beta_{3i} q_i(K_i, e_{2i}, e_{3i}) + K_i \gamma_{3i} - \frac{1}{2} \sum_{k=1}^{K_i} e_{3ik}^2$ .

At *stage 2*, supervisor  $A_{2i}$  chooses his own effort. Formally, he solves the following program [ $P_2$ ]:

$$\max_{e_{2i}} U_{2i} = \beta_{2i} q_i(K_i, e_{2i}, \beta_{3i}) + \gamma_{2i} - \frac{1}{2} e_{2i}^2. \quad (5)$$

where  $q_i(K_i, e_{2i}, \beta_{3i})$  is given by equation (3). From the first-order condition we get:

$$e_{2i} = \left( \left( \frac{2\alpha_2}{2 - \alpha_3} \right)^{\frac{2-\alpha_3}{2}} \beta_{2i}^{\frac{2-\alpha_3}{2}} (\alpha_3 \beta_{3i})^{\frac{\alpha_3}{2}} K_i^\delta \right)^{\frac{1}{2(1-\varepsilon)}} \quad (6)$$

Notice, that the first-order constraint is sufficient for a maximum under assumption 1. Now, firm  $i$ 's third stage equilibrium output is

$$q_i(K_i, \beta_{2i}, \beta_{3i}) = A (\alpha_2^{\alpha_3} \alpha_3^{-\alpha_3} K_i^{2\delta} \beta_{2i}^{\alpha_2} \beta_{3i}^{\alpha_3})^{\frac{1}{2(1-\varepsilon)}}. \quad (7)$$

and agents  $U_{2i}$ 's utility is given by

$$U_{2i} = \frac{2(1-\varepsilon)}{2-\alpha_3} \beta_{2i} q_i + \gamma_{2i}. \quad (8)$$

From equation (7) we find that the principal can increase firm output (and profits) by employing more workers (by increasing  $K_i$ ) or by increasing the PRP of workers and the supervisor (by increasing  $\beta_{2i}$  and  $\beta_{3i}$ ). However, from (4) and (8) we see that increasing PRP implies that workers and the supervisor obtain higher informational rents which reduces the principal's profits. The principal's problem is to choose the combination of PRP schemes (and firm size) that maximizes firm profits. In the next section this problem is analyzed under different endogeneity assumptions.

### 3 Market Equilibrium

How firms react to changes in the competitiveness of markets depends on the time they have to react. In the short run, if a firm wants to increase production because market size has increased, for example, it may only want or be able to increase the production effort of its employees. However, in the mid term it might be more efficient to increase employment instead, or both. In the long run, an increase in production may increase industry profits and cause the entry of new firms in industries with low barriers to entry (cf. Raith, 2003). In this case, all decisions concerning employment must also take into account the reactions of potential entrants. In the remainder of this section, the effect of changes in competition on incentive rates under these different settings is analyzed.

### 3.1 Given firm size and market structure

If firm size cannot be adjusted, at *stage 1*, the principal chooses the wage contracts of her employees to maximize firm profit. Formally, she solves the following program  $[P_1]$ :

$$\begin{aligned} \max_{\beta_{2i}, \gamma_{2i}, \beta_{3i}, \gamma_{3i}} \pi_i &= (a - bq) q_i - (\beta_{2i} q_i + \gamma_{2i}) - K_i (\beta_{3i} q_i + \gamma_{3i}) - F & (9) \\ \text{s.t.} & (2), (6), U_{2i} \geq 0, U_{3ik} \geq 0, \gamma_{2i} \geq \gamma_2 \text{ and } \gamma_{3i} \geq \gamma_3. \end{aligned}$$

The principals' maximization problem is subject to incentive, participation and limited liability constraints. The solution of  $[P_1]$  yields:

**Proposition 1** *There exists a unique symmetric subgame perfect Nash equilibrium in which each firm chooses  $\beta_{2i} = \beta_2$  defined by:*

$$a - b(n + 1) AK^{\frac{\alpha_1}{1-\varepsilon}} \beta_2^{\frac{\varepsilon}{(1-\varepsilon)}} - \frac{2}{\alpha_2} \beta_2 = 0. \quad (10)$$

*Third tier incentive rates are*

$$\beta_{3i} = \frac{\alpha_3}{\alpha_2 K} \beta_{2i}, \quad (11)$$

*and fixed payments are  $\gamma_{2i} = \gamma_2$  and  $\gamma_{3i} = \gamma_3$ .*

From proposition 1 we see that incentive rates depend on firm size, market size and the number of firms. For the effect of changes in these variables on incentive rates we have:

**Corollary 1** *With given firm size and market structure incentive rates of workers and supervisors are higher in larger markets ( $\partial\beta_{2i}/\partial b|_{K,n} < 0$ ,  $\partial\beta_{3i}/\partial b|_{K,n} < 0$ ), lower in markets with more firms ( $\partial\beta_{2i}/\partial n < 0$ ,  $\partial\beta_{3i}/\partial n < 0$ ) and lower in larger firms ( $\partial\beta_{2i}/\partial K < 0$ ,  $\partial\beta_{3i}/\partial K < 0$ ).*

In larger markets the market share of firms increases. Therefore, to produce more, it is necessary to incite agents to make more effort. Thus, incentive rates increase. These results are similar to those we can find in single-agent-single-principal models (cf. Raith, 2003 and Schmidt, 1997). Concerning changes in firm size, as we have seen above, in larger firms the free-rider problem is aggravated. So it becomes more costly for the principal to incite a given effort level and from (2) and (11) we find that workers' equilibrium efforts and incentive rates decrease when firm size increases.

### 3.2 Endogenous firm size and given market structure

If changes in competition are expected to be durable, the principal might want to adopt firm size also. With endogenous firm size, at *stage 1* the principal solves the program  $[P'_1]$ :

$$\begin{aligned} \max_{K_i, \beta_{2i}, \gamma_{2i}, \beta_{3i}, \gamma_{3i}} \pi_i &= (a - bq) q_i - (\beta_{2i} q_i + \gamma_{2i}) - K_i (\beta_{3i} q_i + \gamma_{3i}) - F & (12) \\ \text{s.t.} & (2), (6), U_{2i} \geq 0, U_{3ik} \geq 0, \gamma_{2i} \geq \gamma_2 \text{ and } \gamma_{3i} \geq \gamma_3. \end{aligned}$$

The only difference with respect to program  $P_1$  is that now the principal also maximizes with respect to  $K_i$ . The solution of  $[P'_1]$  yields:

**Proposition 2** *There exists a unique symmetric subgame perfect Nash equilibrium in which each firm chooses size  $K^* = K(b, n)$ , where  $K^*$  is defined by*

$$\frac{2}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*1-\varepsilon-\alpha_1} + b(n+1) A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{*\alpha_1+\varepsilon} - a = 0. \quad (13)$$

*Incentive rates are*

$$\beta_{2i} = \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*1-\varepsilon-\alpha_1} \quad \text{and} \quad \beta_{3i} = \frac{\alpha_3}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*-\varepsilon-\alpha_1} \quad (14)$$

*and fixed payments are  $\gamma_{2i} = \gamma_2$  and  $\gamma_{3i} = \gamma_3$ .*

The main characteristic of the agent's incentive scheme is that it depends on two variables: firm size and the fixed wage level. Furthermore incentive rates depend particularly on the relative contributions of supervisors and workers to production. This is of practical importance when we compare the structure of incentive payments in different industries or when changes in competition lead to changes in task assignment and organizational structure. To see how changes in different measures of competition affect the incentive rates of supervisors and workers, we start by analyzing the effect of changes in the competitiveness of markets on firm size.

**Corollary 2** *Equilibrium firm size is higher in larger markets ( $\partial K^*/\partial b < 0$ ) and in more concentrated markets ( $\partial K^*/\partial n < 0$ ).*

The intuition of this result is straightforward. In larger markets or in more concentrated markets firms have a larger market share and produce more. Therefore, employment is increased. Together, Corollary 1 and 2 imply that changes in the degree of competition have counteracting effects on incentive rates when firm size is an endogenous variable. On the one hand, with an increase in a firm's market share the principal can increase production by increasing production effort, which requires higher powered incentive schemes. On the other hand, she can increase production by employing more agents, which aggravates free-riding and induces lower incentive rates for workers but not for supervisors. From (11) we see that for workers the second effect dominates the first one. In larger markets and in more concentrated markets firm size increases and the workers' incentive rates decrease. For supervisors both effects work in the same direction. Therefore, in larger markets and in more concentrated markets their incentive rate increases. The following result resumes these findings:

**Corollary 3** *With endogenous firm size and given market structure workers' incentive rates are lower in larger markets ( $\partial \beta_{3i}/\partial b \big|_n > 0$ ) and in more concentrated markets ( $\partial \beta_{3i}/\partial n > 0$ ). Supervisors' incentive rates are higher in larger markets ( $\partial \beta_{2i}/\partial b \big|_n < 0$ ) and in more concentrated markets ( $\partial \beta_{2i}/\partial n < 0$ ).*

The major difference between this result and Corollary 1 is that with endogenous firm size changes in the competitiveness of markets can have opposite effects on the incentive rates of supervisors and workers. For example, the entry of firms in the market reduces the market share of incumbent firms and therefore firm production. This reduction is achieved by reducing firm size. However, the reduction in firm size means that the supervisor's effort and incentive rates are reduced while workers' effort and incentive rates increase. This result therefore gives an intuitive explanation for the results of Cuñat and Guadalupe (2005). Changes in the competitiveness of markets affect CEO and executive pay-performance sensitivities in the same direction in firms that respond to these changes with an increase in effort and those which also increase employment, while workers' pay-performance sensitivities are affected in opposite directions in these two kinds of firms. Therefore, when firms with different responses to changes in the competitive environment are aggregated, the effect on PRP sensitivities of workers are less significant than those of CEO's and executives.

### 3.3 Endogenous firm size and market structure

When market structure is endogenous, the number of firms in the market is determined by the cost of entry. This affects the forgoing analysis in two ways. On the one hand, a change in market size will now also cause the entry or exit of firms. On the other hand, a variation in the costs of entry affects the variables of interest in the model only through changes in the number of firms whose implications we have already discussed. From substitution of equations (14) into (7) we see that the equilibrium output is

$$q_i(K_i, \beta_{2i}, \beta_{3i}) = A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{*\varepsilon+\alpha_1} \quad (15)$$

and from substitution of equations (14) and (15) into (12) we find that firm  $i$ 's equilibrium profits are

$$\pi_i = (a - bq) q_i - \left( \frac{\varepsilon + \alpha_1}{\alpha_1} \gamma_3 K^* + \gamma_{2i} \right) - F. \quad (16)$$

Using (13) this can be written as

$$\pi_i = \left( \frac{1 - \alpha_1 - \varepsilon}{\alpha_1} \right) \gamma_3 K^* + bA^2 \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{2\varepsilon} K^{*2(\alpha_1+\varepsilon)} - \gamma_2 - F. \quad (17)$$

In the long-run firms enter until profits are zero and changes in the competitiveness of markets affect the number of firms and firm size simultaneously. Then, the number and size of firms in equilibrium is determined by equation (13) and the zero profit condition in (17). This yields:

**Proposition 3** *There exists a unique symmetric subgame perfect Nash equilibrium in which firms enter until profits are zero and where firm size  $K^* = K(b, F)$  and the number of firms in*

the market  $n^* = n(b, F)$  are defined by

$$\frac{2}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*1-\varepsilon-\alpha_1} + b(n^* + 1) A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{*\alpha_1+\varepsilon} - a = 0 \quad (18)$$

$$\left( \frac{1 - \alpha_1 - \varepsilon}{\alpha_1} \right) \gamma_3 K^* + bA^2 \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{2\varepsilon} K^{*2(\alpha_1+\varepsilon)} - \gamma_2 - F = 0 \quad (19)$$

Incentive rates are

$$\beta_{2i} = \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*1-\varepsilon-\alpha_1} \quad \text{and} \quad \beta_{3i} = \frac{\alpha_3}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*-\varepsilon-\alpha_1} \quad (20)$$

and fixed payments are  $\gamma_{2i} = \gamma_2$  and  $\gamma_{3i} = \gamma_3$ .

Regarding changes in the competitiveness of markets because of variations in market size or entry costs we get the following result:

**Corollary 4** *An increase in market size increases firm size and causes entry ( $\partial K^*/\partial b < 0$ ,  $\partial n^*/\partial b < 0$ ). An increase in entry costs increases firm size and causes exit ( $\partial K^*/\partial F > 0$ ,  $\partial n^*/\partial F < 0$ ).*

This result comes from two counteracting effects on firm size. The first effect, as we have seen in Corollary 3, is that in larger markets firm size will be larger. However, profits will also be larger and so the second effect is that firms will enter into the market, which decreases firm size. Corollary 4 indicates that if market size changes the first effect dominates the second. As expected, we find that the equilibrium number of firms is larger in larger markets and markets with lower entry costs.

To analyze the effect of changes in competition on incentive rates, notice from (20) that market size and entry cost affect incentive rates only indirectly through a change in firm size. Therefore, the results in Corollary 4 mean:

**Corollary 5** *With endogenous firm size and market structure workers' incentive rates are lower in larger markets ( $\partial \beta_{3i}/\partial b > 0$ ) and in markets with higher entry costs ( $\partial \beta_{3i}/\partial F < 0$ ). Supervisors' incentive rates are higher in larger markets ( $\partial \beta_{2i}/\partial b < 0$ ) and in markets with higher entry costs ( $\partial \beta_{2i}/\partial F > 0$ ).*

As far as supervisor incentive rates are concerned, this result is very similar to the findings of Raith (2003). He also finds that incentive rates are higher in larger markets and lower in markets with lower entry costs. The main interest in Corollary 5 is how changes in competition affect workers' PRP. Changes in market size and entry cost have just the opposite effect on workers' incentive rates compared to those of supervisors. This difference can be explained as follows. When market size increases firms want to increase production. In single-principal-single-agent models like those of Raith (2003) and Vives (2005) this increase in production can only be achieved by increasing the agent's effort, which aggravates the moral hazard problem and

requires stronger incentives. Here production can also be increased by employing more agents and this is what happens when market structure is exogenous. However, when more agents are employed the free-rider problem becomes more severe. Therefore, performance-related-pay is reduced and workers make less effort. This implies that firms produce with higher unit costs per output. So, new entrants, which are smaller in size, will have a competitive advantage and the incumbents must reduce firm size to initial levels to be competitive. Thus, the free-rider effect, which is not present in single-principal-single-agent models, is the driving force behind the difference in the results we obtain. Again, as in the case for markets without entry, we can explain why Cuñat and Guadalupe (2005) cannot find significant effects of changes in competition on the incentives rates of workers (for whom there is a free-rider problem) while they find a positive and significant effect on those of CEO's (without a free-rider problem) in the same firms.

## 4 Conclusion

Empirical evidence suggests that performance-related-pay sensitivities increase significantly with product market competition for CEO's. However, for workers, the effects of competition are much weaker and mostly insignificant (cf. Cuñat and Guadalupe (2005), p.1060). This is at odds with theoretical results that suggest that, though the amount of incentive payments should decrease with the hierarchical levels inside a firm, PRP sensitivities should increase equally at all levels with changes in competition. In this paper, a simple model of PRP in hierarchical agency is developed. The three-tier hierarchy includes a principal at the top, a supervisor on the mid tier and workers on the bottom tier. Incentive payments are used in the model because of moral hazard problems concerning supervisor's and workers' effort levels, which determine joint production.

The main results of the paper are displayed in Figure 1. We find that PRP on the lower tiers of a firm generates two kind of heterogeneities. First, changes in the competitiveness of markets can have different impacts on mid-tier and low-tier agents. The reason for this is that when firms apply group-incentive schemes and react to changes in competition by adjusting employment, this adjustment affects the free-rider problem at lower tiers. Second, while a firm's reaction to changes in competition concerning the PRP of mid-tier agents is similar under different endogeneity assumptions, it is very sensitive to these assumptions when we consider workers' PRP. Firms that react to changes in competition by adjusting only their production effort and firms that also adjust employment will apply different changes to the intensity of workers' PRP. The same is true for firms that operate in closed markets and firms that operate in markets with low barriers to entry. Together, these two kinds of heterogeneities explain the observation that the pay-performance sensitivities in worker contracts are significantly lower than those in managerial contracts when aggregated firm data is used.

Of course, this is not to say that free-riding is the only explanation for differences in PRP

in different hierarchical levels. Schmidt (1997) suggests that fear of liquidation (and a costly search for a new job) can act as a spur in a more competitive market. Nalebuff and Stiglitz (1983) and Hart (1983) suggest that more competitors or more similar firms might provide better benchmarks and so it is easier to write high-powered incentives because one can filter out common components of performance. If these benchmarks already exist, as for example for salesmen in a sales-force or managers of stores in large chains, one can expect that additional competition might have a smaller effect on the power of performance contracts. This also can explain a more muted effect on lower tier employees than CEOs.

Though the results have been obtained under very specific assumptions, they can be generalized for several reasons. First, the results depend on the assumption that worker's labor inputs are perfect substitutes. However, this is just the contrary assumption to Raith (2003) and Vives (2005) where the assumption that the results also apply to lower levels of the firm hierarchy implicitly implies that workers' contributions are completely independent. Thus, with less substitutability, the effects found in this paper will also be present while the impact of changes in competition on firm size will be lower and the results concerning effort and incentive rates will be closer to those of Raith (2003) and Vives (2005). Second, we have used firm output as a common unit of incentive measurement. However, concerning top-tier agents we get similar results regarding the effects of changes in competition on PRP as in models which use other units of measurement, like profits or cost reductions. The effect of changes in competition on different layers of a hierarchy using the other units of incentive measure should therefore not be expected to depend on the specific unit of measurement. Finally, the results depend on the assumption that changes in competition do not affect the task and job assignment within firms. However, a mayor effect of changes in competition may merely lead to a restructuring of these conditions (cf. Ichniowski and Shaw, 2003). In this case, a change in the PRP sensitivities is the consequence of the fact that workers perform different tasks with different responsibilities. This analysis is beyond the scope of this paper.



## 5 Appendix

PROOF OF PROPOSITION 1:

From problem  $[P_1]$  we see that it is clearly optimal to set  $\gamma_{2i} = \gamma_2$ , and  $\gamma_{3i} = \gamma_3$ . Now, equations (4) and (8) imply that  $U_{3i} \geq 0$  and  $U_{2i} \geq 0$  if  $\beta_{3i} \geq 0$ ,  $\beta_{2i} \geq 0$  and  $q_i \geq 0$ . Assuming this (we will check later that the conditions are fulfilled), the maximization problem can be rewritten as:

$$\max_{\beta_{2i}, \beta_{3i}} \pi_i = \left( a - b \sum_{i=1}^n q_i - \beta_{2i} - K_i \beta_{3i} \right) q_i - \gamma_2 - K_i \gamma_3 - F \quad (21)$$

where  $q_i = q_i(K_i, \beta_{2i}, \beta_{3i}) = A (\alpha_2^{\alpha_3} \alpha_3^{-\alpha_3} K_i^{2\delta} \beta_{2i}^{\alpha_2} \beta_{3i}^{\alpha_3})^{\frac{1}{2(1-\varepsilon)}}$ . The first-order conditions are

$$\frac{\partial \pi_i}{\partial \beta_{2i}} = \left( a - b \sum_{i=1}^n q_i - b q_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial q_i}{\partial \beta_{2i}} - q_i = 0 \quad \forall i. \quad (22)$$

$$\frac{\partial \pi_i}{\partial \beta_{3i}} = \left( a - b \sum_{i=1}^n q_i - b q_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial q_i}{\partial \beta_{3i}} - K_i q_i = 0 \quad \forall i. \quad (23)$$

Using the symmetry assumption,  $K_i = K$ , and substituting  $\frac{\partial q_i}{\partial \beta_{2i}}$  and  $q_i$  we get:

$$\left( a - b \sum_{i=1}^n q_i - b q_i - \beta_{2i} - K \beta_{3i} \right) \frac{\alpha_2}{2(1-\varepsilon)} q_i \beta_{2i}^{-1} - q_i = 0 \quad \forall i. \quad (24)$$

$$\left( a - b \sum_{i=1}^n q_i - b q_i - \beta_{2i} - K \beta_{3i} \right) \frac{\alpha_3}{2(1-\varepsilon)} q_i \beta_{3i}^{-1} - K q_i = 0 \quad \forall i. \quad (25)$$

This yields

$$\beta_{3i} = \frac{\alpha_3}{\alpha_2 K} \beta_{2i}. \quad (26)$$

$$a - b A K^{\frac{\alpha_1}{1-\varepsilon}} \left( \sum_{i=1}^n \beta_{2i}^{\frac{\varepsilon}{1-\varepsilon}} + \beta_{2i}^{\frac{\varepsilon}{1-\varepsilon}} \right) = \frac{2}{\alpha_2} \beta_{2i}. \quad (27)$$

In equilibrium,  $\beta_{2i} = \beta_2$ . Thus,  $\beta_2$  is implicitly defined by

$$a - b(n+1) A K^{\frac{\alpha_1}{1-\varepsilon}} \beta_2^{\frac{\varepsilon}{1-\varepsilon}} = \frac{2}{\alpha_2} \beta_2. \quad (28)$$

Notice that in equilibrium  $\beta_2 > 0$  because the left hand-side of (28) decreases in  $\beta_2$  and is  $a$  for  $\beta_2 = 0$  and the right hand-side increases in  $\beta_2$  and is 0 for  $\beta_2 = 0$ . Then, from (26)  $\beta_{3i} > 0$ . Therefore,  $q_i > 0$  and the participation constraints are satisfied ( $U_{3i} \geq 0$  and  $U_{2i} \geq 0$ ).

PROOF OF COROLLARY 1:

Applying the implicit function theorem, from (10) we get:

$$\frac{\partial \beta_2}{\partial b} = -\frac{(n+1) K^{\frac{\alpha_1}{1-\varepsilon}} \beta_2^{\frac{\varepsilon}{(1-\varepsilon)}}}{\frac{2}{\alpha_2} + \frac{\varepsilon}{(1-\varepsilon)} b (n+1) A K^{\frac{\alpha_1}{1-\varepsilon}} \beta_2^{\frac{\varepsilon}{(1-\varepsilon)}-1}} < 0, \quad (29)$$

$$\frac{\partial \beta_2}{\partial n} = -\frac{b A K^{\frac{\alpha_1}{1-\varepsilon}} \beta_2^{\frac{\varepsilon}{(1-\varepsilon)}}}{\frac{2}{\alpha_2} + \frac{\varepsilon}{(1-\varepsilon)} b (n+1) A K^{\frac{\alpha_1}{1-\varepsilon}} \beta_2^{\frac{\varepsilon}{(1-\varepsilon)}-1}} < 0, \quad (30)$$

$$\frac{\partial \beta_2}{\partial K} = -\frac{\frac{\alpha_1}{1-\varepsilon} b (n+1) A K^{\frac{\alpha_1}{1-\varepsilon}-1} \beta_2^{\frac{\varepsilon}{(1-\varepsilon)}}}{\frac{2}{\alpha_2} + \frac{\varepsilon}{(1-\varepsilon)} b (n+1) A K^{\frac{\alpha_1}{1-\varepsilon}} \beta_2^{\frac{\varepsilon}{(1-\varepsilon)}-1}} < 0. \quad (31)$$

From (11) we get that  $\text{sign}\left(\frac{\partial \beta_{3i}}{\partial x}\right) = \text{sign}\left(\frac{\partial \beta_2}{\partial x}\right)$ , for  $x = b, n, K$ .

PROOF OF PROPOSITION 2:

From problem  $[P_1]$  we see that it is clearly optimal to set  $\gamma_{2i} = \gamma_2$ , and  $\gamma_{3i} = \gamma_3$ . Now, equations (4) and (8) imply that  $U_{3ik} \geq 0$  and  $U_{2i} \geq 0$  if  $\beta_{3i} \geq 0$ ,  $\beta_{2i} \geq 0$  and  $q_i \geq 0$ . Assuming this (we will check later that the conditions are fulfilled), the maximization problem can be rewritten as:

$$\max_{K_i, \beta_{2i}, \beta_{3i}} \pi_i = \left( a - b \sum_{i=1}^n q_i - \beta_{2i} - K_i \beta_{3i} \right) q_i - \gamma_2 - K_i \gamma_3 - F. \quad (32)$$

where  $q_i(K_i, \beta_{2i}, \beta_{3i}) = A (\alpha_2^{\alpha_3} \alpha_3^{-\alpha_3} K_i^{2\delta} \beta_{2i}^{\alpha_2} \beta_{3i}^{\alpha_3})^{\frac{1}{2(1-\varepsilon)}}$ . The first-order conditions are

$$\frac{\partial \pi_i}{\partial K_i} = \left( a - b \sum_{i=1}^n q_i - b q_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial q_i}{\partial K_i} - \beta_{3i} q_i - \gamma_3 = 0, \quad (33)$$

$$\frac{\partial \pi_i}{\partial \beta_{2i}} = \left( a - b \sum_{i=1}^n q_i - b q_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial q_i}{\partial \beta_{2i}} - q_i = 0, \quad (34)$$

$$\frac{\partial \pi_i}{\partial \beta_{3i}} = \left( a - b \sum_{i=1}^n q_i - b q_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial q_i}{\partial \beta_{3i}} - K_i q_i = 0, \quad (35)$$

where

$$\frac{\partial q_i}{\partial K_i} = \frac{\delta}{1-\varepsilon} q_i K_i^{-1} > 0, \quad (36)$$

$$\frac{\partial q_i}{\partial \beta_{2i}} = \frac{\alpha_2}{2(1-\varepsilon)} q_i \beta_{2i}^{-1} > 0, \quad (37)$$

$$\frac{\partial q_i}{\partial \beta_{3i}} = \frac{\alpha_3}{2(1-\varepsilon)} q_i \beta_{3i}^{-1} > 0. \quad (38)$$

Using these expressions, the system of equations (33) - (35) can be rewritten as:

$$a - b \sum_{i=1}^n q_i(K_i, \beta_{2i}, \beta_{3i}) - bq_i(K_i, \beta_{2i}, \beta_{3i}) = \frac{2}{\alpha_2} \beta_{2i} \quad \forall i, \quad (39)$$

$$\left( \frac{\alpha_2}{2\alpha_1} \frac{\gamma_3}{A} \right)^{1-\varepsilon} K_i^{1-\varepsilon-\alpha_1} = \beta_{2i} \quad \forall i, \quad \text{and}, \quad (40)$$

$$\frac{\alpha_3}{\alpha_2 K_i} \beta_{2i} = \beta_{3i} \quad \forall i. \quad (41)$$

Substituting (40) and (41) into  $q_i(K_i, \beta_{2i}, \beta_{3i})$  we get:

$$q_i = A \left( \frac{\alpha_2}{2\alpha_1} \frac{\gamma_3}{A} \right)^\varepsilon K_i^{\alpha_1+\varepsilon}. \quad (42)$$

Substituting (40) and (42) into (39) we get:

$$a - bA \left( \frac{\alpha_2}{2\alpha_1} \frac{\gamma_3}{A} \right)^\varepsilon \left( \sum_{i=1}^n K_i^{\alpha_1+\varepsilon} + K_i^{\alpha_1+\varepsilon} \right) = \frac{2}{\alpha_2} \left( \frac{\alpha_2}{2\alpha_1} \frac{\gamma_3}{A} \right)^{1-\varepsilon} K_i^{1-\varepsilon-\alpha_1} \quad \forall i. \quad (43)$$

Because of symmetry,  $K_i = K$ ,  $\forall i$ . Then, in equilibrium we get that optimal firm size  $K^*$  is implicitly defined by

$$G(b, n, K^*) = 0, \quad (44)$$

where

$$G(b, n, K) = \frac{2}{\alpha_2} \left( \frac{\alpha_2}{2\alpha_1} \frac{\gamma_3}{A} \right)^{1-\varepsilon} K^{1-\varepsilon-\alpha_1} + b(n+1)A \left( \frac{\alpha_2}{2\alpha_1} \frac{\gamma_3}{A} \right)^\varepsilon K^{\alpha_1+\varepsilon} - a. \quad (45)$$

*Existence* and *uniqueness* are guaranteed because the left-hand side in (43) is strictly decreasing in  $K_i$  and  $a$  for  $K_i = 0$ , while the right-hand side is strictly increasing and 0 for  $K_i = 0$ . Therefore, in equilibrium  $K_i > 0$ , and from (40), (41) and (42)  $\beta_{2i} > 0$ ,  $\beta_{3i} > 0$  and  $q_i > 0$  such that the participation constraints are satisfied ( $U_{3i} \geq 0$  and  $U_{2i} \geq 0$ ). Now, (44) and (45) yield (13). Substitution of (40) into (41) gives (14). To guarantee *sufficiency* we obtain the second-order conditions:

$$\frac{\partial^2 \pi_i}{\partial K_i^2} = \left( a - b \sum_{i=1}^n q_i - bq_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial^2 q_i}{\partial K_i^2} - 2b \left[ \frac{\partial q_i}{\partial K_i} \right]^2 - 2\beta_{3i} \frac{\partial q_i}{\partial K_i}, \quad (46)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{2i}^2} = \left( a - b \sum_{i=1}^n q_i - bq_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial^2 q_i}{\partial \beta_{2i}^2} - 2 \left[ b \frac{\partial q_i}{\partial \beta_{2i}} + 1 \right] \frac{\partial q_i}{\partial \beta_{2i}}, \quad (47)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{3i}^2} = \left( a - b \sum_{i=1}^n q_i - bq_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial^2 q_i}{\partial \beta_{3i}^2} - 2 \left[ b \frac{\partial q_i}{\partial \beta_{3i}} + K_i \right] \frac{\partial q_i}{\partial \beta_{3i}}, \quad (48)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial K_i} = \left( a - b \sum_{i=1}^n q_i - bq_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial^2 q_i}{\partial \beta_{2i} \partial K_i} - \left[ 2b \frac{\partial q_i}{\partial \beta_{2i}} + 1 \right] \frac{\partial q_i}{\partial K_i} - \beta_{3i} \frac{\partial q_i}{\partial \beta_{2i}}, \quad (49)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{3i} \partial K_i} = \left( a - b \sum_{i=1}^n q_i - bq_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial^2 q_i}{\partial \beta_{3i} \partial K_i} - \left[ 2b \frac{\partial q_i}{\partial \beta_{3i}} + K_i \right] \frac{\partial q_i}{\partial K_i} - \beta_{3i} \frac{\partial q_i}{\partial \beta_{3i}} \quad (50)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial \beta_{3i}} = \left( a - b \sum_{i=1}^n q_i - bq_i - \beta_{2i} - K_i \beta_{3i} \right) \frac{\partial^2 q_i}{\partial \beta_{2i} \partial \beta_{3i}} - \left[ 2b \frac{\partial q_i}{\partial \beta_{2i}} + 1 \right] \frac{\partial q_i}{\partial \beta_{3i}} - K_i \frac{\partial q_i}{\partial \beta_{2i}} \quad (51)$$

where

$$\frac{\partial^2 q_i}{\partial K_i^2} = \left( \frac{\delta}{(1-\varepsilon)} - 1 \right) \frac{\delta}{1-\varepsilon} q_i K_i^{-2} < 0, \quad (52)$$

$$\frac{\partial^2 q_i}{\partial \beta_{2i}^2} = \left( \frac{\alpha_2}{2(1-\varepsilon)} - 1 \right) \frac{\alpha_2}{2(1-\varepsilon)} q_i \beta_{2i}^{-2} < 0, \quad (53)$$

$$\frac{\partial^2 q_i}{\partial \beta_{3i}^2} = \left( \frac{\alpha_3}{2(1-\varepsilon)} - 1 \right) \frac{\alpha_3}{2(1-\varepsilon)} q_i \beta_{3i}^{-2} < 0, \quad (54)$$

$$\frac{\partial^2 q_i}{\partial \beta_{2i} \partial K_i} = \frac{\delta}{(1-\varepsilon)} \frac{\alpha_2}{2(1-\varepsilon)} q_i \beta_{2i}^{-1} K_i^{-1} > 0, \quad (55)$$

$$\frac{\partial^2 q_i}{\partial \beta_{3i} \partial K_i} = \frac{\delta}{(1-\varepsilon)} \frac{\alpha_3}{2(1-\varepsilon)} q_i \beta_{3i}^{-1} K_i^{-1} > 0, \quad (56)$$

$$\frac{\partial^2 q_i}{\partial \beta_{2i} \beta_{3i}} = \frac{\alpha_2}{2(1-\varepsilon)} \frac{\alpha_3}{2(1-\varepsilon)} q_i \beta_{2i}^{-1} \beta_{3i}^{-1} > 0. \quad (57)$$

At the extremum the second-order conditions are:

$$\frac{\partial^2 \pi_i}{\partial K_i^2} = - \left[ 2b - \left( \frac{1-\delta-\varepsilon+\alpha_3}{\delta} \right) \frac{2(1-\varepsilon)}{\alpha_2} q_i^{-1} \beta_{2i} \right] \left[ \frac{\partial q_i}{\partial K_i} \right]^2 < 0, \quad (58)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{2i}^2} = - \left[ 2b + \left( 1 + \frac{2(1-\varepsilon)}{\alpha_2} \right) \frac{2(1-\varepsilon)}{\alpha_2} q_i^{-1} \beta_{2i} \right] \left[ \frac{\partial q_i}{\partial \beta_{2i}} \right]^2 < 0, \quad (59)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{3i}^2} = - \left[ 2b + \left( 1 + \frac{2(1-\varepsilon)}{\alpha_3} \right) \frac{2(1-\varepsilon)}{\alpha_2} q_i^{-1} \beta_{2i} \right] \left[ \frac{\partial q_i}{\partial \beta_{3i}} \right]^2 < 0, \quad (60)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial K_i} = - \left[ 2b + \frac{\alpha_3}{\alpha_2} \frac{1-\varepsilon}{\delta} \beta_{2i} q_i^{-1} \right] \frac{\partial q_i}{\partial \beta_{2i}} \frac{\partial q_i}{\partial K_i} < 0, \quad (61)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{3i} \partial K_i} = - \left[ 2b + \frac{\alpha_3}{\alpha_2} \frac{1-\varepsilon}{\delta} \beta_{2i} q_i^{-1} \right] \frac{\partial q_i}{\partial \beta_{3i}} \frac{\partial q_i}{\partial K_i} < 0, \quad (62)$$

$$\frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial \beta_{3i}} = - \left[ 2b + \frac{2(1-\varepsilon)}{\alpha_2} \beta_{2i} q_i^{-1} \right] \frac{\partial q_i}{\partial \beta_{2i}} \frac{\partial q_i}{\partial \beta_{3i}} < 0. \quad (63)$$

Sufficiency is guaranteed by uniqueness of the extremum and since the Hessian matrix  $H$  is negative definite at the extremum:

$$H_1 = \frac{\partial^2 \pi_i}{\partial \beta_{2i}^2} = - \left[ 2b + \left( 1 + \frac{2(1-\varepsilon)}{\alpha_2} \right) \frac{2(1-\varepsilon)\beta_{2i}}{\alpha_2 q_i} \right] \left[ \frac{\partial q_i}{\partial \beta_{2i}} \right]^2 < 0, \quad (64)$$

$$\begin{aligned} H_2 &= \frac{\partial^2 \pi_i}{\partial \beta_{2i}^2} \frac{\partial^2 \pi_i}{\partial \beta_{3i}^2} - \left( \frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial \beta_{3i}} \right)^2 \\ &= 2 \left[ b \left( 1 + \frac{\alpha_2}{\alpha_3} \right) + \frac{2(1-\varepsilon)\beta_{2i}}{\alpha_2 \alpha_3 q_i} \right] \left[ \frac{2(1-\varepsilon)}{\alpha_2} \right]^2 \frac{\beta_{2i}}{q_i} \left[ \frac{\partial q_i}{\partial \beta_{2i}} \frac{\partial q_i}{\partial \beta_{3i}} \right]^2 > 0 \end{aligned} \quad (65)$$

$$\begin{aligned} H_3 &= \frac{\partial^2 \pi_i}{\partial \beta_{2i}^2} \frac{\partial^2 \pi_i}{\partial \beta_{3i}^2} \frac{\partial^2 \pi_i}{\partial K_i^2} + 2 \frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial \beta_{3i}} \frac{\partial^2 \pi_i}{\partial \beta_{3i} \partial K_i} \frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial K_i} \\ &\quad - \frac{\partial^2 \pi_i}{\partial \beta_{2i}^2} \left[ \frac{\partial^2 \pi_i}{\partial \beta_{3i} \partial K_i} \right]^2 - \frac{\partial^2 \pi_i}{\partial \beta_{3i}^2} \left[ \frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial K_i} \right]^2 - \frac{\partial^2 \pi_i}{\partial K_i^2} \left[ \frac{\partial^2 \pi_i}{\partial \beta_{2i} \partial \beta_{3i}} \right]^2 \\ &= \left[ \begin{array}{c} -(2\delta + \alpha_2 + \alpha_3)(2 - \alpha_2 - \alpha_3)b \\ -((2\alpha_1 + \alpha_3)(2 - 2\alpha_1 - \alpha_2) - \varepsilon\alpha_3^2) \frac{1-\varepsilon}{\alpha_2 \delta} \frac{\beta_{2i}}{q_i} \end{array} \right] \frac{8(1-\varepsilon)^3}{\alpha_2^3 \alpha_3 \delta} \left[ \frac{\beta_{2i}}{q_i} \frac{\partial q_i}{\partial \beta_{2i}} \frac{\partial q_i}{\partial \beta_{3i}} \frac{\partial q_i}{\partial K_i} \right]^2 \\ &< 0 \end{aligned} \quad (66)$$

where  $H_i$ ,  $i = 1, 2, 3$  are the successive principal minors of  $H$ .

### PROOF OF COROLLARY 2:

From (44) and (45) we get:

$$\begin{aligned} \frac{\partial K^*}{\partial b} &= - \frac{\frac{\partial G}{\partial b}}{\frac{\partial G}{\partial K}} = \frac{-(n+1)A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{\alpha_1 + \varepsilon}}{\frac{2(1-\varepsilon-\alpha_1)}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{-\varepsilon-\alpha_1} + (\alpha_1 + \varepsilon)b(n+1)A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{\alpha_1 + \varepsilon - 1}} < 0, \\ \frac{\partial K^*}{\partial n} &= - \frac{\frac{\partial G}{\partial n}}{\frac{\partial G}{\partial K}} = \frac{-bA \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{\alpha_1 + \varepsilon}}{\frac{2(1-\varepsilon-\alpha_1)}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{-\varepsilon-\alpha_1} + (\alpha_1 + \varepsilon)b(n+1)A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{\alpha_1 + \varepsilon - 1}} < 0. \end{aligned}$$

### PROOF OF PROPOSITION 3:

When market structure is endogenous firms enter until profits are zero. Therefore,  $n$  and  $K$  are simultaneously determined by equation (13) and by setting the right-hand side of equation (17) equal to zero:

$$G(b, F, K^*, n^*) \equiv \frac{2}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*1-\varepsilon-\alpha_1} + b(n^* + 1)A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{*\alpha_1 + \varepsilon} - a = 0 \quad (67)$$

$$\pi_i(b, F, K^*, n^*) \equiv \left( \frac{1 - \alpha_1 - \varepsilon}{\alpha_1} \right) \gamma_3 K^* + bA^2 \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{2\varepsilon} K^{*2(\alpha_1 + \varepsilon)} - \gamma_2 - F = 0. \quad (68)$$

This yields

$$K^* = K(b, F), \quad (69)$$

$$n^* = n(b, F). \quad (70)$$

Existence is guaranteed for sufficiently large  $a$  in (67) and because from Corollary 2 we have that  $K^*$  is decreasing in  $n^*$ , which implies that profits decrease when  $n$  increases in (68).

#### PROOF OF COROLLARY 4:

Notice that (69) and (70) are continuously differentiable. Then, from the implicit function theorem we get:

$$\begin{aligned} \begin{bmatrix} \frac{\partial K^*}{\partial b} & \frac{\partial K^*}{\partial F} \\ \frac{\partial n^*}{\partial b} & \frac{\partial n^*}{\partial F} \end{bmatrix} &= - \begin{bmatrix} \frac{\partial G}{\partial K^*} & \frac{\partial G}{\partial n^*} \\ \frac{\partial \pi_i}{\partial K^*} & \frac{\partial \pi_i}{\partial n^*} \end{bmatrix}^{-1} \begin{bmatrix} \frac{\partial G}{\partial b} & \frac{\partial G}{\partial F} \\ \frac{\partial \pi_i}{\partial b} & \frac{\partial \pi_i}{\partial F} \end{bmatrix} \\ &= \frac{\begin{bmatrix} -\frac{\partial \pi_i}{\partial b} \frac{\partial G}{\partial n^*} & \frac{\partial G}{\partial n^*} \\ -\frac{\partial \pi_i}{\partial K^*} \frac{\partial G}{\partial b} + \frac{\partial G}{\partial K^*} \frac{\partial \pi_i}{\partial b} & -\frac{\partial G}{\partial K^*} \end{bmatrix}}{\frac{\partial G}{\partial n^*} \frac{\partial \pi_i}{\partial K^*}} \end{aligned} \quad (71)$$

because from (67)  $\frac{\partial G}{\partial F} = 0$ , and from (68)  $\frac{\partial \pi_i}{\partial F} = -1$ , and  $\frac{\partial \pi_i}{\partial n^*} = 0$ . Now, using

$$\frac{\partial G}{\partial b} = (n^* + 1) A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{*\alpha_1 + \varepsilon} > 0, \quad (72)$$

$$\frac{\partial G}{\partial K^*} = \frac{2(1 - \varepsilon - \alpha_1)}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1 - \varepsilon} K^{*- \varepsilon - \alpha_1} \quad (73)$$

$$+ (\alpha_1 + \varepsilon) b (n^* + 1) A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{*\alpha_1 + \varepsilon - 1} > 0 \quad (74)$$

$$\frac{\partial G}{\partial n^*} = b A \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^\varepsilon K^{*\alpha_1 + \varepsilon} > 0, \quad (75)$$

$$\frac{\partial \pi_i}{\partial b} = A^2 \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{2\varepsilon} K^{*2(\alpha_1 + \varepsilon)} > 0, \text{ and} \quad (76)$$

$$\frac{\partial \pi_i}{\partial K^*} = \left( \frac{1 - \alpha_1 - \varepsilon}{\alpha_1} \right) \gamma_3 + 2(\alpha_1 + \varepsilon) b A^2 \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{2\varepsilon} K^{*2(\alpha_1 + \varepsilon) - 1} > 0 \quad (77)$$

we have:

$$\begin{aligned} \frac{\partial K^*}{\partial b} &< 0, \quad \frac{\partial K^*}{\partial F} > 0, \quad \frac{\partial n^*}{\partial F} < 0, \text{ and} \\ \text{sign} \frac{\partial n^*}{\partial b} &= \text{sign} \begin{bmatrix} -\left( \frac{1 - \alpha_1 - \varepsilon}{\alpha_1} \right) \gamma_3 n^* \\ -(\alpha_1 + \varepsilon) (n^* + 1) b A^2 \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{2\varepsilon} K^{*2(\alpha_1 + \varepsilon) - 1} \end{bmatrix} < 0. \end{aligned}$$

PROOF OF COROLLARY 5:

The long-run equilibrium effects of changes in  $b$ , and  $F$  on incentive rates are:

$$\frac{d\beta_{2i}}{db} = (1 - \varepsilon - \alpha_1) \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*- \varepsilon - \alpha_1} \frac{\partial K^*}{\partial b} < 0, \quad (78)$$

$$\frac{d\beta_{2i}}{dF} = (1 - \varepsilon - \alpha_1) \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*- \varepsilon - \alpha_1} \frac{\partial K^*}{\partial F} > 0, \quad (79)$$

$$\frac{d\beta_{3i}}{db} = (-\varepsilon - \alpha_1) \frac{\alpha_3}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*- \varepsilon - \alpha_1 - 1} \frac{\partial K^*}{\partial b} > 0, \text{ and} \quad (80)$$

$$\frac{d\beta_{3i}}{dF} = (-\varepsilon - \alpha_1) \frac{\alpha_3}{\alpha_2} \left( \frac{\alpha_2 \gamma_3}{2\alpha_1 A} \right)^{1-\varepsilon} K^{*- \varepsilon - \alpha_1 - 1} \frac{\partial K^*}{\partial F} < 0. \quad (81)$$

## References

- [1] Baker, G., 1992. Incentive Contracts and Performance Measurement, *Journal of Political Economy* **100(2)**, 598-614.
- [2] Beckmann, M., 1977. Management Production Functions and the Theory of the Firm, *Journal of Economic Theory* **14**,1-18.
- [3] Binmore, K.G., Rubinstein, A. and Wolinsky, A., 1986. The Nash Bargaining Solution in Economic Modelling, *RAND Journal of Economics* **17**, 176-188.
- [4] Bolton, P., Scheinkman, J. and Xiong, W., 2006. Executive Compensation and Short-Terminist Behaviour in Speculative Markets, *Review of Economic Studies* **73**, 577-610.
- [5] Burgess, S. and Metcalfe, P., 2000. Incentive Pay and Product Market Competition, CMPO Working Paper, University of Bristol, No. 00/28.
- [6] Che, Y.-K. and Yoo, S.-W., 2001. Optimal Incentives for Teams, *American Economic Review* **91(3)**, 525-541.
- [7] Cuñat, V. and Guadalupe, M., 2005. How does Product Market Competition Shape Incentive Contracts?, *Journal of the European Economic Association* **3(5)**, 1058-1082.
- [8] Espinosa M.P. and Macho-Stadler, I., 2003. Endogenous Formation of Partnerships with Moral Hazard, *Games and Economic Behavior* **44(1)**, 183-194.

- [9] Ferrall, C. and Shearer, B., 1999. Incentives and Transactions Costs Within the Firm: Estimating an Agency Model Using Payroll Records, *Review of Economic Studies* **66**, 309-338.
- [10] Griffith, R., Harrison, R. and Macartney, G., 2006. Product Market Reforms, Labour Market Institutions and Unemployment, *CEPR Discussion Paper* No. 5599.
- [11] Hart, O.D., 1983. The Market Mechanism as an Incentive Scheme, *Bell Journal of Economics*, **14(2)**, 366-382.
- [12] Holmstrom, B., 1982. Moral hazard in Teams, *The Bell Journal of Economics* **13(2)**, 324-340.
- [13] Holmstrom, B. and Milgrom, P., 1990. Regulating Trade among Agents, *Journal of Institutional and Theoretical Economics* **146(1)**, 169-182.
- [14] Holmstrom, B. and Milgrom, P., 1991. Multi-task Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design, *Journal of Law, Economics, and Organization* **7(S)**, 24-52.
- [15] Holmstrom, B. and Milgrom, P., 1994. The Firm as an Incentive System, *American Economic Review* **84(4)**, 972-991.
- [16] Ichniowski, C. and Shaw, K., 2003. Beyond Incentive Pay: Insiders' Estimates of the Value of Complementary Human Resource Management Practices, *Journal of Economic Perspectives* **17(1)**, 155-180.
- [17] Jensen, M.C. and Murphy, K.J., 1990. Performance Pay and Top-Management Incentives, *Journal of Political Economy* **98(2)**, 225-284.
- [18] Itoh, H., 1991. Incentives to Help in Multi-agent Situations, *Econometrica* **59(3)**, 611-636.
- [19] Itoh, H., 1992. Cooperation in Hierarchical Organizations: An Incentive Perspective, *Journal of Law, Economics, and Organization* **8(2)**, 321-345.
- [20] Itoh, H., 1993. Coalitions, Incentives, and Risk Sharing, *Journal of Economic Theory* **60(2)**, 410-427.
- [21] Kandel, E. and Lazear, E., 1992. Peer Pressure and Partnerships, *Journal of Political Economy* **100(4)**, 801-817.
- [22] Lazear, E., 2000. Performance Pay and Productivity, *American Economic Review* **90(5)**, 1346-1361.
- [23] Macho-Stadler, I. and Pérez-Castrillo, D., 1993. Moral Hazard with Several Agents: The Gains from Cooperation, *International Journal of Industrial Organization* **11(1)**, 73-100.
- [24] Mookherjee, D and Reichelstein, S., 2001. Incentives and Coordination in Hierarchies, *Advances in Theoretical Economics* **1(1)**.



- [25] Murphy, K.J., 1999. Executive Compensation, In *Handbook of Labor Economics*, Vol 3B, Ashanfetter, O. and Carlo, D.E. (eds.), Elsevier Science, North-Holland.
- [26] Prendergast, C., 2002. The Tenuous Trade-Off between Risk and Incentives, *Journal of Political Economy* **110(5)**, 1071-1102.
- [27] Nalebuff, B.J. and Stiglitz, J.E., 1983. Information, Competition, and Markets, *American Economic Review* **73(2)**, 278-283.
- [28] Raith, M., 2003. Competition, Risk and Managerial Incentives, *American Economic Review* **93**, 1425-1436.
- [29] Ramakrishnan, R.T.S. and Thakor, A.V., 1991. Cooperation versus Competition in Agency, *Journal of law, Economics, and Organization* **7(2)**, 248-283.
- [30] Schmidt, K., 1997. Managerial Incentives and Product Market Competition, *Review of Economics Studies* **64**, 191-213.
- [31] Varian, H.R., 1990. Monitoring Agents with Other Agents, *Journal of Institutional and Theoretical Economics* **146(1)**, 153-174.
- [32] Vives, X., 2004. Innovation and Competitive Pressure, *CEPR Discussion Paper* No. 4369.

endogenous variables	influence of exogenous variables on $\beta_{2i}$			
	$b$	$F$	$n$	$K$
none	-	0	-	-
$K$	-	0	-	
$K, n$	-	+		

  

endogenous variables	influence of exogenous variables on $\beta_{3i}$			
	$b$	$F$	$n$	$K$
none	-	0	-	-
$K$	+	0	+	
$K, n$	+	-		

Figure 1. The influence of different exogenous variables on incentive rates under alternative endogeneity assumptions.

# CESifo Working Paper Series

for full list see [www.cesifo-group.org/wp](http://www.cesifo-group.org/wp)

(address: Poschingerstr. 5, 81679 Munich, Germany, [office@cesifo.de](mailto:office@cesifo.de))

---

- 2393 António Afonso and Christophe Rault, 3-Step Analysis of Public Finances Sustainability: the Case of the European Union, September 2008
- 2394 Betsey Stevenson and Justin Wolfers, Economic Growth and Subjective Well-Being: Reassessing the Easterlin Paradox, September 2008
- 2395 Bernhard Eckwert and Itzhak Zilcha, Private Investment in Higher Education: Comparing Alternative Funding Schemes, September 2008
- 2396 Øystein Foros, Hans Jarle Kind and Jan Yngve Sand, Slotting Allowances and Manufacturers' Retail Sales Effort, September 2008
- 2397 Mohammad Reza Farzanegan, Illegal Trade in the Iranian Economy: Evidence from a Structural Model, September 2008
- 2398 Olivier Bos, Charity Auctions for the Happy Few, September 2008
- 2399 Robert S. Chirinko and Debdulal Mallick, The Marginal Product of Capital: A Persistent International Puzzle, September 2008
- 2400 Ben D'Exelle and Arno Riedl, Elite Capture, Political Voice and Exclusion from Aid: An Experimental Study, September 2008
- 2401 Torben M. Andersen and Joydeep Bhattacharya, On Myopia as Rationale for Social Security, September 2008
- 2402 Fabienne Llense, French CEO Compensations: What is the Cost of a Mandatory Upper Limit?, September 2008
- 2403 Valentina Bosetti, Carlo Carraro, Alessandra Sgobbi and Massimo Tavoni, Delayed Action and Uncertain Targets. How Much Will Climate Policy Cost?, September 2008
- 2404 Robert G. Chambers, Rolf Färe, Shawna Grosskopf and Michael Vardanyan, Generalized Quadratic Revenue Functions, September 2008
- 2405 Leonidas Enrique de la Rosa, Overconfidence in a Career-Concerns Setting, September 2008
- 2406 Marcus Drometer and Johannes Rincke, The Design of Political Institutions: Electoral Competition and the Choice of Ballot Access Restrictions in the United States, September 2008
- 2407 Markku Lanne and Helmut Lütkepohl, Stock Prices and Economic Fluctuations: A Markov Switching Structural Vector Autoregressive Analysis, September 2008

- 2408 Thomas L. Brewer, International Energy Technology Transfers for Climate Change Mitigations, September 2008
- 2409 Alexander Kemnitz, Native Welfare Losses from High Skilled Immigration, September 2008
- 2410 Xavier Vives, Strategic Supply Function Competition with Private Information, September 2008
- 2411 Fabio Padovano and Roberto Ricciuti, The Political Competition-Economic Performance Puzzle: Evidence from the OECD Countries and the Italian Regions, September 2008
- 2412 Joan Costa-Font and Mireia Jofre-Bonet, Body Image and Food Disorders: Evidence from a Sample of European Women, September 2008
- 2413 Thorsten Upmann, Labour Unions – To Unite or to Separate?, October 2008
- 2414 Sascha O. Becker and Ludger Woessmann, Luther and the Girls: Religious Denomination and the Female Education Gap in 19<sup>th</sup> Century Prussia, October 2008
- 2415 Florian Englmaier and Stephen Leider, Contractual and Organizational Structure with Reciprocal Agents, October 2008
- 2416 Vittorio Daniele and Ugo Marani, Organized Crime and Foreign Direct Investment: The Italian Case, October 2008
- 2417 Valentina Bosetti, Carlo Carraro, Alessandra Sgobbi and Massimo Tavoni, Modelling Economic Impacts of Alternative International Climate Policy Architectures. A Quantitative and Comparative Assessment of Architectures for Agreement, October 2008
- 2418 Paul De Grauwe, Animal Spirits and Monetary Policy, October 2008
- 2419 Guglielmo Maria Caporale, Christophe Rault, Robert Sova and Anamaria Sova, On the Bilateral Trade Effects of Free Trade Agreements between the EU-15 and the CEEC-4 Countries, October 2008
- 2420 Yin-Wong Cheung and Daniel Friedman, Speculative Attacks: A Laboratory Study in Continuous Time, October 2008
- 2421 Kamila Fialová and Ondřej Schneider, Labour Market Institutions and their Effect on Labour Market Performance in the New EU Member Countries, October 2008
- 2422 Alexander Ludwig and Michael Reiter, Sharing Demographic Risk – Who is Afraid of the Baby Bust?, October 2008
- 2423 Doina Maria Radulescu and Michael Stimmelmayer, The Welfare Loss from Differential Taxation of Sectors in Germany, October 2008

- 2424 Nikolaus Wolf, Was Germany ever United? Evidence from Intra- and International Trade 1885 – 1933, October 2008
- 2425 Bruno S. Frey, David A. Savage and Benno Torgler, Noblesse Oblige? Determinants of Survival in a Life and Death Situation, October 2008
- 2426 Giovanni Facchini, Peri Silva and Gerald Willmann, The Customs Union Issue: Why do we Observe so few of them?, October 2008
- 2427 Wido Geis, Silke Uebelmesser and Martin Werding, Why go to France or Germany, if you could as well go to the UK or the US? Selective Features of Immigration to four major OECD Countries, October 2008
- 2428 Geeta Kingdon and Francis Teal, Teacher Unions, Teacher Pay and Student Performance in India: A Pupil Fixed Effects Approach, October 2008
- 2429 Andreas Haufler and Marco Runkel, Firms' Financial Choices and Thin Capitalization Rules under Corporate Tax Competition, October 2008
- 2430 Matz Dahlberg, Heléne Lundqvist and Eva Mörk, Intergovernmental Grants and Bureaucratic Power, October 2008
- 2431 Alfons J. Weichenrieder and Tina Klautke, Taxes and the Efficiency Costs of Capital Distortions, October 2008
- 2432 Andreas Knabe and Ronnie Schöb, Minimum Wage Incidence: The Case for Germany, October 2008
- 2433 Kurt R. Brekke and Odd Rune Straume, Pharmaceutical Patents: Incentives for R&D or Marketing?, October 2008
- 2434 Scott Alan Carson, Geography, Insolation, and Institutional Change in 19<sup>th</sup> Century African-American and White Stature in Southern States, October 2008
- 2435 Emilia Del Bono and Daniela Vuri, Job Mobility and the Gender Wage Gap in Italy, October 2008
- 2436 Marco Angrisani, Antonio Guarino, Steffen Huck and Nathan Larson, No-Trade in the Laboratory, October 2008
- 2437 Josse Delfgaauw and Robert Dur, Managerial Talent, Motivation, and Self-Selection into Public Management, October 2008
- 2438 Christian Bauer and Wolfgang Buchholz, How Changing Prudence and Risk Aversion Affect Optimal Saving, October 2008
- 2439 Erich Battistin, Clara Graziano and Bruno Parigi, Connections and Performance in Bankers' Turnover: Better Wed over the Mixen than over the Moor, October 2008

- 2440 Erkki Koskela and Panu Poutvaara, Flexible Outsourcing and the Impacts of Labour Taxation in European Welfare States, October 2008
- 2441 Marcelo Resende, Concentration and Market Size: Lower Bound Estimates for the Brazilian Industry, October 2008
- 2442 Giandomenico Piluso and Roberto Ricciuti, Fiscal Policy and the Banking System in Italy. Have Taxes, Public Spending and Banks been Procyclical in the Long-Run? October 2008
- 2443 Bruno S. Frey and Katja Rost, Do Rankings Reflect Research Quality?, October 2008
- 2444 Guglielmo Maria Caporale, Antoaneta Serguieva and Hao Wu, Financial Contagion: Evolutionary Optimisation of a Multinational Agent-Based Model, October 2008
- 2445 Valentina Bosetti, Carlo Carraro and Massimo Tavoni, Delayed Participation of Developing Countries to Climate Agreements: Should Action in the EU and US be Postponed?, October 2008
- 2446 Alexander Kovalenkov and Xavier Vives, Competitive Rational Expectations Equilibria without Apology, November 2008
- 2447 Thiess Buettner and Frédéric Holm-Hadulla, Cities in Fiscal Equalization, November 2008
- 2448 Harry H. Kelejian and Ingmar R. Prucha, Specification and Estimation of Spatial Autoregressive Models with Autoregressive and Heteroskedastic Disturbances, November 2008
- 2449 Jan Bouckaert, Hans Degryse and Thomas Provoost, Enhancing Market Power by Reducing Switching Costs, November 2008
- 2450 Frank Heinemann, Escaping from a Combination of Liquidity Trap and Credit Crunch, November 2008
- 2451 Dan Anderberg, Optimal Policy and the Risk Properties of Human Capital Reconsidered, November 2008
- 2452 Christian Keuschnigg and Evelyn Ribi, Outsourcing, Unemployment and Welfare Policy, November 2008
- 2453 Bernd Theilen, Market Competition and Lower Tier Incentives, November 2008