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Delegation, Worker Compensation, and Strategic Competition

by

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Abstract

We study interfirm competition on a product market where effort decisions are delegated to the firms' workers. Intrafirm organization is captured by a principal-multi-agent framework where firm owners implement alternative compensation schemes for the workers. We show that the value of delegation as well as the optimal design of the compensation scheme crucially depend on the intensity of competition. In particular, our model explains why piece rates and performance-based revenue sharing may be observed in different markets at the same time.

Keywords: Delegation, agency theory, compensation schemes

JEL Classification: C72, L22, M52

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1 Introduction

Traditional principal-agent models deal exclusively with *intrafirm organization* and analyze compensation contracts between a principal (the firm owner) and one or more agents (the workers). In these models, delegation to agents results from agents' superior information or abilities (see, e.g., Laffont and Martimort 2002 or Macho-Stadler and Perez-Castrillo 1997). In this paper, we emphasize a further reason why it might be in the interest of a principal to delegate decisions to agents: strategic competition.

In the industrial organization literature, strategic competition is widely analyzed, but the models either concentrate on *interfirm competition* between monolithic firms (see, e.g., Tirole 1988) or they combine intrafirm and interfirm interaction where principals of competing firms employ manager agents (see, e.g., Vickers 1985, Fershtman 1985, Fershtman and Judd 1987, 2006 Sklivas 1987, Hermalin 1992, Cailland, Jullien and Picard 1995, Schmidt 1997, Jansen, van Lier and van Witteloostuijn 2007). These manager agents decide on quantities (or prices), but they are not involved in the production process itself and face no effort cost of producing.[1] Strategic competition by delegating decisions to worker agents is largely ignored in this literature, i.e. the direct link to the principal-agent models in business economics is missing.

This paper aims to fill this gap. We analyze competing firms each employing worker agents who decide on their effort levels anticipating how their decisions affect their effort costs. The basic principal-agent framework with risk-neutral individuals is therefore extended to account for competition between owner principals on oligopolistic product markets. While single-firm principal-agent models ignore these competition effects, our analysis extends previous work by Güth, Pull and Stadler (2011, 2012) to shed light on how worker compensation is affected by interfirm competition.

In the present paper, we analyze different worker-compensation systems that vary along several dimensions (see, e.g., Gerhart, Minkoff, and Olsen 1995 for an overview). Specifically, we compare (i) a piece-rate compensation system, (ii) a revenue-sharing

[1] In some of the models, firm owners hire managers whose task it is to reduce unit production cost. Hence, managers suffer from effort costs, but these are independent of the level of production (see, e.g., Graziano and Parigi 1998, Raith 2003, Beiner, Schmid and Wanzenried 2011).

system where the workers' share is equally distributed among the workers ($1/n$ revenue sharing) and (iii) a revenue-sharing scheme where an individual worker's share of the revenue depends on his individual performance (performance-based revenue sharing). Accordingly, we cover a spectrum of mechanisms each following a distinct logic: While piece rates are based on individual absolute performance, 1/n revenue sharing is a classical team incentive where only team performance counts. Performance-based revenue sharing combines (absolute) team incentives with individual (relative) performance incentives.[2]

Our approach is appropriate to explain the dominance of the one or the other incentive mechanism depending on (i) the intensity of competition on the product market and (ii) the number of workers employed by each firm. In particular, our analysis predicts that revenue-sharing programs and piece-rate compensation schemes should be wide spread in rather homogeneous markets, characterized by intense (quantity) competition. This is due to a strategic effect of delegating production decisions to workers. In heterogeneous markets with less intense competition this strategic delegation effect is weak, so that firm owners prefer not to delegate - if possible.

The remainder of the paper is structured as follows: In Section 2 we analyze a benchmark model with two competing monolithic firms without delegation. In Section 3 we introduce delegation accompanied by piece-rate compensation. Intrafirm interaction is taken into account by analyzing two different revenue-sharing schemes: In Section 4, the workers' revenue share is equally distributed among the workers, independently of an individual worker's contribution. In Section 5, a worker's revenue share is based on his relative performance. Section 6 compares the outcomes of the different compensation schemes in a more general setting, Section 7 concludes.

[2] While piece-rate compensation schemes are on the decline in manufacturing (see, e.g., Helper, Kleiner and Wang 2010), empirically they still play a role in the form of, e.g., sales commissions. Furthermore, they present an interesting reference case for the analysis of the revenue-sharing compensation schemes.

2 A Benchmark Model with Competing Monolithic Firms

We consider a heterogeneous product market with two firms $i = 1,2$, each producing a substitute good. According to Singh and Vives (1984), the inverse demand functions are specified by

$$p_i = 1 - q_i - \gamma q_j \; ; \quad i, j = 1,2, \; i \neq j \; ,$$

where the (inverse) heterogeneity parameter $\gamma \in [0,1]$ indicates the intensity of competition. In the limit case of $\gamma = 0$, the market is completely separated into two independent monopoly markets without strategic interaction between firms. In the other limit case of $\gamma = 1$, the market is homogeneous implying intense competition between the firms. The single production input is the effort $e_{i,k}$ of workers $k = 1,...,n$ in each firm $i = 1,2$, where the effort-cost function is quadratic, $c(e_{i,k}) = e_{i,k}^2/2$. The output of firm i amounts to $q_i = \sum_{k=1}^{n} e_{i,k}$. In order to keep the model analytically tractable, we assume that the total supply of $2n$ workers is equally distributed across the two firms in the considered market.[3]

We start with analyzing a benchmark scenario where competing monolithic firms do not delegate output decisions. In this no-delegation (ND) game, firms decide on the effort of each worker and hence on the whole firm output such that firm surpluses are determined by

$$S_i = (1 - q_i - \gamma q_j) q_i - q_i^2/(2n) \; .$$

Maximizing these surpluses with respect to the quantities q_i gives the symmetric Nash equilibrium strategies

$$q^{ND} = \frac{n}{1 + (2+\gamma)n} \; ,$$

[3] It can be shown that both firms have an incentive to hire as many workers as possible, given the rival's number of employed workers. Since heterogeneity provides an incentive for workers to equally distribute across firms, this symmetry assumption is justified. The number n of workers employed by each firm can therefore be interpreted as representing half of the market-specific labor force. If the focus were on the endogenous determination of an intermediate number of workers, one could account for a decreasing marginal product of worker effort (see, e.g., Das 1996). However, such an extended model would no longer be tractable for the analysis of different compensation schemes.

implying worker efforts

$$e^{ND} = \frac{1}{1+(2+\gamma)n}$$

and prices

$$p^{ND} = \frac{1+n}{1+(2+\gamma)n} ,$$

leading to the symmetric firm surpluses

$$S^{ND} = \frac{(1+2n)n}{2[1+(2+\gamma)n]^2} . \tag{1}$$

Efforts, prices and firm surpluses are decreasing in the intensity of competition γ. The numerical solutions for $n = 2$ workers per firm and the two extreme cases with minimal ($\gamma = 0$) and maximal ($\gamma = 1$) intensities of competition are presented in Table 1.

Table 1: Results for the ND game with $n = 2$ worker agents per firm

	e^{ND}	q^{ND}	p^{ND}	S^{ND}
$\gamma = 0$	0.200	0.400	0.600	0.200
$\gamma = 1$	0.143	0.286	0.429	0.102

3 Delegation via Piece-Rate Compensation

To analyze the effects of delegation, we proceed by assuming that the two firms, each consisting of one owner (principal) and n workers (agents), play a two-stage delegation game. In the first stage, the owners $i = 1,2$ simultaneously write observable piece-rate contracts with their workers, specifying the wage rates w_i per effort unit. We abstain from fixed worker payments which could be endogenized by introducing binding participation constraints.[4] In this piece-rate (PR) compensation game firm owners earn profits

$$\pi_i = (1 - q_i - \gamma q_j - w_i)q_i , \quad i, j = 1,2, \ i \neq j .$$

[4]Depending on reservation utilities, endogenized fixed payments might become negative. Abstaining from including endogenized fixed payments can be justified (i) by legally prescribed non-negative minimum wages and (ii) by limited liability of workers - excluding negative payments even

Workers are awarded according to their contracts and suffer from effort cost of producing, i.e. they realize net utilities

$$U(w_i, e_{i,k}) = w_i e_{i,k} - e_{i,k}^2/2 \, .$$

In the second stage of the game, workers maximize their net utilities with respect to efforts $e_{i,k}$, such that

$$e_{i,k} = w_i$$

for all $k = 1, \ldots, n$ and $i = 1, 2$. Since workers' effort depends on the firm-specific piece rates w_i only, there is neither intra- nor interfirm interaction between agents.

By anticipating these effort decisions of workers, in the first stage principals maximize profits

$$\pi_i = (1 - (n+1)w_i - \gamma n w_j) n w_i$$

with respect to the piece rates w_i. The equilibrium solution is characterized by the efforts

$$w^{PR} = e^{PR} = \frac{1}{2 + (2+\gamma)n} \, ,$$

the production levels

$$q^{PR} = \frac{n}{2 + (2+\gamma)n} \, ,$$

and the prices

$$p^{PR} = \frac{2+n}{2 + (2+\gamma)n} \, .$$

Firm profits amount to

$$\pi^{PR} = \frac{(1+n)n}{[2 + (2+\gamma)n]^2}$$

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in case of (out-of-equilibrium) negligible effort levels, and (iii) empirically with fixed payments from workers being rarely observed in practice. In a situation with endogenized fixed payments, however, worker efforts and firm surpluses would in fact coincide with the benchmark solution of the no-delegation game. We are indebted to a referee for this remark.

and worker net utilities to

$$U^{PR} = \frac{1}{2[2+(2+\gamma)n]^2},$$

such that the firm surpluses add up to

$$S^{PR} = \pi^{PR} + nU^{PR} = \frac{(3+2n)n}{2[2+(2+\gamma)n]^2}. \tag{2}$$

It becomes obvious that efforts, prices, firm profits and surpluses are decreasing in the intensity of competition γ. The numerical solutions for $n = 2$ workers per firm and the two extreme cases of minimal ($\gamma = 0$) and maximal ($\gamma = 1$) intensities of competition are presented in Table 2.

Table 2: Results for the PR game with $n = 2$ worker agents per firm

	e^{PR}	q^{PR}	p^{PR}	π^{PR}	U^{PR}	S^{PR}
$\gamma = 0$	0.167	0.333	0.666	0.167	0.014	0.194
$\gamma = 1$	0.125	0.250	0.500	0.094	0.008	0.109

Compared to the benchmark solution without delegation (see Table 1), piece-rate compensation leads to a lower surplus in the case without competition ($\gamma = 0$), but to a higher surplus in case of intense competition ($\gamma = 1$). Thus, from the perspective of an isolated firm, delegation to workers has a negative value, i.e. absent any other justification for delegation (e.g. asymmetries in abilities or information), owners prefer not to delegate. With intense interfirm competition, however, delegation has a positive value since piece rates can be used as a strategic instrument to reduce workers' effort and – as a consequence – to raise prices and surpluses.[5] Due to this delegation effect, our model predicts piece rates to be more pronounced and wide spread in rather homogeneous and highly competitive markets as compared to rather heterogeneous or even monopolistic market structures.

While, empirically, the relation between the intensity of competition and incentive compensation for managers has been found to be positive (see, e.g., Cunat and

[5]This effect corresponds to strategic underinvestment in capacities in order to soften price competition and to increase profits (see, e.g., Kreps and Scheinkman 1983 for homogeneous and Maggi 1996 for heterogeneous markets).

Guadalupe 2009 or Beiner, Schmid and Wanzenried 2011), we are not aware of any comparable study for worker compensation. However, as Berger, Herbertz and Sliwka (2011) have shown, the prevalence of incentive compensation systems for workers varies substantially between different markets with a large share of firms using performance-related pay for their workers in, e.g., financial services, and a considerably lower share in, e.g., the food markets. Different degrees of competition intensity might in fact be part of the story.

4 Delegation via a $1/n$ Revenue-Sharing Compensation Scheme

As an alternative to piece-rate compensation, we now analyze the delegation effect of a compensation scheme where each owner principal decides on the revenue share $s_i \in [0,1]$ offered to his worker agents as a whole and where the share is ex ante equally distributed among the n workers of the firm. Again, we abstain from an additional fixed payment. In this revenue-sharing (RSE) game, owners simultaneously write observable revenue-sharing contracts with their workers, specifying the individual revenue shares (s_i/n) and earn profits

$$\pi_i = (1-s_i)(1-q_i-\gamma q_j)q_i, \quad i,j = 1,2,\ i \neq j\ .$$

Each of the agents, $k = 1,...,n$, employed by firm $i = 1,2$, realizes net utility

$$U_{i,k}(e_{i,k}) = (s_i/n)(1-q_i-\gamma q_j)q_i - e_{i,k}^2/2\ .$$

Maximization with respect to the efforts $e_{i,k}$ in the second stage yields the agents' first-order conditions

$$(s_i/n)(1-2q_i-\gamma q_j) - e_{i,k} = 0\ ,$$

whose symmetric solution is

$$e_i^*(s_i,s_j) = \frac{s_i(1+(2-\gamma)s_j)/n}{1+2(s_i+s_j)+(4-\gamma^2)s_is_j}\ .$$

Anticipating these equilibrium efforts, principals realize profits

$$\pi_i(s_i, s_j) = (1 - s_i)(1 - ne_i^* - \gamma ne_j^*)ne_i^* \; .$$

In the first stage, principals maximize profits with respect to s_i. The symmetric equilibrium is implicitly determined by the fourth-order polynomial equation

$$(4 - \gamma^2)s^4 + 8s^3 + (7 - \gamma^2)s^2 - 1 = 0 \; , \tag{3}$$

which has a single solution s^{RSE} in the range $[0, 1]$. This optimal revenue share offered by the principals is increasing in the intensity of competition γ, but does not depend on the number of agents employed. Given the subgame perfect revenue shares s^{RSE}, the equilibrium effort levels are

$$e^{RSE} = \frac{s^{RSE}(1 + (2 - \gamma)s^{RSE})/n}{1 + 4s^{RSE} + (4 - \gamma^2)s^{RSE^2}} \; ,$$

leading to the output levels $q^{RSE} = ne^{RSE}$, prices $p^{RSE} = 1 - (1 + \gamma)ne^{RSE}$, firm profits $(1 - s^{RSE})(1 - (1 + \gamma)ne^{RSE})ne^{RSE}$, worker net utilities $s^{RSE}(1 - (1 + \gamma)ne^{RSE})e^{RSE} - (e^{RSE})^2/2$ and surpluses

$$S^{RSE} = (1 - (1 + \gamma)ne^{RSE})ne^{RSE} - n(e^{RSE})^2/2 \; . \tag{4}$$

The explicit solution for the special case of $\gamma = 1$ is derived in the Appendix. The numerical solutions for $n = 2$ workers per firm and the two extreme cases of minimal ($\gamma = 0$) and maximal ($\gamma = 1$) intensities of competition are presented in Table 3.

Table 3: Results for the RSE game with $n = 2$ worker agents per firm

	s^{RSE}	e^{RSE}	q^{RSE}	p^{RSE}	π^{RSE}	U^{RSE}	S^{RSE}
$\gamma = 0$	0.317	0.097	0.194	0.806	0.107	0.020	0.147
$\gamma = 1$	0.333	0.083	0.167	0.667	0.074	0.015	0.104

Compared to the cases of no delegation (ND) and piece-rate compensation (PR), the firm surplus in the RSE game is strictly dominated. So we do not expect $1/n$ revenue-sharing schemes to be used in practice. In fact, existing revenue-sharing systems typically do not foresee that each individual worker receives the same amount of the revenue share ex ante. Rather, individual worker shares vary between different groups of employees and different hierarchical levels (arguably mirroring different degrees to which the respective workers contribute to firm performance). As will be shown in the next section, our ranking results change in a situation where revenues are not ex ante equally shared among workers, but are based on relative performance.

5 Delegation via a Performance-Based Revenue-Sharing Compensation Scheme

As an alternative, we now follow Güth, Pull and Stadler (2011) and assume that the principals decide on revenue shares $s_i \in [0,1]$ which are distributed across the worker agents according to an incentive device, based on the relative output performance $e_{i,k}/q_i$ of workers. We generalize our previous model by allowing for intermediate intensities of competition γ in order to compare the performance with that of the benchmark case without delegation and that of the alternative compensation schemes discussed above. In this performance-based revenue-sharing (RSP) game, owners earn profits

$$\pi_i = (1-s_i)(1-q_i-\gamma q_j)q_i\ , \quad i,j=1,2,\ i\neq j\ .$$

In the second stage of the game, workers simultaneously choose their effort levels $e_{i,k}$ to maximize net utilities

$$U_{i,k}(e_{i,k}) = s_i(e_{i,k}/q_i)p_i q_i - e_{i,k}^2/2 = s_i e_{i,k}(1-q_i-\gamma q_j) - e_{i,k}^2/2\ .$$

The equilibrium effort levels

$$e_i^*(s_i,s_j) = \frac{s_i(1+(1+(1-\gamma)n)s_j)}{1+(n+1)(s_i+s_j)+((1-\gamma^2)n^2+2n+1)s_is_j}$$

depend on the strategic variables (s_i,s_j) chosen by both of the principals. Thus there is intra- and interfirm interaction between agents. Anticipating these equilibrium efforts, principals realize profits

$$\pi_i(s_i,s_j) = (1-s_i)(1-ne_i^*-\gamma ne_j^*)ne_i^*\ .$$

Maximizing these profits with respect to the revenue shares in the first stage leads to a symmetric equilibrium implicitly determined by the fourth-order polynomial equation

$$[(1-\gamma^2)n^2+2n+1]s^4+[4(n+1)]s^3+[(1-\gamma^2)n^2+2n+4]s^2-1=0\,, \tag{5}$$

which has a single root s^{RSP} in the range $[0,1]$.

Given the subgame perfect revenue share s^{RSP} the equilibrium effort levels are

$$e^{RSP}=\frac{s^{RSP}(1+(1+(1-\gamma)n)s^{RSP})}{1+2(n+1)s^{RSP}+((1-\gamma^2)n^2+2n+1)s^{RSP^2}}\,,$$

leading to the output levels $q^{RS}=ne^{RSP}$, prices $p^{RSP}=1-(1+\gamma)ne^{RSP}$, firm profits $(1-s^{RSP})(1-(1+\gamma)ne^{RSP})ne^{RSP}$, worker net utilities $s^{RSP}(1-(1+\gamma)ne^{RSP})e^{RSP}-(e^{RSP})^2/2$ and surpluses

$$S^{RSP}=(1-(1+\gamma)ne^{RSP})ne^{RSP}-n(e^{RSP})^2/2\,. \tag{6}$$

The explicit solution for the special case of $\gamma=1$ is derived in the Appendix. The numerical solutions for $n=2$ workers per firm and the two extreme cases with minimal ($\gamma=0$) and maximal ($\gamma=1$) intensities of competition are presented in Table 4.

Table 4: Results for the RSP game with $n=2$ worker agents per firm

	s^{RSP}	e^{RSP}	q^{RSP}	p^{RSP}	π^{RSP}	U^{RSP}	S^{RSP}
$\gamma=0$	0.253	0.144	0.288	0.712	0.153	0.015	0.183
$\gamma=1$	0.290	0.118	0.237	0.527	0.089	0.011	0.111

It can be shown that the revenue shares s^{RSP} offered by the principals are increasing in the intensity of competition γ, while efforts, profits and surpluses are decreasing.

Compared to the benchmark solution without delegation (see Table 1), performance-based revenue sharing leads to a lower surplus in the case without competition ($\gamma=0$), but to a higher surplus in case of intense competition ($\gamma=1$). Thus, similar to the alternative of piece-rate compensation, delegation has a negative value for an isolated firm. With intense interfirm competition, however, delegation induces a positive value and can be used as an alternative strategic instrument to reduce workers' efforts and – as a consequence – to raise prices and surpluses.

Compared to the piece-rate compensation model with $n = 2$ workers, surpluses are lower in case of soft competition but higher in case of intense competition. Thus, even in the special case of $n = 2$, there is no unambiguous ranking of the two compensation schemes. This calls for a comparison of the compensation schemes in a more general setting, allowing for varying numbers of workers employed by each firm.

6 Comparison of the Compensation Schemes

In the last step of our analysis, we compare the firms' surpluses in case of (i) no delegation, S^{ND}, (ii) piece-rate compensation, S^{PR}, (iii) 1/n revenue-sharing, S^{RSE}, and (iv) performance-based revenue sharing, S^{RSP}, given alternative numbers of workers employed by each firm. The equilibrium surpluses for $\gamma = 0$, as calculated from (1), (2), (4) and (6), are presented in Table 5a.

Table 5a: Firm surpluses in case of no competition ($\gamma = 0$)

	$n=1$	$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	...	$n \to \infty$
S^{ND}	0.167	0.200	0.214	0.222	0.227	0.231	...	0.250
S^{PR}	0.156	0.194	0.211	0.220	0.226	0.230	...	0.250
S^{RSE}	0.138	0.147	0.150	0.152	0.153	0.153	...	0.156
S^{RSP}	0.138	0.183	0.205	0.217	0.223	0.228	...	0.250

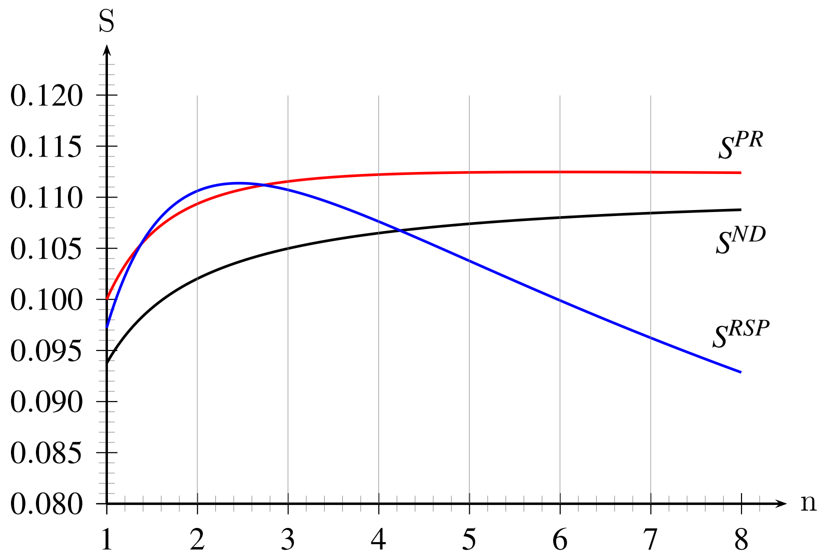
In case of an isolated firm we obtain the clear ranking: $S^{ND} > S^{PR} > S^{RSP} \geq S^{RSE}$, independently of the (finite) number of employed workers. As discussed above, delegation has a negative value meaning that, absent any other justification such as asymmetries in abilities or information, firm owners prefer not to delegate.

On markets characterized by intense competition, however, it depends not only on the intensity of competition but also on the number of agents employed by the principals, which compensation scheme dominates. As shown in Table 5b and illustrated in Figure 1 for the case of $\gamma = 1$, piece-rate compensation dominates for $n = 1$ and $n \geq 3$, whereas performance-based revenue sharing dominates for $n = 2$. Thus the numerical standard case of $n = 2$ workers turns out to be an exception that is due to the inverted-U shaped relationship between n and S^{RSP}: While S^{ND} and S^{RSE} monotonically increase in the number of workers, S^{RSP} first increases, reaches a maximum at $n=3$ and decreases afterwards.

Table 5b: Firm surpluses in case of intense competition ($\gamma = 1$)

	$n=1$	$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	...	$n \to \infty$
S^{ND}	0.094	0.102	0.105	0.107	0.107	0.108	...	0.111
S^{PR}	0.100	0.109	0.111	0.112	0.112	0.113	...	0.111
S^{RSE}	0.097	0.104	0.106	0.108	0.108	0.109	...	0.111
S^{RSP}	0.097	0.111	0.111	0.108	0.104	0.100	...	0.000

Figure 1: Firm surpluses in case of intense competition ($\gamma = 1$)



The reason for the decline of the surplus S^{RSP} for $n \geq 2$ is that not only the principals, but also their agents are involved in interfirm competition. This competition pressure on both hierarchy levels drives the prices down to zero when the number of agents approaches infinity. The surplus S^{PR} also depends in an inverted-U shaped relation on the number of workers (with a maximum at $n = 6$), but is strictly greater than S^{RSP} for $n \geq 3$.

7 Summary and Conclusion

Delegation to sales managers is heavily studied in the industrial organization literature. But managers do not suffer from the effort of producing what they sell. In our approach, we explicitly study agents who produce and suffer effort cost from that production at the same time. Principals implement compensation schemes to which worker agents react by choosing efforts. Furthermore, our performance-based revenue-sharing model accounts for the fact that both, principals and agents, compete with each other.

We find that whether delegation to worker agents via piece rates or via performance-based revenue shares leads to a higher or lower firm surplus compared to the benchmark case of monolithic firms depends on (i) the intensity of competition and (ii) the firm size, measured by the numbers of employed workers. In particular, our approach is able to explain why both piece rates and performance-based revenue sharing can be observed in different heterogeneous markets at the same time.

Appendix

In case of intense competition ($\gamma = 1$), both of the revenue-sharing models can be solved explicitly. In the $1/n$ revenue-sharing model, by factoring out $(1+s)^2$, equation (3) simplifies to the quadratic function

$$3s^2 + 2s - 1 = 0 ,$$

which has the single positive root

$$s^{RSE} = 1/3 ,$$

implying the effort levels

$$e^{RSE} = \frac{1}{6n}$$

for all $2n$ agents employed by the two competing firms. Prices are

$$p^{RSE} = 2/3 ,$$

principals' profits

$$\pi^{RSE} = 2/27 ,$$

workers' net utilities

$$U^{RSE} = \frac{8n-3}{216n^2}$$

and firms' surpluses

$$S^{RSE} = \frac{8n-1}{72n} .$$

The numerical solution values for all variables are summarized in Table 3 for $n=2$, the results for the surplus S^{RSE} are summarized in Table 5b for alternative numbers of agents.

In the performance-based revenue-sharing model, by setting $\gamma=1$ and factoring out $(1+s)^2$, equation (5) simplifies to the quadratic function

$$(2n+1)s^2+2s-1=0\ ,$$

which has the single positive root

$$s^{RSP}=\frac{\sqrt{2n+2}-1}{2n+1}\ ,$$

implying the effort levels

$$e^{RSP}=\frac{\sqrt{2n+2}-1}{(2n+1)\sqrt{2n+2}}\ .$$

Prices are

$$p^{RSP}=\frac{2n+\sqrt{2n+2}}{(2n+1)\sqrt{2n+2}}\ ,$$

principals' profits

$$\pi^{RSP}=\frac{ns^{RSP}(1-s^{RSP^2})}{[1+(2n+1)s^{RSP}]^2}\quad=\quad\frac{n[(2n^2+n-2)\sqrt{2n+2}-2n^2+n+3]}{(n+1)(2n+1)^3}\ ,$$

workers' net utilities

$$U^{RSP}=\frac{s^{RSP^2}(1+2s^{RSP})}{2[1+(2n+1)s^{RSP}]^2}\quad=\quad\frac{8\sqrt{2n+2}+4n^2-4n-11}{4(n+1)(2n+1)^3}\ ,$$

and firms' surpluses

$$S^{RSP}=\frac{ns^{RSP}(2+s^{RSP})}{2[1+(2n+1)s^{RSP}]^2}\quad=\quad\frac{n(4n\sqrt{2n+2}-2n+1)}{4(n+1)(2n+1)^2}\ .$$

The numerical solution values for all variables are summarized in Table 4 for $n=2$, the results for the surplus S^{RSP} are summarized in Table 5b for alternative numbers of agents.

Of course, in case of only $n=1$ agent per firm, the solutions of the two versions of the revenue-sharing model coincide.

References

Beiner, S., Schmid, M., Wanzenried, G. (2011), Product Market Competition, Managerial Incentives and Firm Valuation. European Financial Management 17, 331-366.

Berger, J., Herbertz, C., Sliwka, D. (2011), Incentives and Cooperation in Firms: Field Evidence. IZA Discussion Paper No. 5618, April 2011.

Caillaud, B., Jullien, B., Picard, P. (1995), Competing Vertical Structures: Precommitment and Renegotiation. Econometrica 63, 621-646.

Cunat, V., Guadalupe, M. (2009), Executive Compensation and Competition in the Banking and Financial Sectors. Journal of Banking and Finance 33, 495-504.

Das, S.P. (1996), Incentive Pay, Worker Effort, and Trade Protection. Review of Internatinal Economics 4, 141-151.

Fershtman, C. (1985), Managerial Incentives as a Strategic Variable in Duopolistic Environment. International Journal of Industrial Organization 3, 245-253.

Fershtman, C., Judd, K.L. (1987), Equilibrium Incentives in Oligopoly. American Economic Review 77, 927-940.

Fershtman, C., Judd, K.L. (2006), Equilibrium Incentives in Oligopoly: Corrigendum. American Economic Review 96, 1367.

Gerhart, B.A., Minkoff, H.B., Olsen, R.N. (1995), Employee Compensation: Theory, Practice, and Evidence. CAHRS Working Paper No. 5-1-1995.

Graziano, C., Parigi, B.M. (1998), Do Managers Work Harder in Competitive Industries? Journal of Economic Behavior and Organization 34, 489-498.

Güth, W., Pull, K., Stadler, M. (2011), Intrafirm Conflicts and Interfirm Competition. Homo Oeconomicus 28, 367-378.

Güth, W., Pull, K., Stadler, M. (2012), Strategic Delegation in Price Competition. Theoretical Economics Letters 2, 355-360.

Helper, S., Kleiner, M.M., Wang, Y. (2010), Analyzing Compensation Methods in Manufacturing: Piece Rates, Time Rates, or Gain-Sharing? NBER Working Paper No. 16540, November 2010.

Hermalin, B.E. (1992), The Effects of Competition on Executive Behavior. Rand Journal of Economics 23, 350 - 365.

Jansen, T., van Lier, A., van Witteloostuijn, A. (2007), A Note on Strategic Delegation: The Market Share Case. International Journal of Industrial Organization 25, 531-539.

Kräkel, M. (2003), U-type versus J-type Tournaments as Alternative Solutions to the Unverifiability Problem. Labour Economics 10, 259-380.

Kreps, D., Scheinkman, J. (1983), Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes. Bell Journal of Economics 14, 326-337.

Laffont, J.-J., Martimort, D. (2002), The Theory of Incentives. The Principal-Agent Model. Princeton.

Lin, M.-J. (2008), External Market Condition and Tournaments: Theory and Evidence. Economics Letters 99, 75-78.

Macho-Stadler, I., Perez-Castrillo, J.D. (1997), An Intrduction to the Economics of Information. Incentives and Contracts. Oxford.

Maggi, G. (1996), Strategic Trade Policies with Endogenous Mode of Competition. American Economic Review 86, 237-258.

Raith, M. (2003), Competition, Risk, and Managerial Incentives. Economic Review 93, 1425-1436.

Schmidt, K.M. (1997), Managerial Incentives and Product and Product Market Competition. Review of Economic Studies 64, 191-213.

Singh, N., Vives, X. (1984), Price and Quantity Competition in a Differentiated Duopoly. Rand Journal of Economics 15, 546-554.

Sklivas, S.D. (1987), The Strategic Choice of Managerial Incentives. Rand Journal of Economics 18, 452-458.

Tirole, J. (1988), The Theory of Industrial Organization. Cambridge MA.

Vickers, J. (1985), Delegation and the Theory of the Firm. Economic Journal 95, 138-147.