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Labour incentive schemes in a Cournot duopoly with simple institutional constraints

Abstract

This paper studies equilibrium incentive contracts in a Cournot duopoly, in which institutional arrangements constrain firms to pay (risk-neutral) workers a given salary. In this context, performance-related-pay (PRP) and relative performance evaluation (RPE) are compared in terms of resulting levels of workers' effort (firms' expected output), market price, profits, consumer surplus and social welfare. It is shown that, while under principal-agent standard assumptions (i.e. all wage components are "freely" negotiated by each firm-worker pair) PRP and RPE are equivalent, in the presence of institutional "frictions", RPE outperforms PRP in relation to output, profits, consumer surplus and social welfare. Moreover, RPE also permits to replicate results obtained without institutional constraints, even if the mechanism driving final outcomes is very different.

Classificazione JEL: J33, J41, L13
Keywords: Cournot duopoly, principal-agent model, relative performance evaluation, institutional constraints

Contents

I. Introduction

Despite the widespread existence in labour markets of collective bargaining practices and cogent legislations with regard to minimum wages, a standard assumption that characterizes the principal-agent model is that each single principal/agent pair is free to negotiate, without any institutional constraint, each single pay component. In such a context, a well known result states that, when agents are risk-neutral, optimal incentive contracts based on relative performance evaluation cannot outperform optimal contracts simply based on the (absolute) performance of each single agent.[1]

In a setting with two principal-agent relationships, in which firms (principals) compete *à la* Cournot in the product market and risk-neutral workers (agents) supply costly effort that affects their firms' output, this paper compares simple (linear) forms of standard performance-related-pay, in which the incentive pay for the agent only depends on his/her performance, and relative performance evaluation, in which incentives are linked to a comparison between the agent's performance with that of the "competitor". In this context, due to imperfect product market competition, each agent's incentive contract influences, further than his/her effort choice, also that of the rival firm's agent, with relevant effects on the outcomes of the market as a whole.

We also introduce institutional considerations into the analysis. In particular, to do this in the most simple fashion, we consider the salary, that is, the constant (with respect to output) term of workers' total pay, as given (i.e. not contractible by each single principal/agent pair) and the same for both firms. This is consistent with an institutional setting, commonly observed in many countries' industrial relations arrangements (e.g. Layard and Nick-

[1] By contrast, when agents are risk-adverse, agency theory (see, in particular, Holmström (1982) and Mookherjee (1984)) has provided a rationale for the relative performance evaluation in terms of its informational content. In particular, when agents outcomes are subject to a common element of uncertainty, the output of each individual acts both as a signal of his own performance and as a signal of the realizations of the common uncertain parameter. Thus comparisons of agents performances are valuable because they bring additional pieces of information and act as a filter for the common shock.

ell, 1999; OECD, 1999; Nicoletti et al., 2001), in which collective bargaining over salary takes place at an upper (nation-wide or multi-employer) level between peak associations (e.g. trade unions) and act as binding minima for all workers in the relevant sector.[2] At the same time, some decentralization in wage setting exists in relation to incentive schemes, which are negotiated at the local (i.e. firm's) level.

In this context, our results can be summarized as follows. First, if parties "freely" negotiate all wage components, including the salary,[3] relative performance evaluation and performance-related-pay are equivalent, that is, (in accordance with the standard principal-agent literature) they produce the same results. Instead, when institutional "frictions" are introduced into the analysis, even if workers are risk neutral, relative performance evaluation outperforms performance-related-pay as regards total profits, consumer surplus and, most notably, social welfare (although, with relative performance evaluation, workers' welfare is lower).

Secondly, in the presence of institutional constraints, relative performance evaluation (differently from performance-related-pay) allows to attain the same outcome of the standard principal-agent model (with no institutional frictions) in relation to workers' effort (expected output), market price, consumer surplus and social welfare. This result is novel and is particularly relevant, especially if we take into account the particular social purposes that, generally, institutional arrangements, such as minimum (fair) wages, aims at achieving.

This paper partially relates to the growing literature on managerial delegation and incentive contracts in oligopolies (Vickers, 1985; Fershtman, 1985; Fershtman and Judd, 1987; Sklivas 1987). In this

[2]Notice that this can hold true also for workers who are not union members, due to so-called "extra-coverage" rules. For instance, in Italy, they operate through court ruling on what is considered a minima or a "fair wage" (Dell'Aringa, 2002). The constitutional law imposes a minimum wage as a worker's right and the courts take the sectorial collectively agreed wage rates as the levels of fair wages to be paid to workers, whether or not they are union members.

[3]In particular, in this case, we will adopt the principal-agent's standard hypothesis, according to which the principal has all bargaining power and the salary is chosen so as to *strictly* satisfy the agent's participation constraint (see below). This hypothesis, however, is not essential.

context, different works, starting from Fumas (1992) and Aggarwal and Samwick (1999), study relative performance evaluation under diverse oligopoly settings (e.g. Miller and Pazgal, 2002). In particular, more recently, the relative performance evaluation's results have been compared with those obtained with other compensation schemes (Jansen et al., 2009; Manasakis et al., forthcoming) or they have been studied in situations in which firms delegate output decisions to *risk-adverse* managers under different hypotheses concerning the nature of the shocks affecting firms' performances (Asseburg and Hofmann, 2010). Our paper, however, differs from such a literature for various reasons. Firstly, in a strict sense, we do not consider the delegation issue since, in our framework, output decisions are directly taken by firms to maximize their profits. In doing so, however, they must take workers' effort decision into account. Indeed, by considering the presence of agents' costly effort (which positively affects firms' output), the issue we study is more strictly related (with respect to the delegation framework) to the standard principal-agent problem, in which the agent features as a worker instead of a manager. Secondly, to the best of the authors' knowledge, this is the first paper that studies relative performance evaluation and compares it with performance-related-pay in a duopoly framework, in which the possibility for parties to bargain over wages is constrained by institutional arrangements.

The remainder of the paper is organized as follows: in Section II. we introduce the basic framework and then we show that, under the principal-agent standard assumptions (and with workers' risk neutrality), performance-related-pay and relative performance evaluation give the same outcomes. In Section III. we introduce institutional "frictions" into the analysis and, in this context, we derive and compare results with performance-related-pay and relative performance evaluation in relation to workers' effort, market expected price and output and firms' expected profits. The welfare analysis is relegated to Section IV.. Finally, Section V. concludes.

II. Model

II.A. Economic environment

We consider a market in which two firms $\{i, j\}$ compete *à la* Cournot in production of a homogeneous good. Let assume, for simplicity, that each firm hires and produces with one single worker and, according to the principal-agent literature, that firms' output positively depends on effort supplied by workers. Thus, we have a four-player game: for each of the two firms, we have an owner (principal) and a worker (agent). Since we aim at showing that, in the presence of institutional constraints, the incentive scheme adopted by firms matters even if workers are risk-neutral, we consider risk neutrality for all players and assume that the generic firm i's output, q_i, is given by:

$$q_i = e_i + \epsilon_i \tag{1}$$

where e_i is the level of effort chosen by worker i (employed by firm i), while ϵ_i is a noise term, which affects output but it is not under the worker i's control. Noise terms ϵ_i are assumed to be identically and independently distributed across firms, according to $\epsilon_i \sim N(0, \sigma_i^2)$.[4]

Following the standard agency theory (e.g. Hart and Holmström, 1987), we consider that workers' effort is not contractible because it is not observable by firms. However, since firms' output positively depends on effort, the former can be used to design an (enforceable) incentive scheme to motivate workers. Furthermore, given that the realization of the random term is null on average (hence expected output is equal to effort), the representative firm i's *expected* profit can be written as:

$$\pi_i = pe_i - w_i \tag{2}$$

where w_i is the (expected) wage paid by firm i to its worker

[4]Since we are assuming all agents' risk neutrality, noise terms play no relevant role in this framework.

(in this short-run analysis, we exclude non-labour costs) and p is the *expected* market price, which derives from the following linear product market expected demand:

$$p = a - cQ \tag{3}$$

with $Q = e_i + e_j$.

The workers' utility is positively related to the wage and negatively to the disutility of effort, which is assumed in a quadratic form, $D_i(e_i) = \frac{d_i e_i^2}{2}$,[5], where $d_i > 0$ is an exogenous parameter. For simplicity, we assume workers' homogeneity (i.e. $d_i = d_j = d$), hence, the worker i's expected utility function can be formally represented as:

$$u_i = w_i - \frac{de_i^2}{2} \tag{4}$$

while we normalize to zero his/her reservation utility.

II.B. A simple standard principal-agent model

As a benchmark case for following comparisons, let consider an economic environment in which parties can negotiate both the salary and the incentive pay component. Following the principal-agent literature, we assume that the principal has all the bargaining power and restrict the compensation paid to agent to be a *linear* function of the firm's output.[6] In particular, we compare two alternative incentive structures: performance-related-pay (PRP), in which incentives for the worker are linked to his/her absolute performance measure (output), and relative performance evaluation (RPE), in which the worker's incentive pay is related to how his/her performance is good with respect to that of the competitor (i.e. with respect to the other firm's output). Generally, the wage contract for the worker i can be represented as:

[5] This functional form for effort disutility is standard in the literature (e.g. Prendergast, 1999).

[6] Holmström and Milgrom (1987) provide a rationale for the use of linear incentive contracts in principal-agent relationships.

$$w_i = s_i + b_i(q_i - \theta q_j) \tag{5}$$

in which s_i is the fixed salary, b_i is the key-term that defines the power of incentives provided by the contract (that is, the higher b_i, the higher the incentives), while $\theta \in \{0, 1\}$ permits to distinguish between PRP ($\theta = 0$) and RPE ($\theta = 1$). Hence, once a firm and a worker match, the structure of the game between themselves is as follows: in stage one, the firm optimally design the incentive contract, linking its worker's pay to his/her (absolute or relative) performance, and, in stage two, given the incentive contract, each worker optimally chooses his/her effort, hence determining the firm's output. Formally:

$$\max_{e_i, s_i, b_i} \{\pi_i\}$$

$$\text{s. to: } \begin{cases} e_i = \arg\max_{e_i} \{u_i\} \\ u_i \geq 0 \end{cases}$$

where the two constraints represent the well-known *incentive-compatibility* and *participation* constraints, respectively.

From Eqs. (4) and (5), the worker's expected utility can also be written as:

$$u_i = s_i + b_i(q_i - \theta q_j) - \frac{de_i^2}{2}. \tag{6}$$

and the worker's i best-reply function with respect to incentives, which is obtained by maximizing Eq. (6) with respect to e_i, is given by the following standard equation:

$$e_i = \frac{b_i}{d} \tag{7}$$

which states that the worker i's effort is higher, the higher the incentive key-term b_i provided by the firm and the lower the parameter d related to the worker's disutility of effort.

Since the principal has all the bargaining power, and the salary component does not affect the worker's effort, the fixed term s_i is chosen, as usual, such that the worker's participation constraint is satisfied with strict equality, that is:[7]

$$s_i = \frac{de_i^2}{2} - b_i(q_i - \theta q_j). \tag{8}$$

Under the Cournot-Nash assumption, by embodying in Eq. (2) the effort chosen by the worker in the stage 2, defined by Eq. (7), and taking Eq. (8) into account, we may rewrite the firm i's expected profit equation as:

$$\pi_i = \left[a - c\left(\frac{b_i + b_j}{d}\right)\right]\frac{b_i}{d} - \frac{d}{2}\left(\frac{b_i}{d}\right)^2. \tag{9}$$

From Eq. (9), notice that, by construction, the particular form of the incentive scheme adopted does not appear. This is because by substituting Eqs. (5) and (8) in the firm's expected profit (Eq. (2)), the term $b_i(q_i - \theta q_j)$ cancels out, hence the firm's choice about the incentive-pay form (i.e. PRP vs. RPE) does not affect the power of incentives (b_i) provided by the firm to its worker. Putting it other words, both incentive schemes we are considering produce the same following results.[8]

Differentiation of Eq. (9) with respect to b_i yields the first-order condition for profit maximization by firm i, from which it is straightforward to derive its best-reply function in contract term space as:

$$b_i = \frac{ad - cb_j}{2c + d}. \tag{10}$$

Since firms are symmetric and simultaneously choose their contract incentive term to maximize their respective objective functions, hence $b_i = b_j = b$, by simultaneously solving the resulting first order conditions and substituting, we determine the optimal contract term for the standard principal-agent case as:

[7] In other words, the salary s_i simply plays the role of an "adjustment term". In this regard, also note that it is implicitly assumed that the worker's utility function is common-knowledge.

[8] It is worth noting that: i) this does not depend on the hypothesis that the firm has all the bargaining power (indeed, the same would apply if the worker receives a payoff equal to the disutility of effort plus a positive constant amount), and ii) this holds true for any other possible incentive scheme used by firms (e.g. market-share incentive contracts).

$$b^{PA} = \frac{ad}{3c+d}. \tag{11}$$

Substituting Eq. (11) in Eq. (7), we obtain the symmetric equilibrium effort (firm's expected output), i.e. $e_i = e_j = e$:

$$e^{PA} = \frac{a}{3c+d} \tag{12}$$

and, finally, using Eq. (12), we obtain, from Eqs. (2) and (3), the equilibrium *expected* market price and firm's profit for this case:

$$p^{PA} = \frac{a(c+d)}{3c+d} \tag{13}$$

$$\pi^{PA} = \frac{a^2(2c+d)}{2(3c+d)^2}. \tag{14}$$

III. Incentive contracts with institutional constraints

In this section, we introduce institutional considerations into the analysis. In particular, in contrast with the principal-agent literature's standard assumption, according to which the salary component is an adjustment term (which, in principle, can be either positive or negative) that is bargained by each single firm-worker pair, we consider the salary component of the worker's wage as given for parties and equal for both firms (i.e. $s_i = s_j = \overline{s}$). As discussed in the Introduction, this could be because the salary has been defined at an upper wage bargaining level. Indeed, as observed in many countries' industrial relations arrangements, workers' and firms' trade-unions bargain at upper-national wage bargaining level over the salary (which is the same for all firms operating in the same industry), while other wage components, which generally include incentive schemes, are defined at a lower contracting level between each single firm and its workers (e.g. Del Boca et al., 1999). We also assume that the salary, which has been institutionally defined at the upper level, is sufficiently high that workers always prefer to be employed than unemployed (i.e. the salary is fixed such that the participation constraint is always satisfied).[9]

Thus, in this case, the wage contract for the worker i becomes as:

$$w_i = \overline{s} + b_i(q_i - \theta q_j) \tag{15}$$

and the incentive problem for the firm can be formally represented as follows:

$$\max_{e_i, b_i} \{\pi_i\}$$

$$\text{s. to: } \begin{cases} e_i = \arg\max_{e_i} \{u_i\} \\ s_i = \overline{s} \end{cases}$$

In what follows, analysis starts, first, with the case of PRP.

III.A. PRP ($\theta = 0$)

With PRP, Eq. (15) becomes $w_i = \overline{s} + b_i q_i$ and the worker's i expected utility (Eq. (4)) is:

$$u_i = \overline{s} + b_i q_i - \frac{de_i^2}{2}. \tag{16}$$

Hence, the worker's i best-reply function with respect to incentives, which is obtained by maximizing Eq. (16) with respect to e_i, is the same as for the standard case (as defined by Eq. (7)). Under the Cournot-Nash assumption, by embodying in Eq. (2) the effort chosen by the worker in the stage 2 (and taking Eq. (5) with $\theta = 0$ into account), we may rewrite the expected profit equation as:

$$\pi_i = \left[a - c\left(\frac{b_i + b_j}{d}\right)\right]\frac{b_i}{d} - \left(\overline{s} + b_i\frac{b_i}{d}\right). \tag{17}$$

[9] Formally, $u_i \mid_{\overline{s}} > 0$. This is a quite natural assumption, since a fundamental role for collective bargaining at a nation-wide level is to ensure a basic wage at least high as workers opportunity costs (e.g. Dell'Aringa, 2002).

Differentiation of Eq. (17) with respect to b_i yields the first-order condition for profit maximization by firm i, from which it is straightforward to derive its best-reply function in contract term space as:

$$b_i = \frac{ad - cb_j}{2(c+d)}. \tag{18}$$

Taking firms' symmetry into account, by simultaneously solving first order conditions and substituting, we determine the optimal contract term for the PRP case, b^{PRP}, as:

$$b^{PRP} = \frac{ad}{3c+2d}. \tag{19}$$

Substituting Eq. (19) in Eq. (7), we obtain the symmetric equilibrium effort:

$$e^{PRP} = \frac{a}{3c+2d} \tag{20}$$

and, finally, using Eq. (20), we get, from Eqs. (2) and (3), the equilibrium *expected* market price and firm's profit for this case:

$$p^{PRP} = \frac{a(c+2d)}{3c+2d} \tag{21}$$

$$\pi^{PRP} = \frac{a^2(c+d)}{(3c+2d)^2} - \overline{s}. \tag{22}$$

III.B. RPE ($\theta = 1$)

With RPE, Eq. (15) becomes $w_i = \overline{s} + b_i(q_i - q_j)$ and the worker's i expected utility is:

$$u_i = \overline{s} + b_i(q_i - q_j) - \frac{de_i^2}{2}. \tag{23}$$

From the maximization of Eq. (23) with respect to e_i, we obtain again, as in the standard case, Eq. (7), that is, $e_i = b_i/d$.

Under the Cournot-Nash assumption, by embodying in Eq. (2) the effort chosen by the worker in the stage 2 (and taking Eq. (5) with $\theta = 1$ into account), we may rewrite the expected profit equation as:

$$\pi_i = \left[a - c\left(\frac{b_i + b_j}{d}\right)\right]\frac{b_i}{d} - \left[\overline{s} + b_i\left(\frac{b_i - b_j}{d}\right)\right]. \tag{24}$$

Differentiation of Eq. (24) with respect to b_i yields the first-order condition for profit maximization by firm i, from which it is straightforward to derive its best-reply function in contract term space as:

$$b_i = \frac{ad - b_j(c-d)}{2(c+d)} \tag{25}$$

and (following the same procedure as before), for the RPE case, we get the following results:

$$b^{RPE} = \frac{ad}{3c+d} \tag{26}$$

$$e^{RPE} = \frac{a}{3c+d} \tag{27}$$

$$p^{RPE} = \frac{a(c+d)}{3c+d} \tag{28}$$

$$\pi^{RPE} = \frac{a^2(c+d)}{(3c+d)^2} - \overline{s}. \tag{29}$$

III.C. PRP versus RPE

By comparing the equilibrium market outcomes for expected output, price and profit in the two different cases (with institutional constraints), we can state the following results:

Result 1 *If salaries are fixed institutionally, (expected) output is always higher and (expected) price is always lower with RPE than with PRP.*[10]

Proof. By direct comparisons of Eq. (27) with Eq. (20) and of Eq. (28) with Eq. (21), we get:

$$Q^{RPE} = 2e^{RPE} = \frac{2a}{3c+d} > \frac{2a}{3c+2d} = 2e^{PRP} = Q^{PRP}$$

$$p^{RPE} - p^{PRP} = \frac{a(c+d)}{3c+d} - \frac{a(c+2d)}{3c+2d} = \frac{-2adc}{(3c+d)(3c+2d)} < 0.$$

■

Result 2 *If salaries are fixed institutionally, firms' (expected) profits are always higher with RPE than with PRP.*

Proof. By direct comparisons of Eq. (29) with Eq. (22), we get:

$$\pi^{RPE} - \pi^{PRP} = \left[\frac{a^2(c+d)}{(3c+d)^2} - \overline{s}\right] - \left[\frac{a^2(c+d)}{(3c+2d)^2} - \overline{s}\right] = \frac{3a^2d(c+d)(2c+d)}{(3c+d)^2(3c+2d)^2} > 0.$$

■

Finally, by comparing Eq. (27) with Eq. (12), we also note that workers' effort (hence, firms' expected output) with RPE (under institutional constraints) is equal to that we get in the (standard) principal-agent model without institutional frictions. This also implies that market price are the same for those cases.[11]

[10]Notice that, since random shocks are independent from the particular incentive scheme adopted by firms, higher expected values for a particular (incentive-scheme) case also imply higher actual values.

[11]Obviously, profits could be lower with RPE and institutional constraints than in the standard principal-agent case. In particular, under the assumption that the workers' participation constraint is binding, firms' profits are lower in the presence of institutional constraints if, as most likely, they ensure a salary to workers larger than their opportunity costs (that is, if $\overline{s} > \frac{de^{RPE2}}{2}$ holds).

Result 3 *If salaries are fixed institutionally and firms use RPE incentive schemes, (expected) output and market price are the same as in the standard principal-agent framework without institutional constraints.*

Proof. Simple comparisons between Eqs. (27) and (28) with Eqs. (12) and (13) confirm that $Q^{RPE} = 2e^{RPE} = 2e^{PA} = Q^{PA}$ and $p^{RPE} = p^{PA}$. ■

IV. Welfare analysis

In order to compare expected consumer surplus and social welfare for different cases, recall that, in general, in this framework they are given by, respectively:

$$CS = \frac{cQ^2}{2} = 2ce^2 \tag{30}$$

$$SW = CS + 2pe - de^2. \tag{31}$$

Hence, by using Eqs. (20) and (21), we have that, in the PRP case, the expected consumer surplus is given by:

$$CS^{PRP} = \frac{2a^2c}{(3c+2d)^2} \tag{32}$$

thus, social welfare is:

$$SW^{PRP} = \frac{2a^2c}{(3c+2d)^2} + \frac{2a^2(c+2d)}{(3c+2d)^2} - \frac{a^2d}{(3c+2d)^2} = \frac{a^2(4c+3d)}{(3c+2d)^2}. \tag{33}$$

Similarly, by using Eqs. (27) and (28), in the RPE case, we have:

$$CS^{RPE} = \frac{2a^2c}{(3c+d)^2} \tag{34}$$

$$SW^{RPE} = \frac{2a^2c}{(3c+d)^2} + \frac{2a^2(c+d)}{(3c+d)^2} - \frac{a^2d}{(3c+d)^2} = \frac{a^2(4c+d)}{(3c+d)^2}. \tag{35}$$

By comparing previous results, we can state:

Result 4 *If salaries are fixed institutionally, expected consumer surplus and social welfare are always higher with RPE than with PRP.*

Proof. By direct comparisons of Eq. (34) with Eq. (32), we get:

$$CS^{RPE} - CS^{PRP} = \frac{2a^2c}{(3c+d)^2} - \frac{2a^2c}{(3c+2d)^2} = \frac{6a^2cd(2c+d)}{(3c+d)^2(3c+2d)^2} > 0.$$

and, by direct comparisons of Eq. (35) with Eq. (33):

$$SW^{RPE} - SW^{PRP} = \frac{a^2(4c+d)}{(3c+d)^2} - \frac{a^2(4c+3d)}{(3c+2d)^2} = \frac{a^2d(6c^2+6cd+d^2)}{(3c+d)^2(3c+2d)^2} > 0.$$

■

Finally, since, as shown above, we have that $e^{RPE} = e^{PA}$ and $p^{RPE} = p^{PA}$, we can also affirm the following result:

Result 5 *When salaries are fixed institutionally and firms use RPE to motivate their workers, expected consumer surplus and social welfare are the same as in the standard principal-agent framework without institutional frictions, in which firms "freely" choose all pay components.*

Before concluding, it is worth making some further comments about previous results. Indeed, since they hinge largely on the equilibrium values of the incentive key-term b (which determines the equilibrium workers' effort), for the different cases we have analyzed, this is the point that deserves some major considerations. In this regard, for a better understanding of the rationale behind our results, we may refer to Eqs. (9), (17) and (24), which define firm's expected profit for the three cases: the standard principal-agent framework (in which, recall, PRP and RPE are equivalent) and the "institutionally-dependant" cases with PRP and RPE, respectively. If we differentiate those equations with respect to b_i, we get the marginal effect of the incentive term on firm's expected profit for the three cases as, respectively:

$$\left(\frac{\partial \pi_i}{\partial b_i}\right)^{PA} = \frac{ad - c(2b_i + b_j)}{d^2} - \frac{b_i}{d} \tag{36}$$

$$\left(\frac{\partial \pi_i}{\partial b_i}\right)^{PRP} = \frac{ad - c(2b_i + b_j)}{d^2} - \frac{2b_i}{d} \tag{37}$$

$$\left(\frac{\partial \pi_i}{\partial b_i}\right)^{RPE} = \frac{ad - c(2b_i + b_j)}{d^2} - \frac{b_i}{d}. \tag{38}$$

In relation to the first term of the r.h.s. of Eqs. (36), (37) and (38), which represents the marginal effect of b_i on firm i's expected revenue, two things are worth noting: i) it is decreasing in b_i, and ii) it is exactly the same (and for the same reasons) in all the three cases.[12] Hence, differences in equilibrium b_i's values must be look for in the second term of the r.h.s., which captures the marginal effect of b_i on wages.

With reference to this latter effect, which is always positive (hence, negative with respect to profit), firstly, we must take into account that it operates differently in the principal-agent standard framework with respect to the cases with institutional constraints. Indeed, in the former, an increase in b_i increases the wage only indirectly, because it first produces an increase in worker's effort, hence in worker's disutility. Since in the principal-agent framework wages are fixed so as to equalize workers' disutility from effort, this determines, at the end, also an increase in wages. Recalling that $e_i = b_i/d$, the marginal effect of an increase of b_i on worker i's wage can be formally elucidated, in this case, by the following equation:

$$\left(\frac{\partial w_i}{\partial b_i}\right)^{PA} = e_i'(b_i)D_i'(e_i) = \frac{1}{d}de_i = \frac{b_i}{d}. \tag{39}$$

[12] An increase in b_i, by increasing worker i's effort (hence, output) has both a positive and a negative effect on firm i's revenue, the latter due to decreasing market price. Also note that, even if firm i's does not use relative performance evaluation, incentives provided by the other firm (b_j) produce a (negative) externality for firm i (thus, affecting its own choice about b_i) due to the effect on overall market output and price that they produce.

Instead, in the presence of institutionally fixed salaries (ensuring *a priori* that workers' participation constraints are satisfied) the mechanism through which an increase in b_i translates in a higher wage is very different, since, given the salary, it directly operates via an increase in the incentive-pay component. Formally, for PRP:

$$\left(\frac{\partial w_i}{\partial b_i}\right)^{PRP} = e_i'(b_i)b_i + e_i = \frac{1}{d}b_i + \frac{b_i}{d} = \frac{2b_i}{d} \tag{40}$$

and (recalling that, in the symmetric equilibrium, $b_i = b_j$) for RPE:

$$\left(\frac{\partial w_i}{\partial b_i}\right)^{RPE} = e_i'(b_i)b_i + e_i - e_j = \frac{1}{d}b_i + \frac{b_i}{d} - \frac{b_j}{d} = \frac{b_i}{d}. \tag{41}$$

Clearly, by comparing Eqs. (39), (40) and (41), and reminding that marginal revenue with respect to b_i (equal for the three cases) is decreasing in b_i, we get that, when there are institutional constraints, the equilibrium incentive key-term (hence, effort) with RPE is greater than with PRP. Furthermore, incentives and effort with RPE in the presence of institutional arrangements are the same than in the standard principal-agent framework (without institutional frictions), even if the underlying mechanisms that produce such results are very different.[13] These results drive the following ones on expected output, market price, consumer surplus and social welfare.

V. Conclusion

In this paper, we have studied equilibrium incentive contracts in a Cournot duopoly where firms are constrained by institutional

[13] Indeed, by comparing Eqs. (39) and (41), it clearly emerges that, while they are generally different, hence they imply different worker's effort levels (the same appears, more directly, also by comparing reaction functions defined by Eqs. (10) and (25)), in equilibrium, they become equal due to the symmetry hypothesis. Admitting for some asymmetries, with RPE, workers' effort might be also higher in the "institutionally-dependant" case than in the standard principal-agent framework. The analysis of an "asymmetric" context is beyond the scope of this work and is left for future research.

arrangements (e.g. owing to a centralised monopolistic union or a legal minimum wage) to pay a given salary. Even though our model is specific, it points out that, if some "frictions" in the fixing process of the salary do exist, the particular incentive scheme adopted by firms matters. In particular, we have compared two alternative incentive schemes, namely PRP and RPE, and we have shown that they differently affect market and social outcomes, even if workers are risk-neutral. This result contrasts with the standard principal-agent literature, according to which, with risk-neutral agents, PRP and RPE produce the same results.

More in detail, we have found that output, profits, consumer surplus and social welfare are higher with RPE than with PRP. By contrast, workers' utility is lower with RPE. This is because, with RPE, worker's effort and, as a consequence, disutility are higher with respect to PRP, the incentive-pay component is lower (null, in equilibrium), while the salary is the same, because it is fixed institutionally.

Furthermore, in the RPE case, the same outcomes of the standard principal-agent model, in which all pay components are "freely" chosen, are achieved with reference to effort (expected output), market price, consumer surplus and social welfare. Putting it other words, the "efficiency" of the standard principal-agent model also is preserved under institutional constraints, when firms adopt the proper incentive scheme. Obviously, in this case, differences could exist concerning the distribution of the surplus. In particular, we might expect that profits will be generally lower (and, conversely, workers' utility higher) with institutional constraints and RPE than in the standard case.

Finally, it is worth mentioning some potential ways of extending this paper, which represent the directions of our research. In particular, it would be interesting to consider other possible incentive schemes (e.g. market share related pay) and to extend previous analysis to other market competitive settings, such as differentiated oligopoly or price competition, or by introducing asymmetries in relation to both workers and firms.

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