E C O N O M I C S   B U L L E T I N

# On the choice of incentives in firms: influence activity, monitoring technology and organizational structure

Marco Delmastro
*Autorità Garante della Concorrenza e del Mercato*

## *Abstract*

Economists have offered a number of explanations on the introduction of monetary incentives within firms. These range from the classical agency model to the impact exerted by factors such as monitoring technology, influence activity and organizational structure. Numerous empirical contributions have recently provided evidence on part of this literature, especially as concerned the trade−off between incentives and insurance. However there is still much to do in order to offer a complete picture of firm's incentive system. The purpose of this paper is to provide a test to factors that have been usually underrepresented in empirical work but that may be key in favoring or inhibiting the introduction of performance bonuses.

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# 1 Introduction

Economists have offered a number of explanations on the introduction of monetary incentives within firms. These range from the classical agency model to the impact exerted by factors such as monitoring technology, influence activity and performance measurement (for a recent review see Gibbons 1998). Numerous empirical contributions have recently provided evidence on part of this literature, especially as concerned the trade-off between incentives and insurance (see Aggarval and Samwick 1999. See also Prendergast 1996 for a review of empirical evidence on compensation policies). However there is still much to do in order to offer a complete picture of firm's incentive system.

The purpose of this paper is to provide a test to factors that have been usually underrepresented in empirical work but that may be key in favoring or inhibiting the introduction of monetary incentives. In particular, Politecnico di Milano and University of Pavia have recently conducted an empirical survey on the organization of plants whose data allow me to test the role played by a number of organizational factors that are usually tackled in theoretical work but not in empirical research. I am aware that this represents only a first step towards a more complete analysis of a firm's incentive structure. However, information at disposal gives me an unique occasion to introduce in the empirical literature new determinants of the decision of adopting monetary incentives.

As an introductionary remark it is worth noticing that Italian labor legislation has two contractual negotiation levels: national and local. While at the national level trade-unions and employers negotiate the base salary, at company level bonuses and incentive schemes are defined by a bargaining process between firm management and workers. In particular, a firm management may or may not decide to introduce bonuses. Moreover, bonuses may be linked to measures of individual and/or team performance. In this paper I do not deal with the determination of the base salary but I concentrate on the determinants of the introduction of team and individual bonuses.

The remaining part of the paper is organized as follows. In Section 2 I briefly illustrate, by looking at economic theory, how the structure of incentives depends on some characteristics of firm's technological and organizational structure. Section 3 presents the empirical survey upon which this paper is based. Moreover, I illustrate measures that capture aspects such as firm and plant organizational structure, efficiency of monitoring technology and allocation of decision-making activity. These allow me, in Section 4, to test, through the estimates of four duration models, the effect of these and other explanatory variables upon the decision to introduce team and individual monetary incentives within sample firms.

## 2 Agency models: monitoring technology, influence activity and performance measurement

I start by using a version of the Holmstrom and Milgrom (1987) linear principal-agent model. Then I look at some extensions that take into account important factors that may influence the structure of incentives. In particular I shall focus upon monitoring technology, influence activities and performance measurement.

### 2.1 Traditional setting: incentives versus insurance

Assume that there are $n$ identical risk averse employees and one risk neutral principal (the owner). An employee takes an unobservable action $e$, whilst the principal observes a random signal

$$\hat{e} = e + \epsilon, \qquad E(\epsilon) = 0, var(\epsilon) = \sigma_\epsilon^2$$

where $\sigma_\epsilon^2$ is the variance of the observation error.

The employee's total pay $w$ is given by

$$w = S + b(e + \hat{e}),$$

where $S$ is a fixed wage and $b$ is the piece rate (premium rate).

Employees are assumed to have the same mean-variance utility function with convex disutility of effort $\frac{ke^2}{2}$. If we assume constant return to workers and an expected output per employee proportional to effort, say $ae$, by solving firm's problem we obtain the optimal piece rate

$$b^* = \frac{a}{1+rk\sigma_\epsilon^2} \qquad (1).$$

So, if $r = 0$ (agents are risk neutral) and $a = 1$, then we obtain the standard result $b = 1$. The employees' payment performance sensitivity is clearly a decreasing function of the variance on the measure of performance ($\sigma_\epsilon^2$), the coefficient of risk aversion ($r$), and the curvature of the employees' disutility of effort function ($k$). Also, it is increasing in the productivity of workers ($a$).

FitzRoy and Kraft (1995) extend this model to take into account firm's monitoring technology. In particular, they assume that the observation-error variance is reduced by monitoring expenditure. Thus, higher monitoring expenditure reduces observation-error variance and increases optimal piece rate. Moreover, given monitoring technology, complexity of observation of employees' effort is linked to the complexity of tasks and to the industrial environment. The optimal piece rate is a negative function of exogenous complexity of observation of employees' performance.

## 2.2 Influence activity

Perri (1994) develops previous framework taking into account influence activity (Milgrom 1988). In this case the principal observes an imperfect signal which is affected by employees' influence activity $i$

$$\hat{e} = e + i + \epsilon.$$

This signal is adjusted for expected influence activity $\hat{\imath}$, so that total pay is

$$w = S + b(e + i - \hat{\imath} + \epsilon).$$

In this setting, even if employees' influence activity is anticipated by the principal, it will be rational to engage in such activity because the principal expects the agents to behave opportunistically. In other words, given principal expectations, if $i < \hat{\imath}$, then $E(w) < S+be$. Agents' costs (of effort and influence) are assumed to be convex and given by $\frac{ke^2}{2} + \frac{uki^2}{2}$, where $u$ is a parameter of the cost of influence.

By differentiating firm's expected profits, we obtain the optimal piece rate

$$b^* = \frac{a}{1+1/u+rk\sigma_\epsilon^2} \qquad (2).$$

The employees' payment performance sensitivity is an increasing function of the cost of influence. The higher this cost, the lower employees' influence activity $i$. When influence is costly, employees will not be tempted to engage in these activities. In this case the principal will find convenient to link payment to performance. Otherwise, employees will be tempted to influence the signal of firm value. Thus, the principal will avoid to link compensation to firm value.

## 2.3 Performance measurement

Classic agency model assumes that principal's objective is always a contractible performance measure. However, this is often not the case. The inability to use total value as the basis of incentive contracts may lead to "the folly of rewarding A, while hoping for B". Let us follow Baker (1992). Assume agents' risk neutrality (i.e., $r = 0$) and define $P(e, \epsilon)$ as a measure of individual performance, and $V(e, \epsilon)$ firm value.

Baker shows that under these conditions the optimal piece rate is

$$b^* = \frac{1+\rho\sigma_{V_e}\sigma_{P_e}}{1+\sigma_{P_e}^2}, \qquad (3)$$

where $\rho$ is correlation between the marginal product of effort on value ($V_e$) and that on performance measure ($P_e$), $\sigma_{V_e}$ is standard deviation of $V_e$ and $\sigma_{P_e}$ is standard deviation of $P_e$.

Equation (3) shows that the correlation between the marginal product of effort and of value is key in the determination of optimal premium rate. The higher this correlation, the higher the piece rate: "If these marginal products are not strongly correlated, then the agent's effort choice will not match the principal's desired effort level in most states. Because the agent's disutility of effort function is convex, choosing the wrong level of effort is costly. In response, to this cost, the principal reduces the piece rate and reduces incentives" (Baker 1992, pg. 606).

# 3 Data

In this paper we use information on the organization of plants and their parent companies for a sample composed of 438 Italian manufacturing plants and for the period 1975-1997. In particular, Politecnico di Milano and Università di Pavia have designed a questionnaire analysis on Italian manufacturing plants aimed at collecting data on the organization of plants and on technology adoptions (see Colombo and Delmastro 1999 for a more detailed description of collected information on the organization and some descriptive evidence).

Information on sample plants provided by the survey and relevant to the purpose of the present paper includes:
i) the eventual use of a bonus system based on measures of individual and/or team performance;
ii) a detailed description of plants' decision-making structure. More precisely, for a series of strategic decisions I know the hierarchical level that is responsible and how the decision is made (see again Colombo and Delmastro 1999);
iii) the year of adoption by each plant of advanced manufacturing technologies such as on-line connection with headquarters, and of innovative management techniques such as rotation of productive workers;
iv) plant size (i.e. number of employees), sector of operation and ownership status.

## 3.1 Explanatory variables

In order to test predictions of economic theory presented in section 2, I considered a set of explanatory variables which are illustrated in what follows. Table 1 reports definitions of explanatory variables.

As to monitoring technology, I introduced the time-varying dummy variable *MONITORING TECHNOLOGY* which is 1 for plants that by year t-1 had adopted intra-firm network technology (i.e. LAN and on-line connection with headquarters). Advances in information technology enable managers to access to timely information about production and reduce the variance on the measure of performance (see Hubbard 1998). These increase the ability of managers to collect and process information on a plant's operations and decrease principal's costs of investigation. Therefore, advances in communication technology by reducing the variance on the measure of employees performance should lead to an increase in the use of team and individual bonuses (see equation 1). On the contrary, other things equal (i.e. monitoring technology), a more complex environment reduces principal capacity to effectively monitor plant employees, thus induces more variance on the measure of performance. Industries characterized by a high level of scientific base are likely to suffer from strong informational asymmetries between the agents and the principal. The variable *R&D*, which is the proportion of R&D employees to total employment by a three-digit NACE-CLIO industry classification, is a measure of complexity of technological environment (note that each plant has been assigned to the industry which accounts for the largest proportion of its output). According to equation (1), I would thus expect *R&D* to negatively influence the likelihood of a plant introducing monetary incentives.

Since equation (1) shows that there should exist a strong link between plant employees' productivity and the optimal piece rate, I introduced a number of variables that may capture this effect. *JOB SHOP* is a dummy variable which indicates, when equal to one, plants that are characterized by job-shop kinds of operations. Instead, when plants are involved in line production this variable assumes value equal to 0. More interestingly, I consider advanced manufacturing technologies (AMTs) to which the recent empirical literature on technological change has devoted considerable attention (see for instance Dunne 1994). In particular I focus on the following AMTs: flexible manufacturing systems and cells (FMSs), machining centers, NC and CNC stand-alone machine tools, and programmable robots. As all such technologies pertain to the production sphere, they directly affect production processes and consequently the organization of plants. I also want to test the existence of a "cluster effect": AMTs may affect the productivity of workers, thus the introduction of monetary incentives, especially when they are introduced together rather than in isolation. For this purpose, I have defined three time-varying dummy variables: *AMT1, AMT2* and *AMT34* equal 1 for plants which by year t-1 had adopted 1,2 and 3 or 4 AMTs, respectively.

In addition, I considered time dependent dummy variables regarding the introduction of the following human resource management practices (HRMPs): quality circles, just-in-time and job rotation. *HRMP1* and *HRMP23* equal 1 for plants which by year t-1 had adopted 1 and 2 or 3 HRMPs, respectively. In the year following adoption they are switched to 1. These work policies are at the core of recent empirical (Ichniowski et al. 1997) and theoretical research on the organization of firms (Kandel and Lazear 1992). This body of literature argues that the introduction of managerial innovations is part of a new organizational paradigm characterized by greater decentralization of decision-making activities, multitasking (rather than specialization of tasks), reduced bureaucratization and use of monetary incentives (see for instance Lindbeck and Snower 2000). In this respect, Holmstrom and Milgrom (1994) maintain that incentive schemes and other human resources management practices should covary in cross-sectional data.

Turning attention to influence activity, I expect its extent within a plant to be closely linked with the characteristics of decision-making (see Milgrom and Roberts 1988). Collected data include the managerial level that is responsible over the decision concerning plant's incentive procedures (i.e. introduction and definition of bonus systems and other monetary incentives). The time-varying dummy variable *PLANT MANAGER* is 1 when real but not formal authority over this decision is assigned to the plant manager, whilst is 0 when it is centralized at a higher hierarchical level (i.e. the owner in single-plant firms or a plant manager's corporate superior in multi-plant organizations). As they involve the presentation of evidence, influence activities provide decision makers with information that helps them to take decisions. As the objectives of the organization and the plant employees taking part to the negotiation diverge, it is likely there will be too much influence activity (Inderst et al. 2000). As long as the plant manager works inside the plant, he or she enjoys an informational advantage with respect to his/her corporate superior(s). In this case, plant employees will find more costly to alter information concerning plant value and their performance. Note also that influence activities are high when they are likely to be successful. The decentralization of real but not formal authority to the plant manager and thus the possibility of overruling his/her decisions are means by which the superior exploits informational advantage of plant manager and reduces influence activities of plant employees (due to both a low discretionary power of the plant manager and a closure of direct communication channels assured by the distance between plant manager's corporate superior, who works outside the plant, and plant employees). According to equation (2), when influence activity is more costly then the firm will find convenient to introduce monetary incentives. Thus I would expect a positive impact of *PLANT MANAGER* on the probability of introducing team and individual bonuses.

*SINGLE-PLANT* is a dummy variable that intends to distinguish establishments owned by a multi-plant organization from single-plant firms. In single-plant organizations the firm and the plant output coincide, while in multi-plant firms plant output represents only a proportion of the overall production of the group. Everything being equal, correlation between the marginal product of effort of plant employees on firm value and that on performance measurement declines as the number of plants increases. Thus I would expect single-plant organizations to be more likely to introduce incentive schemes based on measures of team and/or individual performance (see equation 3).

Finally, I included plant- and regional-specific control variables.

At plant level, I included both the variable *SIZE* which is the logarithm of the number of plant employees, and *SKILL* which is the percentage of plant employees with a high-school leaving certificate or higher degree. In addition, I included *UNIONIZATION*, which is the regional value of workers' unionization rate. This variable allows me to control for the influence of employees' bargaining power in the definition of firm's compensation policy.

### 3.2 Results

Table 2 presents the results of two right-censored Exponential duration models (recall that the period under scrutiny is 1975-1997)[1]. The dependent variables are given by two time-varying dummy variables which equal 1 for plants that by year t had adopted team (Model I) or individual (Model II) compensation schemes. In Model I the dependent variable is thus the duration needed to introduce bonuses based on measures of team performance, while in Model II is the duration needed to introduce bonuses based on measures of individual performance.

Generally speaking, the results of econometric estimates are robust and support the hypotheses presented in previous sections. In order to assess the joint contribution of explanatory variables to the fit of the models, I have proceeded to run chi-square tests (reported at the bottom of Table 2) for the joint hypothesis that all coefficients apart from the constant are equal to zero (se Kiefer 1988, pg.674). The tests are equal to 82.88 for Model I and 58.21 for Model II, showing that the explanatory power of independent variables is highly significant.

First of all, results of Table 2 show that individual and team bonuses are substitute and not complement. In particular, the likelihood of adopting an incentive scheme based on individual measures of performance is negatively affected by prior use of team bonuses. The reverse is also true, even though the coefficient of *INDIVIDUAL BONUSES* in the team bonuses regression is only almost significant.

Second, the variance on the measure of performance significantly impacts on the probability of adopting monetary incentives. The coefficient of *MONITORING TECHNOLOGY* is positive in both regressions but significant (at 1%) only for team bonuses, while scientific complexity, i.e. *R&D*, negatively affects the introduction of both kinds of bonus systems.

Innovations in production technology increase the probability of adopting team and individual monetary incentives, with the coefficient of *AMT2* and *AMT34* being positive and significant in both regressions. In addition, the introduction of a bonus system is also favored by prior adoption of HRMPs. Note also that when a plant's production is organized by job-shop kinds of operations, then the introduction of individual bonuses is more likely. The same does not hold true for team bonuses.

On the contrary, team, but not individual, bonuses are more often introduced in plants owned by single-plant firms where the correlation between marginal product of team effort on firm value and that on (team) performance measure is higher with respect to plants owned by multi-plant organizations.

Finally, when is the plant manager who has real authority on plant's incentive procedures then it is more likely that a firm introduces compensation schemes based upon measures of individual performance. This result is probably due to the fact that the plant manager enjoys an information advantage with

[1] I have also regressed two Weibul models that present similar results. Since the parameter of Weibul models that rules duration dependence is equal to one, then there is no duration dependence. In this case Weibul and Exponential models are equivalent.

respect to his/her superior on the measures of performance. Therefore by both assigning real responsibility to the plant manager and retaining possible overruling superior will exploit information returns to scale reducing variance on the measure of performance and minimizes influence activities of plant employees who otherwise would try to alter information concerning both plant value and their performance.

However, it is fair to recognize that *PLANT MANAGER* does not provide a complete picture of influence activities. In particular, plant employees are very likely to try to influence the decisions of the plant manager so as to defend their personal quasi-rents, especially when the plant manager is entitled with discretionary decision power, a condition which distinguishes situations where he or she is in charge of a large number of plant's strategic decisions. Thus I have proceeded to introduce into the estimates another variable which captures plant manager's discretionary power. *PM POWER* is the proportion of the following plant's strategic decisions that are assigned to the plant manager: (i) purchases of stand-alone machinery, (ii) purchases of large-scale capital equipment, (iii) introduction of new technologies, (iv) hiring and dismissals, and (v) career paths. Table 3 presents results of the estimates in which *PM POWER* has been included. They show that the adoption of monetary incentives is significantly more likely not only when the plant manager is assigned responsibility over plant's incentives procedures, but also when he or she has no strong discretionary power on other plant's strategic decisions which are instead centralized at a hierarchical level outside the plant.

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# Tables

Table 1 - Definitions of Explanatory Variables

| Variable name | Variable description |
|---|---|
| Monitoring technology | 1 for plants that by year t-1 had adopted intra-firm network technology |
| R&D | Proportion of R&D employees to total sector employment (3-digit class.) |
| Job shop | 1 for plants characterized by job shop kinds of operation |
| AMT1 | 1 for plants that by year t-1 had adopted 1 AMT[a] |
| AMT2 | 1 for plants that by year t-1 had adopted 2 AMTs[a] |
| AMT34 | 1 for plants that by year t-1 had adopted 3 or 4 AMTs[a] |
| HRMP1 | 1 for plants that by year t-1 had adopted 1 HRMP[b] |
| HRMP23 | 1 for plants that by year t-1 had adopted 2 or 3 HRMPs[b] |
| Plant Manager | 1 for plants in which at year t the plant manager is assigned real authority on the defintion of bonuses |
| Single-plant | 1 for plants owned by single-plant firms |
| Size | Logarithm of plant employees |
| Skill | Percentage of plant employees with high school leaving certificate or higher degree |
| Unionization | Unionization rate (regional value) |

*Legend:*

[a] AMTs: machining centers, programmable robots, numerically (or computerized numerically) controlled stand-alone machine tools, flexible manufacturing systems.

[b] HRMPs: job rotation, quality circles, just-in-time.

Table 2 - Results of exponential duration models

| | Models | |
|---|---|---|
| Variable[a] | Team bonuses | Individual bonuses |
| Constant | -3.7548 (.4013)*** | -4.4980 (.6271)*** |
| Individual bonuses$_{t-1}$ | -.2401 (.1834) | — |
| Team bonuses$_{t-1}$ | — | -.7455 (.2595)*** |
| Monitoring technology | .4566 (.1685)*** | .1002 (.3014) |
| R&D | -3.5807 (1.9872)* | -9.8189 (4.4092)** |
| Job shop | -.0875 (.1217) | .5457 (.1800)*** |
| AMT1 | .2295 (.1619) | -.3224 (.2794) |
| AMT2 | .6213 (.1871)*** | .2078 (.3377) |
| AMT34 | .7170 (.2438) *** | .8086 (.3724)** |
| HRMP1 | .0319 (.1663) | -.3896 (.3240) |
| HRMP23 | .5056 (.2067) ** | .5718 (.3386)* |
| Single-plant | .3365 (.1763)* | .0638 (.2747) |
| Plant manager | .1704 (.1212) | .4101 (.1802)** |
| Size | .1040 (.0650) | .0438 (.1072) |
| Skill | .0021 (.0033) | .0018 (.0051) |
| Unionization | -.0605 (.6214) | 1.3135 (.9020) |
| Number of firms | 438 | 438 |
| Loglikelihood | -1254.047 | -688.3391 |
| LR test (degrees of freedom) | 82.8780 (14)*** | 58.2054 (14)*** |
| Number of records | 6,558 | 7,942 |

*Legend:*
[a] Standard errors in parentheses.
*** Significant at the 0.01 level.
** Significant at the 0.05 level.
* Significant at the 0.10 level.

TABLE 3 - RESULTS OF EXPONENTIAL DURATION MODELS

| | Models | |
|---|---|---|
| Variable[a] | Team bonuses | Individual bonuses |
| Constant | -3.5511 (.4049)*** | -4.3544 (.6366)*** |
| Individual bonuses$_{t-1}$ | -.2435 (.1842) | — |
| Team bonuses$_{t-1}$ | — | -.7457 (.2598)*** |
| Monitoring technology | .4672 (.1699)*** | .1000 (.3013) |
| R&D | -3.3004 (1.9955)* | -9.4234 (4.4827)** |
| Job shop | -.0942 (.1217) | .5511 (.1810)*** |
| AMT1 | .2099 (.1619) | -.3527 (.2798) |
| AMT2 | .5901 (.1872)*** | .2129 (.3382) |
| AMT34 | .7141 (.2446)*** | .8329 (.3745)** |
| HRMP1 | .0457 (.1665) | -.3598 (.3248) |
| HRMP23 | .5418 (.2079)*** | .5784 (.3390)* |
| Single-plant | .3635 (.1765)** | .0226 (.2754) |
| Plant manager | .3796 (.1382)*** | .6438 (.2029)*** |
| PM Power | -.1208 (.0442)*** | -.1311 (.0622)** |
| Size | .1020 (.0647) | .0716 (.1079) |
| Skill | .0013 (.0033) | .0003 (.0050) |
| Unionization | -.2137 (.6243) | 1.1786 (.9089) |
| Number of firms | 438 | 438 |
| Loglikelihood | -1249.9450 | -686.8629 |
| LR test (degrees of freedom) | 91.08 (15)*** | 61.1578 (15)*** |
| Number of records | 6,558 | 7,942 |

*Legend:*

[a] Standard errors in parentheses.

*** Significant at the 0.01 level.

** Significant at the 0.05 level.

* Significant at the 0.10 level.