THE COMPOSITION OF COMPENSATION POLICY: FROM CASH TO FRINGE BENEFITS

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Abstract. We develop a Principal-Agent model to analyze the optimal composition of the compensation policy with both monetary and non-monetary incentives. We characterize nonmonetary benefits as symbols to capture a large set of non-wage compensations such as fringe benefits, status, identity (or self-image) or even sanctions. We determine the optimal composition of the compensation policy when the principal fully or imperfectly knows the agent's preferences. We first show that wages and symbols are relative substitutes at the bottom and relative complements at the top of the wage structure. Second, we show that offering a mixed contract is always more profitable when the principal has a relative comparative advantage compared to the agent's valuation of symbols. Finally, we analyze how the optimal mixed contract is modified when the principal faces further institutional constraints such as having to pay a fixed wage or symbol.

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1. Introduction

A firms' compensation policy has three independent dimensions: the level, the functional form and the composition of rewards (Baker et al.[4]). The level of compensation determines the quality and quantity of employees - that is who the firm can attract, the functional form determines the links between pay and performance - that is how employees perform once they're hired, and the composition defines the relative amounts of the components of the pay package such as cash, fringe benefits, working conditions, relationships with co-workers, leisure etc. Most of the research on incentives has privileged the first two dimensions. During the last 10 years, researchers' interest in studying non-monetary benefits as part of worker compensation schemes has increased (see for instance, Dale-Olsen [10], Goldman et al. [13], Hart [14], Hashimoto and Zhao [15], Rajan and Wulf [17], Royalty [18], Wood [19], Yermack [22], etc.). However, the literature is still rather thin. The focus of the researchers the last decade has primarily been on empirics (important exceptions are, for instance, Akerlof and Kranton [1], Oyer [16], Becker et al. [5], Auriol and Renault [2] and [3]), about for example the prevalence of fringe benefits, gender differences in fringe benefits, tax preferences for fringe benefits, how fringe benefits affect firm performance and worker turnover, and job-lock issues caused by health and pension plans.

Our short paper tackles the task of providing an understanding of the optimal composition of firms' compensation package. We contribute to the literature on incentives by proposing an agency framework in which the agent may be compensated for her effort by a wage and a nonmonetary reward, and the non-monetary compensation is treated as a *symbol*. This concept of symbol allows us to express a wide range of non-monetary benefits, like fringe benefits, perks, status, identify and sanctions.

The symbolic nature of non-wage benefits is a crucial assumption in our analysis and relies on the idea that most nonpecuniary benefits have, as a common denominator, a symbolic dimension at least implicitly. Overall non-monetary benefits represent a significant share of compensation, around one third of total labour costs in OECD countries (Dale-Olsen [8], Watters [20]) and are multi-faceted. They embed employer-provided benefits (pension scheme, health and life insurance, stock options), non-wage amenities (e.g. office space or working condition), fringe benefits, perquisites or payments-in-kind (free car, free housing, travel or lower valued fringes such as merchandises, free coffee etc). But despite their multiple components, most non-monetary benefits have a symbolic dimension. Like true symbols (medals or public prizes awarded during lavish ceremonies) any form of privilege (merchandise, company car, travel etc.) commands recognition by others. In fact, basically all types non-monetary benefits are inherently symbolic because even when they are offered to attract and retain employees (like health insurance, pension scheme or stock options) and/or have a direct monetary equivalent, they improve material well-being or signal employer's interest and recognition to workers. By treating non-monetary benefits as symbols, we therefore consider that symbols are not a cheap substitute for money. More precisely, the notion of symbol refers to nonpecuniary rewards with a symbolic, trophy-like, value and not immediately liquid for the agent, whereas benefits which are "almost-liquid"are embedded into the variable describing monetary wage.

This paper analyzes the optimal combination of wage and non-wage benefits in a Principal-Agent framework with moral hazard. However this problem is not trivial. For instance, the program in which the compensation package is composed of a nonmonetary reward only, does not necessarily admit a solution. In other words, incentive-compatibility does not trivially meet profitability for the principal.

We show that under symmetric information over the agent's preferences for symbols, mixed incentives Pareto-dominate purely monetary incentives. Under asymmetric information over the agent's preference relation, a compensation policy comprising a fixed fringe benefit combined with a variable wage also Pareto-dominates purely monetary incentives. This result is interesting because it offers an explanation to why some firms provide non-discriminatory non-performance related benefits (i.e., to all employees) while other provide performance-related benefits to selected groups of employees. In our model, of course, when the agent's preference over non-monetary benefits is pure private information, and the principal has no prior about it, then the principal has to resort to pure monetary rewards only.

Our article is composed of six sections. Section 2 presents our contribution to the related literature. Section 3 describes the model. Section 4 characterizes the optimal contract under symmetric information over the agent's preference for symbols. Section 6 analyzes the optimal contract under asymmetric information (partial or full) over the agent's preference for symbol, and section 7 concludes the article. All the proofs are relegated in Appendix.

2. Related literature

Several papers have analyzed the optimal incentives mix with monetary and non-monetary benefits (see for instance Auriol and Renault [2] and [3], Fershtman, Hvide and Weiss [11], Akerlof and Kranton [1], Oyer [16], Becker, Murphy and Werning [5]). These approaches focus on symbolic differentiation in the workplace such as social status and identity, and examine how the firm may use the workers' different preferences for such symbols in order to elicit more effort.

Auriol and Renault [3] analyze hierarchies as an incentive device in a promotion system and show that when agents with a higher rank are more responsive to monetary incentives, the optimal hierarchical structure associated with a promotion system is based on seniority and has two ranks, an agent's rank being solely determined by his seniority. When the responsiveness of effort to incentives diminishes, hierarchies are based both on merit an seniority and have three ranks with the young at the bottom, the old who were unsuccessful when young in the middle and the old who were successful when young at the top. Our model analyzes a different issue as we focus on a static set-up without promotion. Though receiving a large amount of symbol may confer a hierarchical status, we rather focus on situations where the allocation of symbols is not linked to past performance or merit but to a 'current' performance measure, in order to examine the static trade-off between wage and symbols in the optimal compensation mix.

Fershtman, Hvide and Weiss [11] focus on heterogeneity in workers' preferences for social status and productivity. They examine whether competing firms can induce the workers who care more (less) about status to exert more (less) effort, and how cultural diversity affects labor market equilibrium. They show that in equilibrium, firms mix workers with different status concerns and workers with status concerns will have more high-powered incentives, work more and earn more than workers who do not care about status.

Focusing on internal labor contracts, Auriol and Renault [2] develop a comprehensive analysis of status allocation in a hierarchy by disentangling static and dynamic effects. In their model, high status agents are also willing to exert more effort in exchange for additional income while better paid agents are willing to exert more effort in exchange for an improved status.

From a static perspective, they examine whether an employer would ex ante choose to differentiate status among a-priori identical workers. They show that although agents with a high status are more responsive to monetary incentives, the resulting benefits are outweighed by the impact of a lower work motivation for those with lower status. In the long run however, it is optimal to give young agents both low status and monetary incentives as their motivation to work stems solely from the prospect of being promoted. Because individual preferences exhibit complementarities between status and money, symbolic and material rewards are mutual reinforcers. In our single-agent model, symbols are likely to be traded against monetary rewards, but this depends on the marginal rate of substitution between wages and symbols which, given a general concave utility function, is higher at low wage levels.

Another difference between our model and Auriol and Renault [2]'s approach is that symbols are granted ex post, that is after effort and production have occurred while in Auriol and Renault, status is awarded ex ante. As in a standard static moral hazard model, our assumption relies on the fact that to induce a high effort level, incentives - whether monetary or non monetary - must be linked to the current observable performance measure and can be paid only at the end of the period. Despite such a difference, we obtain a result similar to Auriol and Renault's 'symbolic egalitarianism' according to which, in a static context, identical agents receive identical wage and status.

Focusing on identity in the workplace, Akerlof and Kranton [1] develop a model in which identity and monetary rewards are relatively substitutable. They show that if a worker has an identity as insider (outsider), the presence of identity in the utility function reduces (increases) the wage differential needed to induce the worker to take the high effort action. Relative complementarity between identity and wage may arise on the contrary when effort takes more than two values.

Here, we do not assume that individuals with greater income and status (identity concerns) have higher (lower) marginal utility of income than those with lower status (identity concerns) and lower income. In our framework, symbols and monetary incentives are then relative complements at the top of the wage structure but relative substitutes at the bottom of the wage structure. By considering a standard utility function in which wage and symbol are imperfect substitutes or complements, our model hence proposes a general framework for the analysis of optimal contracts in the presence of both monetary and non monetary incentives. We are therefore able to offer a general formulation for the trade-off in the utility function between wage and symbols. This implies that our model differs from previous approaches in several dimensions.

First, by characterizing non-monetary rewards through their symbolic dimension our analysis is applicable not only to social status, but also to many types of symbols like perks or any form of privilege or non-monetary recognition in the workplace.

Second, since we rely on a very standard Principal-Agent framework with moral hazard, the contract offered to the agent proposes a level of wage and symbol conditional upon observable output. Hence symbols are received ex post, and not ex ante as for instance in Auriol and Renault [2]. Such an assumption is standard in Principal-Agent models without status, but in the real world as well, ex post and performance-based allocation of status is also observed in many situations (see for instance the awards to salesperson).

Finally, to solve analytically the model, we have to rely on a static and single-agent context, which does not allow analyzing long run issues regarding contract renegotiation, promotions or between-firms competition.

3. The Model

3.1. **Basic set-up and definitions.**

We consider a moral hazard model[1] between a Principal and an Agent. The output of the relationship is a random observable variable and the agent's effort is unobservable by the principal. The principal designs the optimal contract by proposing a compensation package composed of a monetary wage and/or a nonmonetary reward. The nonmonetary reward is characterized by two essential dimensions: its symbolic nature and its value for the agent who receives it.

We label nonmonetary rewards under the term of **symbol**. The notion of symbol encompasses non-wage amenities like fringe benefits (e.g. health and life insurance, vacation trips, use of automobile, childcare services etc) and all types of nonmonetary incentives with a trophy value. Examples of various symbols are receiving a medal (military or civil like an olympic medal), an academic prize, a business award or recognition (e.g. being

[1]The analysis can be extended to any other type of agency relationship (adverse selection, signalling,...).

elected the "Manager of the year"). The main characteristics of symbols is that they are not immediately liquid for the agent, their role therefore does not consist in yielding a monetary, tradable, revenue. Symbols also have a trophy value and affect one's image (either self-image and identity or social image and hierarchical status in the organization).

In a standard principal-agent framework, the timing of events is such that rewards, whether monetary or non monetary, are attributed ex post. Hence, wages and symbols are offered and accepted ex ante (in the beginning of the relationship) but paid ex post, once the agent's performance is observed by both parties. This assumption is justified form a theoretical perspective because we rely on a static model where rewarding tools must be based on observable and verifiable variables. In a dynamic context however (for instance as in Auriol and Renault [2]) attributing symbols ex ante may matter in the long run, as this is the case for promotions for instance. Our assumption that symbols can be attributed ex post, once production has occurred, is evident for symbols such as medals, prizes, business recognitions etc. which have to be conditioned to the observation of a performance measure. For symbols like status or identity, within a static model they matter in the short run if they are attributed at the end of the period as a real rewarding tool. Our model might be interpreted as a reduced form of a dynamic setting where symbols would be essential to the long run relationship between the principal and the agent. For instance, a promotion would be attributed in the beginning of a new period, depending on past performance. Here, promotion would reward ex post, the effort exerted in the current period.

The **value of symbols** depends on the agent's preferences between monetary and nonmonetary benefits. These preferences are representative of the agent's value system[2]. To define the value and costs of symbols, we denote by Ω the infinite overall set of symbols. The **agent's preferences** are characterized by a standard[3] preference relation $\succsim$ defined over Ω and by a **real symbolic equivalent** (of ω) $s \in S$ such that[4]:

$$s = h(\omega), \quad \omega \in \Omega$$

where h represents a *self-satisfaction or ego function*[5] and where S is the set of real numbers "equivalent " to the set of symbols Ω.

[2]For instance, these preferences indicate whether it is worth proposing to salespersons nonmonetary benefits in the form of travel, merchandize or cash given that they already have to travel for accomplishing their job duties.

[3]In the sense that $\succsim$ is complete and transitive and that $(\succsim, \Omega)$ satisfies the usual condition of *perfect separability.*

[4]From a mathematical standpoint, h is an *order isomorphism* defined from $(\succsim, \Omega)$ into $(\mathbb{R}, \geq)$. Hence rather than using Ω, we can use the set $S = h(\Omega)$. It is worth working with this set S because any element $s \in S$ is a real number while the ω are pure symbols. Since $h(\omega)$ captures the nonmonetary reward provided by the symbol ω, the set S is interpreted thorough our paper as the set of nonmonetary rewards.

[5]The agent prefers ω to ω' because ω provides more self-esteem than does ω'.

The **cost of symbols** for the principal is defined by the cost of a symbol ω, $c(\omega) \in \mathbb{R}_+$, and its equivalent for s:

$$c(h^{-1}(s)) \in \mathbb{R}_+, \quad s \in S$$

To simplify notations, and when no confusion arises, we replace the notation $c(h^{-1}(s))$ by $c(s)$. Note that function c is not necessarily either monotonically increasing or decreasing. For now, c is simply assumed to be twice continuously differentiable.

3.2. **Technology and preferences.**

Given the costs and rewards defined previously, we characterize in this section the principal's profit, the agent's utility and effort and the output of the relationship.

The stochastic **production level** can take n possible values: $x \in X = \{x_1, ..., x_n\}$ where $x_1 < x_2 < x_3 < ... < x_n$.

The agent's **effort level** can take two possible values: $e \in \left\{e^L, e^H\right\}$ with $e^L < e^H$.
The agent's **cost of effort** is denoted by $v(e)$ where $v'(e) > 0$, $v(0) = 0$.
The stochastic influence of effort in production is defined by the probabilities $p_i^H = \Pr(x = x_i | e = e^H) > 0$, $p_i^L = \Pr(x = x_i | e = e^L) > 0$. The probabilities of success satisfy the usual monotone likelihood ratio property.

The agent's compensation is composed of a **monetary wage** $w(x_i)$ and a **nonmonetary component** $s(x_i)$. To simplify exposition, we will use the following notations in the rest of the paper:

$$w(x_i) = w_i \qquad s(x_i) = s_i \qquad v(e^k) = v^k \qquad i = 1..n, \quad k = H, L$$

The agent is risk-averse and her **utility function** is defined by:

$$U_i = u(w_i, s_i) - v(e^k), \quad i = 1..n, \quad k = H, L$$

where $u(.,.)$ is a strictly increasing (in both arguments) concave utility function. U_i denotes the ex post utility obtained by the agent in the n states of nature corresponding to outputs x_i, $i = 1..n$.

This utility function relies on two main assumption. First, we assume that utility is separable between the money-symbol mix and effort. This corresponds to the conventional assumption of separability of utility between money and effort in the basic Principal-Agent model. The second assumption is more important and relates to the utility function $u(w(x), s(x))$. We do not impose indeed any particular form for this function and keep it very general. In the literature, most models rely on a particular case of this general utility function (with an exception for Becker et al. [5]). For instance, wages and symbolic rewards are additively separable in Akerlof and Kranton [1], multiplicative in Auriol and Renault [2] and [3]. Our model hence generalizes theses approaches in a static and single-agent framework.

Finally, we assume that the principal is risk-neutral, with a **profit function** defined by:

$$B_i = x_i - w_i - c(s_i), \quad i = 1..n$$

where w_i denotes the agent's monetary reward, $c(s_i)$ is the C^2 cost of the nonmonetary reward s_i, and x_i is the output level.

3.3. The Agent's value system.

The agent's value system plays a crucial role in the optimal compensation policy. The reward package will indeed depend on the agent's preferences over wage and non-wage benefits. In practice, knowing the agent's value system is crucial to determine the best compensation policy.

The agent's value system is represented by his preference relation $\succsim$ or equivalently by the real symbolic equivalent $h = s(\omega)$ of this preference relation.

Two situations can then arise.

(1) **Symmetric information**: In this case, h is known both by the principal and by the agent. This is our benchmark case (see section 4).

(2) **Asymmetric information**: In this case, h is not perfectly known by the principal and is *conditional* to the observation of a random variable[6] $\theta \in \Theta$ (see section 6). This case corresponds to a partial asymmetry of information. There is full asymmetric information when the principal does not know the probability distribution of θ. These cases are analyzed in section 5.

4. Optimal contract under symmetric information over preferences

In this section, we first describe incentive feasible contracts and then characterize the properties of the optimal contracts when there is symmetric information over the agent's preferences.

[6]The random variable θ can be interpreted as a signal over the agent's preferences and can thus allow introducing heterogeneous types of agent. In this situation, the design of the compensation package may become a screening and auto-selection device leading to an endogenous sorting of workers according to their type (Besley and Ghatak [6] developed a similar argument).

4.1. **Incentive feasible contracts.**

Since the agent's effort is not observable, the principal can only offer a contract based on the observable and verifiable production level. Such a contract links both the monetary (wage w) and the non-monetary compensation (symbol $s = h(\omega)$) to the random output x. With n possible output levels x_i, the contract is defined by a pair of wage and symbol w_i and s_i $\forall i = 1..n$.

The problem of the principal is to decide whether to induce the agent to exert effort the high or low effort and then which incentive contracts should be used, that is which composition of wage and symbol should be offered.

Each effort level that the principal would like to induce corresponds to a set of contracts ensuring participation and incentive compatibility. Both types of constraints are defined as follows.

The *incentive compatible constraint* imposes the agent to prefer to exert the high effort level:

$$\text{(ICC)} \qquad \sum_{i=1}^{n} \left(p_i^H - p_i^L\right) u(w_i, s_i) \geq v^H - v^L$$

The *participation constraint* ensures that if the agent exerts the high effort level, this yields at least her outside opportunity utility level (reservation utility $\underline{U}$):

$$\text{(PC)} \qquad \sum_{i=1}^{n} p_i^H u(w_i, s_i) - v^H \geq \underline{U}$$

Definition 1. *A contract is incentive feasible if it induces a high effort level e^H (satisfies the incentive compatible constraint (ICC)) and ensures the agent's participation (satisfies the participation constraint (PC)).*

The following assumption with respect to the cost of symbols guarantees the existence of a solution in all possible contractual arrangements, in particular when for instance the agent is paid with symbols only (see Appendix for details).

Assumption 1. *The cost function c is a strictly increasing convex function.*

As a **benchmark**, let first consider the case of **complete information over effort**, that is when both the agent and the principal can observe the agent's effort level, and this public information is verifiable by a third party. The effort level can then be included into the contract, and if the principal wants to induce the high effort level e^H, her problems write:

$$\text{(FB)} \qquad \left| \begin{array}{l} \underset{(w_i,s_i)_{i=1..n}}{Max} \ \sum_{i=1}^{n} p_i^H (x_i - w_i - c(s_i)) \\ \text{subject to (PC)} \end{array} \right.$$

In this program, only the agent's participation constraint matters for the principal because the agent can be forced to exert a positive effort level (if not, deviation would be detected and could be punished). Denoting by λ the multiplier of the participation constraint and optimizing with respect to w_i and s_i leads to the following first order conditions:

$$-p_i^H + \lambda p_i^H u_w^{'}(w_i^\star, s_i^\star) = 0 \tag{4.1}$$

$$-p_i^H c^{'}(s_i^\star) + \lambda p_i^H u_s^{'}(w_i^\star, s_i^\star) = 0 \tag{4.2}$$

where $w_i^\star$ is the first best monetary transfer and $s_i^\star$ is the first best symbol.

¿From (4.2) and (4.2), we derive that $\lambda = \frac{1}{u_w^{'}(w_i^\star, s_i^\star)} = \frac{c^{'}(s_i^\star)}{u_s^{'}(w_i^\star, s_i^\star)}$ and finally that $w_i^\star = w^\star$, $s_i^\star = s^\star$ $\forall i = 1..n$.

With a verifiable effort level, the agent obtains full insurance and constant wage and symbol whatever the output level.

We now characterize the optimal compensation scheme under imperfectly observable effort (second-best) but symmetric information over the agent's preferences (value system represented by function $h(\omega) = s$).

4.2. Optimal mixed contracts.

When effort is not observable by the principal but information over the agent's preferences is symmetric, the principal's problem writes:

$$\text{(MIX)} \quad \left| \begin{array}{l} \underset{(w_i, s_i)_{i=1..n}}{Max} \ \sum_{i=1}^n p_i^H (x_i - w_i - c(s_i)) \\ \text{subject to (ICC) and (PC)} \end{array} \right.$$

The following proposition characterizes the solution of (MIX) and the relationships between the wage and symbols offered.

Proposition 1. *Under symmetric information over preferences, the optimal solution of (MIX), $(w_i^{mix}), (s_i^{mix})$, characterized by the following equation,*

$$\frac{u_s^{'}(w_i^{mix}, s_i^{mix})}{u_w^{'}(w_i^{mix}, s_i^{mix})} = c^{'}(s_i^{mix}), \quad \forall i = 1..n. \tag{4.3}$$

exhibits stronger wage/symbol congruence at high wage levels.

The fact that the optimal compensation policy depends on the degree of substitutability between monetary and nonmonetary rewards relies on the concavity (in the two arguments) of the utility function: in the plane (w_i, s_i), a convex indifference curve exhibits increasing marginal rate of substitution between s_i and w_i, $\text{MRS}_{sw} = \frac{u_s^{'}(.,.)}{u_w^{'}(.,.)}$. In other words, the value that the agent places on one extra unit of a symbol is higher at high wage levels, and lower at low wage levels.

When the agent has a *CES utility function* (constant elasticity of substitution), we assume that $u(w_i, s_i) = [\alpha w_i^{-\varepsilon} + \beta s_i^{-\varepsilon}]^{-\frac{v}{\varepsilon}}$ where $\varepsilon \geq -1$, and α, β

and v are positive constants. The optimality condition derived from proposition 1 writes: $\frac{\beta}{\alpha}\left[\frac{w_i^{mix}}{s_i^{mix}}\right]^{\varepsilon+1} = c^{'}(s_i^{mix})$, that is: $\frac{w_i^{mix}}{s_i^{mix}} = \left[\frac{\alpha}{\beta} \times c'(s_i^{mix})\right]^{\frac{1}{\varepsilon+1}}$.

We see that $\frac{w_i^{mix}}{s_i^{mix}}$ varies with the elasticity of substitution between wages (w) and symbols (s): $\sigma = \frac{1}{1+\varepsilon}$.

As ε increases, s and w become less and less substitutable. In the limit case when $\varepsilon = +\infty$ (*Leontief utility function*), s and w are complementary and the optimality condition implies $w_i^{mix} = s_i^{mix} \quad \forall i = 1..n$.

When ε decreases, s and w become more substitutable. For instance, when $\varepsilon = 0$ (*Cobb-Douglas function*) then $\frac{w_i^{mix}}{s_i^{mix}} = \frac{\alpha}{\beta}c^{'}(s_i^{mix}) \quad \forall i = 1..n$.

Finally, when the agent has constant absolute risk aversion, the optimal symbol offered is fixed[7].

Interestingly, the optimal mixed contracts replicate two important results in Auriol and Renault [2] and Akerlof and Kranton [1].

First, our model exhibits 'symbolic egalitarianism', as in Auriol and Renault [2]. Indeed, since the cost of symbols for the principal is independent of the agent's type, when offering contracts to different types of agents, the optimal mixed contract characterized by proposition 1 is such that identical agents, that is agents who value identically symbols and have same the preference function $h(.)$, would receive identical symbols and wages (the right hand side of equation (4.3) would be independent of the agent's type).

Second, Akerlof and Kranton [1] observe that identity and monetary incentives would be relative substitutes or complements, depending on whether the agent can exert two or more effort levels (substitutes for 2 effort levels and possibly complements for more effort levels). Here, we obtain a similar result with two effort levels since according to proposition 1, symbols and monetary incentives are relatively substitutable at low wage levels and relatively complementary at higher wage levels. We therefore find a more general result of Akerlof and Kranton as relative complementarity arises even for two effort levels. Moreover, in Akerlof and Kranton, a worker who derives identity from her job is willing to work for a lower overall pay. Here, we obtain a similar result. In our model, a worker who derives identity from her job would be characterized by a high value for symbol h and a marginal utility from gaining identity (changing a worker's identity form insider to outsider as in Akerlof and Kranton). From proposition 1 we see that

[7]If the agent has constant absolute risk-aversion, her utility function writes $u(w_i, s_i) = 1 - exp(-Aw_i - Bs_i)$ where $w_i, s_i \geq 0$ and $A, B > 0$ are respectively the absolute aversion coefficients over the monetary and the non-monetary dimensions. The optimality condition derived from proposition 1 writes: $\frac{B}{A} = c^{'}(s_i^{mix})$. Since c is a strictly increasing convex function, then $\frac{B}{A} = c'(s_i^{mix})$ implies $s_i^{mix} = s_0$, $\forall i$, with $s_0 = c^{'-1}\left(\frac{B}{A}\right) > 0$. Hence, if the agent's preferences are characterized by constant absolute risk aversion (CARA utility function), the optimal compensation is such that the non-monetary reward (s_0) is fixed. This non-monetary reward s_0 is indirectly connected to the optimal wage through $\frac{B}{A}$: the higher $\frac{B}{A}$, the higher s_0. Hence, the congruence between wage and symbol is higher at high wage levels. This property holds for standard utility functions.

to maintain the ratio $u^{'}(s_i)/u^{'}(w_i)$ constant, if $u^{'}(s_i)$ increases, then $u^{'}(w_i)$ should decrease and therefore the wage w_i should be lower. Hence, as in Akerlof and Kranton, when identity plays a big role in motivating workers ($h(.)$ positive and large), a firm would be likely to invest in changing workers' identities because there is a cost advantage for the firm in terms of lower wage variations needed to induce effort.

Let consider more precisely the utility functions considered in Akerlof and Kranton [1] and Auriol and Renault [2] to see what would be the optimal compensation mix in these cases.

Let consider first the utility function similar to Akerlof and Kranton [1]: $u(w_i, s_i) = ln(w_i) - e_i + h(s_i)$ where $h(s_i)$ would be defined as $h(s_i) = I_{s_i} - t_{s_i}|e^*(s_i) - e|$, with I_{s_i} is the identity utility from receiving symbol s_i and t_{s_i} is disutility from diverging from the ideal effort level $e^*(s_i)$. In this case, the solution of the program (MIX) leads to $w_i.(I^{'}_{s_i} - t^{'}_{s_i}) = c^{'}(s_i)$ so that the optimal compensation contract is characterized by relative substitutability between wages and symbolic identity. Indeed, given $c^{'}(s_i)$, the higher $I^{'}_{s_i} - t^{'}_{s_i}$, the lower the wage w_i needed to induce the agent to work hard.

Let now consider the utility function similar to Auriol and Renault [2]: $u(w_i, s_i) = w_i \times s_i$ (Cobb-Douglas case). In this case, the solution of the program (MIX) writes: $\frac{w_i^{mix}}{s_i^{mix}} = c^{'}(s_i^{mix}), \quad \forall i = 1..n$. Hence, with such a class of utility functions, the monetary and the non-monetary dimension of the compensation are relative complements. Indeed, given $c^{'}(s_i)$, the higher s_i, the higher the wage w_i needed to induce the agent to work hard. Auriol and Renault [2] further show that differentiation in terms of social status is optimal in a long term perspective, i.e. it is optimal to give young agents a status as low as possible along with no monetary incentives, but promotions are more substantial for those who have been successful in the past. Here, we obtain that when wages and symbols are relative complements in the utility function, the optimal compensation mix is twofold: low symbol and low wage (suggesting possible low firm tenure) together with high symbol and high wage (suggesting possible high firm tenure and/or high past performance). Our model therefore proposes a general (though different) framework allowing both relative substitutability (at low wage level) and relative complementarity (at high wage levels) between wages and symbols.

In sum, the optimal composition of the compensation package and the degree of substitutability between monetary and nonmonetary benefits varies with the workers' wage level. There is some empirical evidence in line with this issue. Dale-Olsen [9] shows that in Norwegian non-public sector establishments in 2002, there seems to exist a positive correlation between wages and fringe benefits. However, when accounting for the size of the establishments then Norwegian manufacturing is actually characterized by a convex relationship between fringe benefits and workforce size to the position in the conditional wage distribution. This convex relationship means that high wage establishments offer more fringes to their employees and have a higher size, but very low wage establishments also offer more fringes and are large (in terms of size)[8]. These facts are not inconsistent with our assessment that congruence is higher for high wage levels.

5. Equilibrium contracts chosen by the principal

We have shown that the optimal contract is characterized by a mix of wage and symbols characterized in equilibrium by the condition expressed in proposition 1. In the real world, many types of contracts are offered to employees, corresponding to very different amounts and nature of symbols (office space, status, health and life insurance, company car etc.). Apparently identical employees (with the same level of skills) may also be offered different amounts of symbols or wages, depending on their preferences. Similarly, in the public sector, as opposed to the private sector, the wage is quasi independent of output but symbols play an important role in motivating civil servants. Moreover, the principal may not have any information over the agent's preferences for symbols or wages. To examine this issue, we need to take into account which type of contract would most likely be offered in this asymmetric information context. We will highlight in particular two classes of contracts, in which the principal has no information over the agent's preferences either for symbols or for wages.

Before examining such equilibrium contracts, let note that one might think that it is always more profitable for the principal to offer a mixed contract because when there are more rewarding tools, incentives are more powerful and this automatically increases the principal's profit. However, when offering a mix of rewards, the principal relies on more incentives instruments but also bears more costs. Let consider for example a particular type of non-monetary benefits such that $c(s_i) = w_i \quad \forall i = 1..n$. In this case, a mixed contract reduces the principal's profit compared to a purely monetary contract. Hence, the issue of the optimal composition of the compensation policy is not trivial.

5.1. **Purely monetary versus mixed contracts.**

We now consider how the optimal contract is affected when the principal does not know the agent's preferences for symbols.

When the principal has no information over the agent's preferences for symbols, the only solution is to offer a contract based on monetary incentives only. This corresponds to a situation where the utility function $u_i(w_i, s_i)$ is projected over the space of wage only, that is $U_i = f(w_i) - v^k$, $i = 1..n$, $k = H, L$, with $f'(.) > 0$, $f''(.) \leq 0$, $f(0) = 0$.

[8]US data from the Bureau of Labor Statistics show that very low wage employees receiving only health benefits and sick leave sometimes have a very high percentage of total compensation in fringe benefits. This is due to the fact that the cost of health benefits is very large relative to the wages of a minimum wage employee and comparisons should be made very carefully in such particular cases (see Campbell [7]).

This case corresponds to the standard Principal-Agent framework with moral hazard, in which the compensation package is composed of a monetary wage only. The contract based on performance-based wages only solves the following program:

$$(\text{MON}) \qquad \left| \begin{array}{l} \underset{(w_i)_{i=1}^n}{Max} \sum_{i=1}^n p_i^H (x_i - w_i) \\ \text{subject to} \\ \sum_{i=1}^n p_i^H f(w_i) - v^H \geq \underline{U} \\ \sum_{i=1}^n \left(p_i^H - p_i^L\right) f(w_i) \geq v^H - v^L \end{array} \right.$$

The solution of this program is denoted by:

$w_i^{mon} = u'^{-1}\left(\frac{1}{\lambda_2 + \mu_2\left(1 - \frac{p_i^L}{p_i^H}\right)}\right) \quad \forall i = 1..n$ where λ_2 and μ_2 are strictly positive Lagrange multipliers.

An important remark has to be made at this point: (MON) is not a particular case of (MIX). To see this let take the following example: let assume that the agent's utility function is Cobb-Douglas and defined by $U_i = w_i \times s_i$ and the cost function writes $c(s_i) = s_i^2/2$ in (MIX), and where the agent's utility function is defined by $U_i = w_i$ in (MON) (which is a particular case of $U_i = w_i \times s_i$ for which $s_i = 1$). To provide a simple and transparent example, we also restrict our attention to the case of two output levels, that is $i = 1, 2$, $x_1 = 0$, $x_2 = 1$, $w_1 = 0$ and $w_2 = w$.

In this case, the optimal solution of (MIX) is such that $\frac{w_i^{mix}}{s_i^{mix}} = c'(s_i^{mix})$, that is: $w_i^{mix} = s_i^{mix}.c'(s_i^{mix}) = (s_i^{mix})^2, \quad \forall i = 1..n$. In turn, one naturally wonders whether (MON) corresponds to a particular case of (MIX). This is in fact not the case. Were (MON) a particular case of (MIX), then the optimal wage should correspond in both situations, that is we should observe that $w^{mon} = w^{mix}$ when $s^{mix} = 1$. Indeed, the optimal solution of (MON) when $U_i = w_i$ is such that[9] : $-p_i^H + \lambda p_i^H u'(w_i^{mon}) = 0$ (see (4.2)), that is $\lambda = 1$, and since the participation constraint is binding, we get: $\sum_{i=1}^n p_i^H w_i = v^H$. The equilibrium wage then is such that: $w^{mon} = \frac{v^H}{p^H}$. However, when $s_i^{mix} = 1$ then $w_i^{mix} = (s_i^{mix})^2 = 1$ and the only reason for which we would have $w^{mon} = \frac{v^H}{p^H} = 1$ would be that $v^H = p^H$ which must be assumed a priori for exogenous reasons, not based on sound economic foundations.

Among the two different types of contracts (MON) and (MIX), what would the principal choose? Let Π^{mon} and Π^{mix} denote the principal's optimal profits in the programs (MON) and (MIX). We have to determine whether Π^{mon} is higher or lower than Π^{mix}. The following theorem proposes a sufficient condition for having $\Pi^{mon} < \Pi^{mix}$. Before introducing this

[9]This corresponds to the standard principal-agent framework with moral hazard and agent's risk neutrality.

result, we shall define the set of admissible symbols. Let us state:

$$C = \left\{ \begin{array}{c} (w_i, s_i)\forall i = 1..n, \text{ such that } \sum_{i=1}^{n} p_i^H u(w_i, s_i) - v^H = \underline{U} \\ \textit{and } \sum_{i=1}^{n} \left(p_i^H - p_i^L\right) u(w_i, s_i) = v^H - v^L \end{array} \right\}$$

C therefore also writes :

$$C = \left\{ (w_i, s_i)\forall i = 1..n, \text{ such that } \sum_{i=1}^{n} p_i^L u(w_i, s_i) = \underline{U} + v^L \right\}$$

The set of admissible symbols S_a is defined as the support of C, that is $S_a = \{(s_i)\, \forall i = 1 \ldots n \in S\, s.t.\, (w_i, s_i)\forall i = 1 \ldots n \in C\}$.

Theorem 1. *Under symmetric information over the agent's preferences, condition* (2) *implies condition* (1)*:*

1. $\Pi^{mix} > \Pi^{mon}$ *and* $\sum_{i=1}^{n} p_i^H u(w_i^{mix}, s_i^{mix}) - v^H = \sum_{i=1}^{n} p_i^H f(w_i^{mon}) - v^H$
2. $\forall (s_i)\, \forall i = 1 \ldots n \in S_a\,,\; E(s) = \sum_{i=1}^{n} s_i p_i^H > E(c(s)) = \sum_{i=1}^{n} c(s_i) p_i^H$

where (w_i^{mon}) $\forall i = 1..n$ *solves (MON) and* (w_i^{mix}, s_i^{mix}) $\forall i = 1..n$ *solves (MIX).*

This result indicates that when the principal knows the agent's preferences, she always finds it profitable to offer a mixed contract, while the agent is indifferent (she receives the same reservation utility) if there exists a subset of symbols for which $E(s) > E(c(s))$ that is: in expected terms, the value (for the agent) attached to symbols exceed its costs for the principal. In other words, the employer should have a *relative comparative advantage* in offering non-monetary benefits to the employee.

5.2. **Partial asymmetry of information over the preferences for symbols.**

We now consider that the principal may have some partial information over the agent's preferences for symbols. When the agent's preferences are not perfectly known by the principal, h is then conditional to the observation of a random variable $\theta \in \Theta$. The agent's preferences over wage and non-wage amenity is denoted by $\succsim^{\theta}$ and its corresponding real symbolic equivalent writes $h(\omega, \theta)$. Three subcases are distinguished:

(1) The principal does not know (and has no prior on) the probability distribution of θ.

In this case, the principal can only resort to pure monetary incentives.

(2) The principal knows the probability distribution of θ.

In this case, a mixed monetary/nonmonetary incentives mechanism can be designed by working on the expected self-satisfaction of a symbol ω denoted $\widehat{h}(\omega) = \widehat{s} = E_\Theta [h(\omega, \theta)]$.

(3) The principal does not know (and has no prior on) the probability distribution of θ but she knows that there exist (at least) two symbols $\omega', \omega'' \in \Omega$ such that $\omega' \succ \omega''$.

In this case, the principal can design a mixed contract composed of a variable wage and a fixed nonmonetary reward s' (associated to ω'). Since the compensation package is composed of a monetary wage and a nonmonetary reward fixed and independent of output, the optimal contract solves program (MIX) when the agent's utility is defined by $u_i = u(w_i, s^{'})$ and the principal's expected profit by $B_i = \underset{\{w_i\}_{i=1}^n}{Max} \sum_{i=1}^n p_i^H [x_i - w_i] - c(s^{'})$. The corresponding program is denoted by $(MIX^{'})$ (see appendix). The optimal compensation package is then characterized by the following proposition.

Proposition 2. *When the principal knows that there exist (at least) two symbols $\omega', \omega'' \in \Omega$ such that $\omega' \succ \omega''$, then the optimal contract $(w_i^{mix^{'}}, s^{'})$ $\forall i = 1..n$ solution of $(MIX^{'})$ is such that:*

$$u_w^{'}(w_i^{mix^{'}}, s^{'}) = \frac{1}{\lambda' + \mu' \left(1 - \frac{p_i^L}{p_i^H}\right)}$$

with $\lambda^{'}$ and $\mu^{'}$ the strictly positive Lagrange multipliers.
Moreover, if $s' > c(s')$ then $(w_i^{mix^{'}}, s^{'})$ Pareto-dominates purely monetary incentives (no symbol at all) (w_i^{mon}).

This proposition shows that even when the principal imperfectly knows the agent's value system, a mixed contract can still be offered and is Pareto-improving compared to the purely monetary contract provided that $s' > c(s')$: the agent obtains the same reservation utility while the principal's profit are increased if she has a comparative advantage in offering the symbol to the agent. This proposition is important since in most firms and organizations, many fringe benefits are not conditioned to the firm's result. This is the case for instance of health insurance, nursery, or free car. Our results suggest that using a fixed fringe benefit and a variable monetary wage as an incentive device may improve firms' profits provided that $s' > c(s')$. In particular, a profitable firm's strategy would be to target the fringe benefits policy. On the one hand, fixed non-wage amenities would be offered on the basis of weak information (only that employees have a preference for them) and could thus be interpreted as a way to retain employees and reduce turnover (see Dale-Olsen [9]). This could be the case of health insurance for example. On the other hand, symbols with a high trophy value would be offered on the basis of strong information, employers should know what trade-off determine workers preferences between wage and non-wage rewards, and could thus be profitably linked to the firm's results. This could be the case of status in the organization.

6. Optimal contracts under institutional constraints

Let now consider the situation where information is symmetric but the principal faces institutional constraints over the contracts that she may offer. An institutional constraint represents an exogenous rule set by the government or by a social norm, and prevents the principal from offering a contract based on (MIX). Here, we will consider two types of institutional constraints: the first one imposes that the agent receives a fixed symbol (with output-dependent wage), and the second one imposes that the agent receives a fixed wage (with output-dependent symbol).

A contract with fixed symbol and output-dependent wage may be offered in any type of firm and corresponds to symbols that cannot be made dependent on output measures. This is the case of nonmonetary benefits like health insurance for instance. This type of contracts are in fact built as $(MIX^{'})$ (see previous section). The only difference is that here information is symmetric and the principal chooses the symbol that she wants to offer given an institutional constraint, whereas in the previous section, information is asymmetric and the symbol offered derives directly from the agent's preferences. Proposition 2 therefore applies here.

A contract with fixed wage and output-dependent symbol is very likely within public service organizations where civil servants are generally not paid according to an individual performance measure whereas the symbolic dimension of their contract depends on an output measure (x_i) and may take the form of a promotion (at the end of the current period), a medal or a prize, or any form of public recognition of the work done[10]. This type of contract is labeled $(\overline{MIX})$. In this case, the program solved by the principal is identical to (MIX) except that wage is fixed and equal $\overline{w}$.

When the contract is composed of a fixed wage and an output-dependent symbol, utility writes $u_i = u(\overline{w}, s_i)$ that is $U_i = u(\overline{w}, s_i) - v^k$, $i = 1..n$, $k = H, L$. In this case, the optimal output-dependent symbol $(s_i^{\overline{mix}})\quad \forall i = 1..n$ that solves $(\overline{MIX})$ is characterized by the following proposition.

Proposition 3. *Under symmetric information over the agent's preferences, the optimal solution of* $(\overline{MIX})$, $(\overline{w}, s_i^{\overline{mix}})\quad \forall i = 1..n$, *is such that:*

$$\frac{u_s'(\overline{w}, s_i^{\overline{mix}})}{c'(s_i^{\overline{mix}})} = \frac{1}{\overline{\lambda} + \overline{\mu}\left(1 - \frac{p_i^L}{p_i^H}\right)}$$

[10]In such a contract, the monetary compensation may even be very low: in some developing and emerging countries like China for instance, labor contracts are often based on high symbolic compensations (housing, catering, etc.) and very low monetary compensations.

with $\overline{\lambda}, \overline{\mu}$, the strictly positive Lagrange multipliers of $(\overline{MIX})$.

Moreover, if the principal has a comparative advantage in offering symbols to the agent, then the contract $(\overline{MIX})$ Pareto-dominates (MON) .

Offering a contract with fixed wage and output-dependent symbol may imply that the agent's risk exposure with respect to monetary rewards is reduced. Indeed, let consider that $\overline{w}$ is such that $\overline{w} \geq I_\Lambda$ where I_Λ is the certainty equivalent of the lottery $\Lambda = (p_1^H, w_1^{mon}, ...; p_n^H, w_n^{mon})$ $\forall i = 1..n$. In this case, the principal can rely on nonmonetary incentives to reduce monetary risk exposure. Since expected utility is the same under both types of contract (MON) and $(\overline{MIX})$, choosing the riskier contract in terms of monetary reward reveals a preference for risk. Becker et al. [5] develop a model in which a higher status raises the marginal utility of income to explain the demand for risky activities. Higher status is acquired by the winners of lotteries and other risky activities and the willingness to participate in risky activities is the result of the importance of status in the agents' preferences. This assumption implies a complementarity between status, income and "risk-loving". In our framework, risk-averse agents (regarding the monetary transfer) prefer the variable part of rewards to bear on symbols. However, potentially higher symbols (conditional on output) are associated with lower risk in terms of monetary wage in contract $(\overline{MIX})$, which is preferred by risk-averse agents. Our assumption of a general utility function implies that the links between symbol, wage and risk are more complex and depend on the agent's wage level and propensity to risk exposure.

7. Conclusion

This paper develops a Principal-Agent model to analyze the optimal composition of the compensation policy with both monetary and nonmonetary incentives. Our results are compatible with the empirical literature concerning nonmonetary incentives.

¿From an economic policy perspective, taking into account the tax system might reinforce our results in the following sense. A mixed monetary/nonmonetary incentives scheme would be more interesting both for the principal and for the agent under a progressive tax system for the lower part of the income distribution subject to a traditional threshold level. Indeed, for such categories of workers, a monetary bonus may sometimes be completely suboptimal when it implies that the agent switches up to the higher income category, making her pay taxes and losing social transfers. For the principal as well, if labor taxes are progressive, a non-purely monetary incentives scheme represents a non-negligible fiscal advantage, even though we have seen that the role of costs in the optimal compensation package is not trivial.

Our static model could be extended to dynamic one in order to analyze the long term relationship between wage and symbols. For instance, a desire for a status in the future can induce workers to perform efficiently, therefore reducing the need for monetary incentives.

Appendix: Proofs

Proof of proposition 1.

We can solve the program (MIX) using Kuhn and Tucker's method because the cost function is a convex function and $\sum_{i=1}^{n} p_i^H u(w_i, s_i)$ and $\sum_{i=1}^{n} \left(p_i^H - p_i^L\right) u(w_i, s_i)$ are negative semidefinite functions. Moreover the solution if it exists is a *global maximum.* Let $L\left(w_1, \ldots, w_n; s_1, \ldots, s_n, \lambda_1, \mu_1\right)$ the Lagrangean of program (MIX) with $\lambda_1, \mu_1 \geq 0$. Kuhn and Tucker's conditions are given as follows:

$$\begin{array}{ll} (a) & -p_i^H + \lambda_1 p_i^H u_w'(w_i, s_i) + \mu_1 \left(p_i^H - p_i^L\right) u_w'(w_i, s_i) = 0 \\ (b) & -p_i^H c'(s(x_i)) + \lambda_1 p_i^H u_s'(w_i, s_i) + \mu_1 \left(p_i^H - p_i^L\right) u_s'(w_i, s_i) = 0 \\ (c) & \lambda_1 \left[\sum_{i=1}^{n} p_i^H u(w_i, s_i) - v^H - \underline{U}\right] = 0 \\ (d) & \mu_1 \left[\sum_{i=1}^{n} \left(p_i^H - p_i^L\right) u(w_i, s_i) - v^H + v^L\right] = 0 \end{array}$$

(a) also writes:

$$\lambda_1 p_i^H + \mu_1 \left(p_i^H - p_i^L\right) = \frac{p_i^H}{u_w'(w_i, s_i)} \tag{7.1}$$

Hence :

$$\lambda_2 = \sum_i \frac{p_i^H}{u_w'(w_i, s_i)}$$

Since $u_w'(w_i, s_i) > 0$ then $\lambda_1 > 0$ (we reach exactly the same conclusion using Kuhn and Tucker's condition (b)). Concerning μ_1 , if $\mu_1 = 0$ then (a) and (b) implie respectively that:

$$\lambda_1 = \frac{1}{u_w'(w_i, s_i)}$$

and

$$\lambda_1 = \frac{c'(s(x_i))}{u_s'(w_i, s_i)}$$

$\lambda_1 = \frac{1}{u_w'(w_i, s_i)}$ implies that (using the implicit functions theorem) $w_i = \phi\left(\lambda_1, s_i\right)$. Therefore, $\lambda_1 = \frac{c'(s_i)}{u_s'(w_i, s_i)}$ also writes:

$$\lambda_1 = \frac{c'(s_i)}{u_s'\left[\phi\left(\lambda_1, s_i\right), s_i\right]}$$

Let us denote $\frac{c'(s_i)}{u_s'[\phi(\lambda_1, s_i), s_i]}$ by $\psi(s_i)$. The previous equation then becomes :

$$\lambda_1 = \psi(s_i)$$

That is :

$$s_i = \psi^{-1}(\lambda_1)$$

In other words, the agent receives the same symbol whatever the result. In this case, the agent chooses the lowest effort level e^L. Therefore, such a mechanism is not optimal. Hence we have $\mu_1 > 0$. The optimal mixed monetary/non-monetary incentives scheme $(w_i^{mix}), (s_i^{mix})$ is then given by :

$$\frac{u_s'(w_i^{mix}, s_i^{mix})}{u_w'(w_i^{mix}, s_i^{mix})} = c'(s_i^{mix}), \quad \forall i = 1..n.$$

□

Lemma 1. *Let denote by q the following random variable:*

$$q = w^{mon} - c(s^{mix}) - w^{mix}$$

q denotes the difference between the optimal wage of the monetary incentives scheme w^{mon} and the overall cost of the mixed monetary/non-monetary incentives scheme. The following two conditions are equivalent.

(1) $\Pi^{mix} \geq \Pi^{mon}$
(2) $E[q] \geq 0$

Proof of lemma 1.

$$\Pi^{mon} = \sum_{i=1}^{n} p_i^H (x_i - w_i^{mon})$$
$$\Pi^{mix} = \sum_{i=1}^{n} p_i^H \left[x_i - c(s_i^{mix}) - w_i^{mix}\right]$$

Thus :

$$\Pi^{mix} \geq \Pi^{mon} \Leftrightarrow \sum_{i=1}^{n} p_i^H \left[w_i^{mon} - c(s_i^{mix}) - w_i^{mix}\right] \geq 0$$

That is :

$$E[q] \geq 0$$

□

Proof of theorem 1.

Using lemma 1, the proof consists in showing that condition (2) implies $E[q] > 0$.

Let us remind that C writes :

$$C = \left\{ (w_i, s_i) \forall i = 1..n, \text{ such that } \sum_{i=1}^{n} p_i^L u(w_i, s_i) = \underline{U} + v^L \right\}$$

Clearly, the optimal solution $(w_i^{mix}, s_i^{mix}) \forall i = 1..n$ of program (MIX) belongs to C.

Now let w_i^{mon} $\forall i = 1..n$ denote the optimal solution of program (MON). Let determine $(\underline{w}_i, \underline{s}_i)$ $\forall i = 1..n \in C$ such that :

$$w_i^{mon} = \underline{w}_i + \underline{s}_i \quad , \; i = 1..n \tag{7.2}$$

Such a $(\underline{w}_i, \underline{s}_i)$ $\forall i = 1..n$ necessarily exists because it is deduced from a system of nonlinear equations.

Using condition (2) of theorem 1, we have:

$$\sum_{i=1}^{n} p_i^H \underline{s}_i > \sum_{i=1}^{n} p_i^H c(\underline{s}_i) \quad , \forall\ i = 1..n$$

We finally get :

$$\underbrace{\sum_{i=1}^{n} p_i^H \left(x_i - w_i^{mon}\right)}_{\Pi^{mon}} \quad < \quad \underbrace{\sum_{i=1}^{n} p_i^H \left[x_i - \underline{w}_i - c(\underline{s}_i)\right]}_{\underline{\Pi}^{mix}}$$

Let recall that $(w_i^{mix}, s_i^{mix}) \forall i = 1..n$ the optimal solution of program (MIX) belongs to C. Moreover by definition we have : $\Pi^{mix} \geq \underline{\Pi}^{mix}$. Hence:

$$\Pi^{mix} > \ \Pi^{mon}.$$

It remains to show that :

$$\sum_{i=1}^{n} p_i^H u(w_i^{mix}, s_i^{mix}) - v^H = \sum_{i=1}^{n} p_i^H u(w_i^{mon}) - v^H$$

This comes directly from the fact that the agent has the same reservation utility under (MIX) and (MON). □

Proof of proposition 2.

Applying the same reasoning as in the proof of proposition 1, we have $\lambda^{'} > 0$ and $\mu^{'} > 0$. The optimal incentives scheme $(w_i^{mix^{'}}, s^{'})$ that solves $(MIX^{'})$ is given by :

$$u_w^{'}(w_i^{mix^{'}}, s^{'}) = \frac{1}{\lambda' + \mu' \left(1 - \frac{p_i^L}{p_i^H}\right)} \quad \forall i = 1..n$$

Finally, using the same strategy of proof as for theorem 1, we get that the solution of $(MIX^{'})$ Pareto-dominates the solution of (MON) iff $s' > c(s')$. □

Proof of proposition 3.

Applying the same reasoning as in the proof of proposition 1, we have $\overline{\lambda} > 0$ and $\overline{\mu} > 0$. The optimal incentives scheme $(\overline{w}, s_i^{\overline{mix}})$ is given by :

$$\frac{u_s'(\overline{w}, s_i^{\overline{mix}})}{c'(s_i^{\overline{mix}})} = \frac{1}{\overline{\lambda} + \overline{\mu} \left(1 - \frac{p_i^L}{p_i^H}\right)}$$

The agent is indifferent between the solution of $(\overline{MIX})$ and the solution of $(MIX^{'})$ because in both case she gets her reservation utility.

Finally, using the same strategy of proof as for theorem 1, we get that the solution of $(\overline{MIX})$ Pareto-dominates the solution of (MON) iff $s' > c(s')$. □

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