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Financial contracts with several types of agents

Laura CONSTANTIN
Bucharest University of Economic Studies, Romania
constantin.laura95@yahoo.com
Ștefan Virgil IACOB
"Artifex" University of Bucharest, Romania
stefaniacob79@yahoo.com
Dana Luiza GRIGORESCU
Bucharest University of Economic Studies, Romania
danaluiza2004@yahoo.com

Abstract. *The article analyses the optimal financial contracts with several types of agents, studying the situation of informational symmetry (symmetrical information) and the situation of informational asymmetry (asymmetric information). In the situation of informational symmetry, the equilibrium point between the principal (decision maker, for example the bank) and the agent (a natural or legal person) is determined, respectively the optimal transfer (rate) and the optimal amount that the agent can borrow. The two main characteristics of the contract are highlighted, represented by the situation of Pareto efficiency (Pareto optimality) and the situation in which the Agent obtains exactly the minimum threshold reserved by the market. In the situation of informational asymmetry, it is solved with the help of informational rents and the solution is compared with the first rank solution, where we have symmetrical information. The characteristics of the contract are highlighted, namely the situation in which the efficiency of Pareto is kept only for the efficient agent who obtains an informational rent. For the other agents, the solution is no longer Pareto - optimal. Following the described analysis, models will be obtained that are classified in relation to the types of agent: rich, good payers or not and good professionals.*

Keywords: financial contracts, agents, information symmetry, balance, market.

JEL Classification: C60, C70.

Introduction – presentation of hypotheses

In the Principal – Agent model, if the Principal has less information on some variables that can influence the relationship of the contract and implicitly its economic results, the ADVERSE SELECTION problem appears.

In this situation, the Principal does not know the type of Agent and the information asymmetry appears before signing the contract, generating a loss of efficiency (a degradation of the first rank solution).

For the Principal (Decision Maker) it is optimal to propose a menu of contracts, one for each type of agent and to motivate the Agent to choose exactly the contract addressed to him.

The optimal contraction is the optimal Pareto for the efficient Agent (better placed) who will obtain an informational rent. The inefficient agent will obtain exactly the minimum reserved utility threshold and the Principal's concern will be the signing of the contract (realization of the participation restriction) only by the inefficient Agent.

Financial markets are significantly affected by asymmetry in formations. In the proposed model, the principal is a creditor (the borrower). He grants a volume x loan to the Agent. The capital costs the creditor rx, because he could have placed it elsewhere in the economy, at an interest rate r, without risk.

If t is the transfer (payment) of the debtor (debtor) to the creditor, the utility function of the Principal is written: $B(t, x) = t - rx$

The utility function of the Agent (profit) becomes:

$U(t, x) = \gamma f(x) - t$

Where:

$f(x)$ is the production obtained using x units of capital;

γ an efficiency parameter.

We will assume that the production function $f(\cdot)$ has the usual properties, namely it is strictly ascending, i.e. $f'(\cdot) > 0$ and with decreasing yields at scale, $f''(\cdot) < 0$.

In situations the contract is more complex. The agent can have more than two possible types.

Next we will consider the case where the Agent is of three types: B, M and G (inefficient, medium and efficient).

The model raises difficulties in determining the incentive and participation restrictions, which are not only technical, but also closely related to the analyzed economic problem.

In simple models, the optimal situation is obtained by intuiting which of the participation and incentive restrictions are saturated and then verifying ex post that the other remaining restrictions are satisfied by the solution of the relaxed problem.

Literature review

A number of researchers have analyzed the optimal financial contracts with several types of agents. Thus, Abdellaoui, Bleichrodt, and L'Haridon, (2008) are concerned with identifying an optimal method of measuring aversion to utility and loss according to perspective theory. Julien, Salanie, and Salanie (2007) analyzes and evaluates the risk aversion of agents under moral danger. Laffont (1995) addresses the theory of contingent markets, models incomplete market systems and defines the concept of a perfect forecast balance, covering two fundamental institutions for risk sharing: the stock market and insurance. Marin, Emanuel, and Pătrașcu (1998) write a treatise on contract theory. Marinescu, Marin, and Manafi (2012) are concerned with an adverse selection model with a finite number of types and information rents, and in 2013 they address in their paper a series of theoretical and practical problems in microeconomic level, issues of which Mas-Golell, Whinston and Green (2005) are also concerned. Game theory is approached in their paper by Roman and Manafi (2016).

Methodology, data, discussions, results

- **The model in the situation of informational symmetry**

If the Decision Maker knows the type of Agent, then the optimal contract is given by the optimal solution of the following nonlinear optimization problem:

$$\max_{(x,t)}[t - rx]$$

$s.r.$

$\gamma\, f(x) - t \geq 0$

$x \geq 0, t \geq 0$

We apply the Kuhu-Tucker multipliers method and we obtain:

$$L(x,t;\lambda) = t - rx + \lambda\,[\gamma f(x) - t]$$

The first order conditions (necessary and sufficient in this case) become:

$$\frac{\partial L}{\partial x} \leq 0,\ x \geq 0,\ x * \frac{\partial L}{\partial x} = 0$$

$$\frac{\partial L}{\partial t} \leq 0,\ t \geq 0,\ t * \frac{\partial L}{\partial t} = 0$$

$$\frac{\partial L}{\partial \lambda} \leq 0,\ \lambda \geq 0,\ \lambda * \frac{\partial L}{\partial \lambda} = 0$$

or

$$-r + \lambda\gamma f'(x) \leq 0,\ x \geq 0, x[-r + \lambda\gamma f'(x)] = 0 \qquad (1)$$

$$1 - \lambda \leq 0, t \geq 0, t(1 - \lambda) = 0 \qquad (2)$$

$$\gamma f(x) - t \geq 0, \lambda \geq 0, \lambda[\gamma f(x) - t] = 0 \qquad (3)$$

From the group of relations (2) it is observed that$\lambda > 0$ and from (3) results:

$$\gamma f(x) - t = 0 \quad (4)$$

So yes $t > 0$, where from $\lambda = 1$ and $x > 0$.

Then from (1) we obtain $-r + \gamma f'(x) = 0$ (5)

The optimal contract$(\tilde{x}, \tilde{t})$ is given by the solution of the system formed by the equations (4) and (5).

$$\begin{cases} \gamma f(x) - t = 0 \\ -r + \gamma f'(x) = 0 \end{cases}$$

where from:

$\tilde{x} = (f')^{-1} * \left(\frac{r}{\gamma}\right)$ and $\tilde{t} = \gamma f(\tilde{x})$

We customize the efficiency parameter γ in the crowd $\{\gamma^B, \gamma^M, \gamma^G\}$ with $\gamma^B < \gamma^M < \gamma^G$ and so $\frac{r}{\gamma^B} > \frac{r}{\gamma^M} > \frac{r}{\gamma^G}$.

Taking into account the monotony of the function $f'(\cdot)$ we obtain:

$$(f')^{-1} * \left(\frac{r}{\gamma^B}\right) < (f')^{-1} * \left(\frac{r}{\gamma^M}\right) < (f')^{-1} * \left(\frac{r}{\gamma^G}\right)$$

meaning:

$$\tilde{x}^B < \tilde{x}^M < \tilde{x}^G$$

The principal lends less to the type of inefficient Agent. On the contrary, the effective agent gets a bigger loan.

It is interesting to analyse the case where the Agents (types of Agents) are grouped and how the loans are granted in this case.

- **Graphic analysis of optimal contracts and economic interpretation**

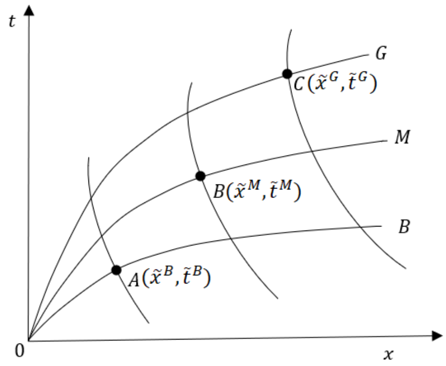
The optimal contracts (equilibrium points) are obtained at the intersection of the two curves, i.e. the objective function of the Principal (the function of profit) and the restriction of participation (saturated) of the Agent.

In the two-dimensional space x0t we will graphically represent the functions given by (4) and (5) for the three possible values of γ $(\gamma^B, \gamma^M, \gamma^G)$.

From Graph 1 and from the placement of the equilibrium points A, B, C it is observed that the efficient agent is required to transfer (higher effort).

The same cannot be said of loans. There are two opposite effects, namely: The inefficient agent, for example, will be required to have a lower level of transfer (effort) and consequently a lower credit. On the other hand, the effort for him being more 'expensive' (he obtains a lower production) he will request a higher credit. The difference is given by the bargaining power between the two participants.

Graph 1



It is also found that for the Type G Agent it is more convenient to declare type M or B, in this way he can obtain a higher loan with a lower effort (transfer).

Another characteristic of the optimal contract in the situation of informational symmetry is that of being PARETO OPTIMAL according to the equation (5).

The relation (4) shows that the Agent obtains exactly the utility threshold reserved by the market.

If the Principal has less information than the Agent, on some variables that can influence the relationship of the contract and implicitly its economic results, we will show that for the Principal it is optimal to propose a menu of contracts. The contracts must be one for each type of Agent, but he must choose and sign exactly the contract intended for him.

Adverse selection (antiselection) models show informational asymmetry before signing the contract. The agent will disclose private information to the Principal (through the chosen contract) only if it is in his interest to do so.

The principal must construct the model in such a way that the lack of information that generates a loss of efficiency (a departure from the Pareto optimum) is mitigated.

- **The case of adverse selection with several types of Agents**

The principal does not recognize the type of Agent, but believes that it is one of the three {B, M, G} with the probability Π^B, respectively Π^M or Π^G, where the positive numbers Π^B, Π^M or Π^G are so $\Pi^B + \Pi^M + \Pi^G = 1$.

The objective function for the Principal is to maximize the expected profit in relation to the menu of contracts$\{(x^B, t^B), (x^M, t^M), (x^G, t^G)\}$ namely:

$$\max_{(x^B,t^B),(x^M,t^M),(x^G,t^G)} \{ \Pi^B[t^B - r\,x^B] + \Pi^M[t^M - rx^M] + \Pi^G[t^G - rx^G]\} \quad (6)$$

The restrictions of the model, in accordance with those stated above, are of two types:

- Participation restrictions, one for each type of agent, namely:

$$\gamma^B f(x^B) - t^B \geq 0 \quad (7)$$

$$\gamma^M f(x^M) - t^M \geq 0 \tag{8}$$

$$\gamma^G f(x^G) - t^G \geq 0. \tag{9}$$

The agent will sign the contract if the transfer t is less than the gross gain $\gamma f(x)$.

- Incentive restrictions compatible with the type of Agent, through which the Principal ensures that each type of Agent chooses exactly the contract intended for him. These are of two types, as follows:
  – Local (ascending, descending);
  – Global (ascending, descending);

They are written like this:

$$\gamma^G f(x^G) - t^G \geq \gamma^G f(x^M) - t^M \tag{10}$$

$$\gamma^M f(x^M) - t^M \geq \gamma^M f(x^B) - t^B \tag{11}$$

$$\gamma^G f(x^G) - t^G \geq \gamma^G f(x^B) - t^B \tag{12}$$

$$\gamma^M f(x^M) - t^M \geq \gamma^M f(x^G) - t^G \tag{13}$$

$$\gamma^B f(x^B) - t^B \geq \gamma^B f(x^M) - t^M \tag{14}$$

$$\gamma^B f(x^B) - t^B \geq \gamma^B f(x^G) - t^G \tag{15}$$

We will rewrite the model in the informational rent variables, using the notations:

$$U^G = \gamma^G f(x^G) - t^G \geq 0$$

$$U^M = \gamma^M f(x^M) - t^M \geq 0$$

$$U^B = \gamma^B f(x^B) - t^B \geq 0$$

Objective function (6) in the new variables$x^G,\ x^M,\ x^B, U^G, U^M, U^B$ becomes:

$$\max_{x^G, x^M, x^B, U^G, U^M, U^B} \{ \Pi^G[\gamma^G f(x^G) - r x^G] + \Pi^M[\gamma^M f(x^M) - r x^M] + \Pi^B * [\gamma^B f(x^B) - r x^B] - [\Pi^G U^G + \Pi^M U^M + \Pi^B U^B]\} \tag{16}$$

Incentive restrictions in terms of information rents become:

$$U^G \geq U^M + \Delta\gamma f(x^M) \tag{17}$$

$$U^M \geq U^B + \Delta\gamma f(x^B) \tag{18}$$

$$U^G \geq U^B + 2\Delta\gamma f(x^B) \tag{19}$$

$$U^M \geq U^G - \Delta\gamma f(x^G) \tag{20}$$

$$U^B \geq U^M - \Delta\gamma f(x^M) \tag{21}$$

$$U^B \geq U^G - 2\Delta\gamma f(x^G) \tag{22}$$

Where:

$$\Delta\gamma = \gamma^G - \gamma^M = \gamma^M - \gamma^B$$

The mathematical model consists of the objective function (16) with the incentive restrictions to which are added the usual sign conditions $U^G \geq 0, U^M \geq 0, U^B \geq 0$.

In the model, only ascending constraints are relevant.

We sense that Agent M will not claim to be of type G. Likewise, Agent Type B will not claim to be of type M or G.

Proposition 1. The implementability condition is: $x^G \geq x^M \geq x^B$.

Demonstration

Indeed, adding the relations (17) and (20), respectively (18) and (21), we obtain:

$\Delta\gamma\, f(x^G) \geq \Delta\gamma f(x^M)$

and

$\Delta\gamma f(x^M) \geq \Delta\gamma f(x^B)$

meaning:

$f(x^G) \geq f(x^M) \geq f(x^B)$

As the production function f (·) is strictly increasing, it results:$x^G \geq x^M \geq x^B$.

The set of admissible solutions is empty in this case, so there is at least one contract for each type of Agent.

Moreover, if this condition is verified, then the global ascending restriction (19) is a consequence of the local ascending (17) and (18) restrictions.

Indeed from (17) and (18), if they are satisfied, we obtain:

$$U^G \geq U^M + \Delta\gamma f(x^M) \geq U^B + \Delta\gamma f(x^B) + \Delta\gamma f(x^M) \geq U^B + \Delta\gamma f(x^B) + \Delta\gamma f(x^B) =$$
$$= U^B + 2\Delta\gamma\, f(x^B)$$

Proposition 2. If the ineffective Agent's participation restriction is satisfied, then the other participation restrictions are also satisfied.

Demonstration

Using, again, the relations (17) and (18) we obtain:

$U^M \geq U^B + \Delta\gamma f(x^B) \geq U^B \geq 0$

$U^G \geq U^M + \Delta\gamma f(x^M) \geq U^M \geq 0$

In other words, the Principal is concerned only with the participation of the inefficient Agent. If he accepts the contract, then the other two types of Agents will sign the contract.

The mathematical model is simplified and becomes:

$$\max_{x^G,x^M,x^B,U^G,U^M,U^B} \{ \Pi^G[\gamma^G f(x^G) - r x^G] + \Pi^M[\gamma^M f(x^M) - r x^M] + \Pi^B[\gamma^B f(x^B) -$$
$$- r\, x^B] - [\, \Pi^G U^G + \Pi^M U^M + \Pi^B U^B]\} \quad (23)$$

s.r.

$U^G \geq U^M + \Delta\gamma f(x^M)$ (24)

$U^M \geq U^B + \Delta\gamma f(x^B)$ (25)

$U^B \geq 0$ (26)

$x^G \geq x^M \geq x^B$ (27)

Proposition 3. At the optimum point $U^B = 0$.

Demonstration

We assume that the optimal solution is: $(\bar{x}^G, \bar{x}^M, \bar{x}^B, \bar{U}^G, \bar{U}^M, \bar{U}^B)$ with $\bar{U}^B > 0$.

Whether $\varepsilon > 0$, an arbitrarily small number (so that $\bar{U}^B - \varepsilon \geq 0$).

We rewrite the restrictions of the problem, namely:

$\bar{U}^G - \varepsilon \geq \bar{U}^M - \varepsilon + \Delta\gamma f(\bar{x}^M)$

$\bar{U}^M - \varepsilon \geq \bar{U}^B - \varepsilon + \Delta\gamma f(\bar{x}^B)$

$\bar{U}^B - \varepsilon \geq 0$

We can say that the crowd: $(\bar{x}^G, \bar{x}^M, \bar{x}^B, \bar{U}^G - \varepsilon, \bar{U}^M - \varepsilon, \bar{U}^B - \varepsilon)$, it is at least an admissible solution.

For this solution, the value of the objective function becomes:

$$\Pi^G * [\gamma^G f(\bar{x}^G) - r\bar{x}^G] + \Pi^M * [\gamma^M f(\bar{x}^M) - r\bar{x}^M] + \Pi^B * [\gamma^B f(\bar{x}^B) - r\bar{x}^B] -$$
$$-[\Pi^G \bar{U}^G + \Pi^M \bar{U}^M + \Pi^B \bar{U}^B] + \varepsilon,$$

strictly higher than the value for the optimal solution$(\bar{x}^G, \bar{x}^M, \bar{x}^B, \bar{U}^G, \bar{U}^M, \bar{U}^B)$ which is a contradiction, therefore $U^B = 0$ (at the optimum point).

Restrictions are simplified and become:

$U^G \geq U^M + \Delta\gamma f(x^M)$

$U^M \geq \Delta\gamma f(x^B)$

Proposition 4. At the optimum point $U^M \geq \Delta\gamma f(x^B)$.

Demonstration

We assume that at the optimum point we have $U^M > \Delta\gamma f(x^B)$. Whether $\varepsilon > 0$, small enough and arbitrarily chosen so that $U^M - \varepsilon \geq \Delta\gamma f(x^B)$.

How the first restriction can be written: $U^G - \varepsilon \geq U^M - \varepsilon + \Delta\gamma f(x^M)$ we can say that the solution $(x^G, x^M, x^B, U^G - \varepsilon, U^M - \varepsilon, 0)$ it is an admissible solution.

If we note withF_{max}, the optimal value of the objective function (maximum profit of the Principal) then, calculating the value of the objective function for the above admissible solution, we obtain:

$F_{max} + (\Pi^G + \Pi^M)\varepsilon > F'_{max}$, in contradiction with the definition of the optimal contract.

Consequently, we have: $U^M = \Delta\gamma f(x^B)$.

Similarly, using the perturbation technique, as above, we obtain that the first restriction is saturated, i.e.:

$U^G = \Delta\gamma[f(x^B) + f(x^M)]$.

Taking into account the above and relinquishing the restriction $x^G \geq x^M \geq x^B$ (will be checked in the end) the mathematical model is reduced to maximizing a function of three variables:

$F(x^G, x^M, x^B)$

Where:

$$F(x^G, x^M, x^B) = \Pi^G[\gamma^G f(x^G) - rx^G] + \Pi^M[\gamma^M f(x^M) - rx^M] + \Pi^B[\gamma^B f(x^B) - rx^B] - \Pi^G\Delta\gamma[f(x^B) + f(x^M)] - \Pi^M\Delta\gamma f(x^B)$$

It is found that $U^B = 0$ and $U^M = \Delta\gamma f(x^B)$ check relationships (20), (21) and (22) initially omitted from the restriction system.

As we intuited above most likely a Type B Agent will never claim to be type M or G, just as the Type M Agent will never claim to be type G.

Conversely, an efficient agent can be declared inefficient because in this way its usefulness increases. With less effort he would get a bigger reward. The optimal contract in the situation of asymmetric information (optimal solution of rank II) is obtained by cancelling the partial derivatives of the first order of the function $F'(x^G, x^M, x^B)$.

We have:

$$\frac{\partial F}{\partial x^G} = \Pi^G[\gamma^G f'(x^G) - r] = 0$$

Where from:

$$f'(x^G) = \frac{r}{\gamma^G} \text{ or } x^G_{opt} = (f')^{-1}\left(\frac{r}{\gamma^G}\right) = (\tilde{x}^G) \quad (28)$$

$$\frac{\partial F}{\partial x^M} = \Pi^M\left[\gamma^M f'^{(x^M)} - r\right] - \Pi^G\Delta\gamma f'(x^M) = 0$$

Or:

$$f'(x^M)[\Pi^M\gamma^M - \Pi^G\Delta\gamma] = \Pi^M r$$

$$f'(x^M) = \frac{\Pi^M r}{\Pi^M\gamma^M - \Pi^G\Delta\gamma} > \frac{\Pi^M r}{\Pi^M\gamma^M} = \frac{r}{\gamma^M} = f'(\tilde{x}^M) \quad (29)$$

$$x^M_{opt} = (f')^{-1}\left(\frac{\Pi^M r}{\Pi^M\gamma^M - \Pi^G\Delta\gamma}\right) \text{ and } x^M_{opt} < \tilde{x}^M \quad (30)$$

According to the concavity of the function$f(\cdot)$:

$$\frac{\partial F}{\partial x^B} = \Pi^B[\gamma^B f'(x^B) - r] - \Pi^G \Delta\gamma f'(x^B) - \Pi^M \Delta\gamma f'(x^B) = 0$$

Or:

$$f'(x^B)[\ \Pi^B\gamma^B - \Pi^M\Delta\gamma - \Pi^G\Delta\gamma] = \Pi^B r$$

$$f'(x^B) = \frac{\Pi^B r}{\Pi^B\gamma^B - \Pi^M\Delta\gamma - \Pi^G\Delta\gamma} > \frac{r}{\gamma^B} = f'(\tilde{x}^B)$$

Then:

$$x^B_{opt} = (f')^{-1}\left(\frac{\Pi^B r}{\Pi^B\gamma^B - \Pi^M\Delta\gamma - \Pi^G\Delta\gamma}\right) \text{ and } x^B_{opt} < \tilde{x}^B \quad (31)$$

Taking into account the sentences (3) and (4) and the relations (28), (29) and (31) the optimal contract of rank II: $\{(x^G_{opt},\ t^G_{opt}), (x^M_{opt}, t^M_{opt}), (x^B_{opt}, t^B_{opt})\}$ it is written:

$$x^G_{opt} = (f')^{-1}\left(\frac{r}{\gamma^G}\right),\ t^G_{opt} = \gamma^G f(x^G_{opt}) - \Delta\gamma[f(x^M_{opt}) + f(x^B_{opt})]$$

$$x^M_{opt} = (f')^{-1}\left(\frac{\Pi^M r}{\Pi^M\gamma^M - \Pi^G\Delta\gamma}\right),\ t^M_{opt} = \gamma^M f(x^M_{opt}) - \Delta\gamma f(x^B_{opt})$$

$$x^B_{opt} = (f')^{-1}\left(\frac{\Pi^B r}{\Pi^B\gamma^B - \Pi^M\Delta\gamma - \Pi^G\Delta\gamma}\right), t^B_{opt} = \gamma^B f(x^B_{opt})$$

Conclusions

The above results can be summarized in the following theorem:

Theorem 1: In an asymmetric information situation, the optimal financial contract with several types of Agents has the following characteristics:

- It is Pareto-optimal (Pareto efficient) for the more efficient, better placed Agent (relation 28).
- For Agents, the rewards are lower than those in the symmetric information situation (relationships 30 and 31).
- Regarding the effort (transfer) it is not possible to specify an inequality relationship between t^G_{opt}, x^M_{opt} and x^B_{opt}.
- Finally we have to check the double inequality$t^G_{opt} \geq x^M_{opt} \geq x^B_{opt}$ which I did not take into account initially, when obtaining the reduced problem.

Case Study

We will consider the particular case in which the production function with decreasing yields is$f(x) = \sqrt{x}$ and the other parameters are: $r = 2\%$, $\gamma^B = 2$, $\gamma^M = 2{,}4$, $\gamma^G = 2{,}8$ so $\Delta\gamma = 0{,}4$. We will also assume that the three types of agents are equiprobable, i.e. $\Pi^G = \Pi^M = \Pi^B = \frac{1}{3}$

The optimal contract in the situation of symmetrical information is obtained according to the relations (4) and (5)6 solving the system:

$$\begin{cases} \gamma f(x) - t = 0 \\ -r + \gamma f'(x) = 0 \end{cases} \quad \text{or} \quad \begin{cases} \gamma\sqrt{x} = t \\ \frac{\gamma}{2\sqrt{x}} = r \end{cases}$$

Where from:

$$\begin{cases} t = \gamma\sqrt{x} \\ x = \frac{\gamma^2}{4r^2} \end{cases}$$

We customize for each type of Agent and we get:

$$For\ B\colon (\tilde{x}^B, \tilde{t}^B) = \left(\frac{1}{0{,}02^2}, 2\sqrt{\frac{1}{0{,}02^2}}\right) = (2500, 100).$$

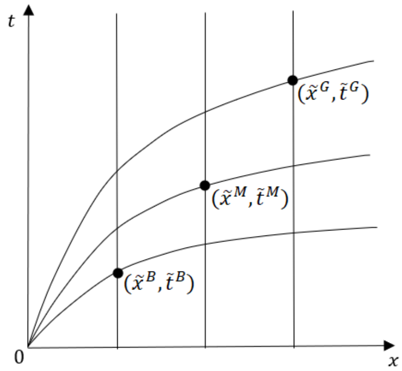
$$For\ M\colon (\tilde{x}^M, \tilde{t}^M) = (3600, 144).$$

$$For\ G\colon (\tilde{x}^G, \tilde{t}^G) = (7000, 168).$$

It is observed that $\tilde{x}^B < \tilde{x}^M < \tilde{x}^G$. And in terms of effort, inequality is maintained depending on the type of Agent: $\tilde{t}^B < \tilde{t}^M < \tilde{t}^G$.

Graphically, the solution can be obtained by intersecting the two curves $x = \frac{\gamma^2}{4r^2}$ and $t = \gamma\sqrt{x}$, for each type of Agent, with the *x*0*t* plan.

Graph 2



In the situation of asymmetric information, the optimal contract for each type of Agent is obtained using the relationships (28), (30) and (31).

For:

$f'(x^B_{opt}) = \frac{\Pi^B r}{\Pi^B\gamma^B - \Pi^M\Delta\gamma - \Pi^G\Delta\gamma} = \frac{r}{\gamma^B - 2\Delta\gamma} = \frac{1}{60}$, where from:

$$x^B_{opt} = 900$$

$$t^B_{opt} = \gamma^B f(x^B_{opt}) = 2\sqrt{x^B_{opt}} = 60$$

So the optimal contract for B is: $(x_{opt}^{B}, t_{opt}^{B}) = (900, 60)$

For M:

$f'(x_{opt}^{M}) = \frac{\Pi^{M} r}{\Pi^{M}\gamma^{M} - \Pi^{G}\Delta\gamma} = \frac{1}{100}$, where from:

$x_{opt}^{M} = 2500$

$t_{opt}^{M} = \gamma^{M} f(x_{opt}^{M}) - \Delta\gamma f(x_{opt}^{B}) = \gamma^{M}\sqrt{x_{opt}^{M}} - \Delta\gamma\sqrt{x_{opt}^{B}} = 112$

So the optimal contract for M is: $(x_{opt}^{M}, t_{opt}^{M}) = (2500, 112)$

For:

$f'(x_{opt}^{G}) = \frac{r}{\gamma^{G}}$, where from:

$x_{opt}^{G} = 7000$

$t_{opt}^{G} = \gamma^{G} f(x_{opt}^{G}) - \Delta\gamma[f(x_{opt}^{M}) + f(x_{opt}^{B})] = 392$

So the optimal contract for G: $(x_{opt}^{G}, t_{opt}^{G}) = (7000, 392)$

The optimal contract is also PARETO – optimal only for the efficient Agent.

For the others, there is a loss of efficiency influenced by the type of Agent and by the (subjective) probabilities associated by the Principal to each type of Agent.

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