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Experimental investigation »

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Managerial incentives under competitive pressure: Experimental investigation

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Abstract

We investigate the effects of competition on managerial incentives and effort in a laboratory experiment. Each owner offers compensation to his manager in two different contexts: monopoly and Cournot duopoly. After accepting the compensation, the manager chooses an effort level to increase the probability of reduced costs of his firm. Theory predicts that the entry of a rival firm in a monopolistic industry affects negatively both the incentive compensation and the effort level. Our experimental findings confirm that the entry of a rival firm reduces the incentive compensation but not the manager's effort level. However, despite the reduction of the incentive compensation, the manager continues to accept the contract offers and exert the same level of effort.

JEL Classification: M52, J33, A13, C91, D82

Keywords: Managerial Incentives, Effort, Competition, Moral hazard, Experiments

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1. Introduction

The relation between a firm's competitive environment and his internal incentives is still unclear. Some papers showed that in a competitive market firms might distort the incentives of their managers in order to affect product market competition (Fershtman and Judd (1987) and Skilvas (1987)). The firm can therefore use managerial incentives to guide the behavior of his manager on the market. In this respect, managerial incentives are important strategic instruments that enable firms to influence market competition. But just the reverse logic may hold: product market competition may affect firm's internal incentives. The issue of optimum incentives in a context of competing firms has been addressed parsimoniously both by the theoretical and the empirical literature. Since the seminal papers by Hart (1983) and Holmstrom (1982), an abundant theoretical literature on optimum incentives has developed. The large bulk of this literature concentrates on optimum incentives schemes in an "isolated firm" (see Gibbons (1998) and Prendergast (1999) for reviews). Few papers address the issue of how a firm's owner should design the contract for his manager to account efficiently for competition by rival firms.

The main difficulty, both from a theoretical and empirical point of view, is that competition affects at the same time the firm's profit, the incentives provided to the manager and the manager's effort. Competition can affect directly each of these variables, and since they are related, any direct impact on one of them, indirectly affects the others. For instance, suppose that managers react directly by increasing their effort. Their reaction will feed back on the firm's profit and therefore on the manager's incentives. Suppose that competition affects directly the firm's profit. Expecting that, the owner will provide higher or lower incentives to his manager who will adjust her level of effort. Because of that, an increase in product market competition has actually an ambiguous effect on managerial incentives. On the one hand, under harsher competition, profit expectations are lower, and firm owners might be tempted to offer smaller bonuses to their managers. On the other hand, as competition becomes fiercer, firm owners may be encouraged to offer larger bonuses to successful managers because successful cost-reductions for instance, increase the firm's market share and the owner's profits. The theoretical literature clearly favors the first scenario (Martin (1993), Horn et al., (1994), Schmidt (1997)). However Raith (2003) showed

that the second scenario can arise under plausible hypotheses. Empirical evidence is very parsimonious and disputable.

The few papers which dealt with the relation between incentives and competition investigated three main issues: (i) the change in information structure induced by increased competitive pressure, (ii) the impact on the manager's effort choice, (iii) the impact on the incentive schemes.

(i) Holmstrom (1982), Hart (1983), Nalebuff and Stiglitz (1983), Scharfstein (1988) and Hermalin (1992) rely on the fact that competition modifies the principal's information structure about managerial effort. The principal can therefore take into account the additional information to design the incentives scheme offered to the manager. However, increased competition has an ambiguous effect and depends crucially on the managers' utility function. If the manager is infinitely risk-averse (Hart, 1983), he provides more effort under harsher competition, allowing the principal to exert any level of effort at reduced cost. Competition is therefore a substitute to the incentives. However, under the more realistic assumption of bounded risk-aversion (Scharfstein, 1988) competition will increase the cost of exerting effort from the manager.

(ii) Competition has a direct impact on managers' effort choice (Hermalin (1992), Schmidt (1997)) because of the threat of losing the bonus, or worse, being fired. The effect is non-ambiguous: managers react to increased competition by raising their effort level in order to prevent bad performance.

Competition affects indirectly the incentives provided by the firm's owner depending on the impact on the firm's profit (Hermalin (1992), Martin (1993), Horn et al. (1994), Schmidt (1997), Raith (2003), Baggs and Bettignies (2007)). The principal increases (lowers) the incentives if the profit raises (falls) and the manager adjust her effort accordingly. However, as shown in Raith (2003), the alteration of the competitive environment affects the industry equilibrium as a whole, since the number of firms, the cost structure and the effort levels are affected.

Several empirical papers deal with the issue. In their seminal paper Jensen and Meckling (1976) found only a weak correlation between the manager's compensation scheme and the

firm's performance. Accordingly, since owners' contract offers to their manager are independent of the firm's performance, competitive pressure should not be an issue. However, Hall and Liebman (1998) found a strong and positive correlation between firms' performance and managers' compensation. A few papers (Nickell (1996), Beiner et al. (2009), Baggs et al. (2007)) studied the effect of competition. These papers focused on the impact on incentives, productivity and agency costs. Their main findings can be summarized as follows: increasing competition on the product market has a positive effect on employees' productivity (Nickell, 1996), on managers' incentives (Beiner et al., 2009) and a negative effect on agency costs (Jagannathan and Srinivasan, 1999). While these findings contrast with the theoretical predictions, there are several important methodological issues that preclude a credible conclusion. In particular it is difficult to observe and measure meaningfully a change in competitive pressure or in the level of effort of the managers. Even if the variation of competitive pressure could be isolated, the data on incentives and efforts, are usually concealed, in particular because we consider the theoretical case where effort is not observable!

In order to overcome the above limitations, it is useful to rely on experimental methods which can produce the data that are relevant for the analysis. In this paper, we set up a controlled environment which allows us to observe precisely and without ambiguity the effects of a change in the competitive environment on owners contract offers and on managers' effort choices. We compare a monopoly situation to a duopoly situation. The monopoly was chosen because it corresponds to the standard theoretical case where the incentives do not depend on the competitive environment. We compare the monopolistic firm to a Cournot duopoly, based on a simple model from which we derive non-ambiguous predictions. Managers can choose a level of effort which determines the probability of a cost-reducing innovation. The model predicts that increased competition lowers the firm's incentives and the managers' level of effort.

We designed a within-subject experiment to study the effect of increased competition. In a first sequence the firm has no rival and we can therefore observe the incentives and the manager effort choice without competition. In a second sequence a second firm enters into the market. We can therefore observe how principals react by adjusting their incentives and consequently how agents adjust their effort. We control for order effects by running a

second treatment where the ordering of sequences is reversed. Our main findings are as follows: duopoly firms offer lower incentives than monopolistic firms, but managers accept the contract offers and maintain their effort level despite the reduced incentives. Furthermore, managers tend to choose effort levels that induce an equal split of the expected surplus of the contract offer.

The remainder of the paper is organized as follows. Section 2 presents the theoretical predictions. Section 3 describes the experimental procedure. Section 4 contains the results. The first part of Section 4 analyses the principals' contract offers. In the second part of Section 4, we analyse in detail the agents' decisions. Section 5 gives a summary.

2. Theoretical background

In this section we provide a theoretical background that will be useful for framing the design of our experiment. We introduce a simple model that allows us to compare managerial incentives under monopolistic and competitive market structures. We restrict the analysis to the comparison of such incentives between a monopolistic firm and a Cournot duopoly on the product market. We first introduce the timing of the game for the duopoly case, before discussing the outcomes for the monopoly and the duopoly case.

Assumptions

Consider a market with 2 firms, i and j , producing a homogenous product and facing a linear demand function, $p(Q) = a - Q$ where $Q = q_i + q_j$. The number of active firms in the market is either one (monopoly) or two (duopoly). Each firm is an agency that is composed of a single principal (the owner) and a single agent (the manager). The manager's effort affects the firm's marginal cost. We assume that for each firm, it can take one of two values: c_l (low) or c_h (high), with $0 < c_l < c_h$. Initially, each firm faces the high cost level, c_h . Managers can decide to make costly efforts that increase the probability of a successful innovation that reduces the firm's marginal cost. The chosen effort is not observable by the principal.

We assume that agents and principals are both risk-neutral. Principals maximize their expected profit by offering a compensation scheme (w_l, w_h) to their agent, where w_l is the agent's compensation if the cost is low and w_h his compensation if the cost is high. Given

that the compensation scheme is accepted agents choose a costly effort level that increases the probability that the cost is low. Principal i 's ex post payoff is $U_{is}^P = \Pi_{is} - w_{is}$, where Π_{is} is the profit realized by firm i in state $s = h, l$ while w_{is} is the corresponding transfer to the agent defined by the compensation scheme. The agent's ex post utility function is additively separable and depends on his monetary payment, w , and on the cost of effort : $U^A = w_{is} - C(e)$. We assume $C(e) \equiv C(p) = \frac{\gamma}{2}e^2$, that is choosing a level of effort is identical to choosing a probability of success of a cost reducing innovation (i.e. that the marginal cost is low).

2.1 Timing of the game

The timing of the game involves 4 successive stages, as follows:

Stage 1: each principal announces privately a compensation scheme (w_l, w_h) to her agent, where $w_l - w_h$ is the bonus in case of successful cost-reducing innovation.

Stage 2: each agent decides whether to accept or reject the proposed compensation scheme. In case of a rejection, the game is over and both the agent and the principal earn zero. If he accepts the compensation scheme, the agent moves to stage 3.

Stage 3: The agent chooses the probability $p \in [0,1[$ that the firm's marginal cost be reduced, with a cost of effort $C(p) = \frac{\gamma}{2}p^2$.

Stage 4: the innovation success is determined stochastically according to the probability chosen by the agent in stage 3: with probability p the cost will be low. The realized marginal costs become common knowledge and firms compete "à la Cournot" on the product market.

2.2 Monopoly payoffs

Since the monopolistic firm faces the whole market demand, it's profit is given by:

$\Pi = (a - q - c)q$, where $c \in \{c_l, c_h\}$ and $q \geq 0$ is output. The monopoly profit is maximized

at output $q(c) = \frac{a-c}{2}$, which yields a profit $\Pi(c) = \left(\frac{a-c}{2}\right)^2$. The monopoly profit is then given

by $\Pi_h = \left(\frac{a-c_h}{2}\right)^2$ if the cost is high and $\Pi_l = \left(\frac{a-c_l}{2}\right)^2$ if the cost is low. It will be useful to

define $\Delta\Pi = \Pi_l - \Pi_h$ the expected surplus that the monopoly can realize if its marginal cost is reduced.

Assumption 1. $\gamma > \frac{1}{2}\Delta\Pi$.

Assumption 1 ensures that the level of effort under monopoly is strictly inferior to 1. The principal chooses a dual option (p, w) , $w = (w_l, w_h)$, which solves:

$$\max_{(p,w)} E(\Pi_i) = p(\Pi_l - w_l) + (1 - p)(\Pi_h - w_h) \quad (1)$$

subject to:

$$p \in \arg \max_{\hat{p} \in [0,1]} \hat{p}w_l + (1 - \hat{p})w_h - C(\hat{p}) \quad (\text{IC})$$

$$pw_l + (1 - p)w_h - C(p) \geq 0 \quad (\text{IR})$$

$$w_u \geq 0, \text{ for } u = l, h \quad (\text{WC})$$

IC, IR and WC are the incentive compatibility constraint, the individual rationality constraint and the wealth constraint respectively. As usual, the active constraints at the optimum solution are (IC) and (WC), so that the optimal contract that solves the above second best problem in the monopoly case is given by:

$$\begin{cases} w_l^M = C'(p^M) = \frac{\Delta\Pi}{2} \\ w_h^M = 0 \\ p^M = \frac{w_l^M}{\gamma} = \frac{\Delta\Pi}{2\gamma} \end{cases} \quad (2)$$

In the monopoly firm, the principal offers no compensation if the marginal cost is high, but if the marginal cost is low, he offers a bonus that increases with the expected surplus of the cost-reduction¹. Assumption 1 guarantees that the level of effort (p) chosen by the agent in the monopoly case is strictly lower than 1.

2.3 Duopoly payoffs

Assume now that there are two (initially symmetric) firms, identified by i and j . Under Cournot competition the profit of firm is given by: $\Pi_i = (a - Q - c_i)q_i$. Equilibrium outputs and profits are $q_i(c_i, c_j) = \frac{1}{3}(a - 2c_i + c_j)$, and $\Pi_i(c_i, c_j) = \frac{1}{9}(a - 2c_i + c_j)^2$, for $c_i, c_j \in \{c_l, c_h\}$, and symmetrically for firm j . Firm i 's profit is then given by $\Pi_{hh} = \frac{1}{9}(a - c_h)^2$ if both cost are high, $\Pi_{ll} = \frac{1}{9}(a - c_l)^2$ if both cost are low, $\Pi_{hl} = \frac{1}{9}(a - 2c_h + c_l)^2$ if cost of firm i is

¹ Schmidt (1997) analyzes a model where the manager supports a cost of work investigation, L , if the firm is liquidated with a probability l . He shows that the manager obtains zero compensation when marginal cost is high and $C'(p) - lL$ when marginal cost is low. If the cost of search for the work is equal to zero in the Schmidt's model, the result is the same.

high and cost of firm j is low and $\Pi_{lh} = \frac{1}{9}(a - 2c_l + c_h)^2$ if cost of firm i is low and cost of firm j is high.

Principal i selects a dual option (p_i, w_i) , $w_i = (w_l^i, w_h^i)$, which solves:

$$\max_{(p,w)} E(\Pi^i) = p^j [p^i(\Pi_{ll} - w_l^i) + (1 - p^i)(\Pi_{hl} - w_h^i)] + (1 - p^j) [p^i(\Pi_{lh} - w_l^i) + (1 - p^i)(\Pi_{hh} - w_h^i)] \quad (3)$$

subject to:

$$p^i \in \max_{\hat{p}^i \in [0,1]} [\hat{p}^i w_l^i + (1 - \hat{p}^i) w_h^i - C(\hat{p}^i)] \quad (IC_i)$$

$$p^i w_l^i + (1 - p^i) w_h^i - C(p^i) \geq 0 \quad (RC_i)$$

$$w_u^i \geq 0, \text{ pour } u = l, h \quad (WC_i)$$

The optimal contract solving the second best problem in the duopoly case is given by:

$$\begin{cases} w_h^D = 0 \\ w_l^D = C'(p^i) = \frac{\gamma(\Pi_{lh} - \Pi_{hh})}{2\gamma - (\Pi_{ll} - \Pi_{hl} - \Pi_{lh} + \Pi_{hh})} \\ p^D = \frac{w_l^D}{\gamma} = \frac{\Pi_{lh} - \Pi_{hh}}{2\gamma - (\Pi_{ll} - \Pi_{hl} - \Pi_{lh} + \Pi_{hh})} \end{cases} \quad (4)$$

According to (4) the optimal compensation schemes of the duopoly and the monopoly firms are identical: the compensation is equal to zero under high cost and equal to the marginal cost of effort if the effort successfully reduces the firm's cost. By assumption 1 the level of effort of the agent in the duopoly case is strictly lower than 1. Note that uniqueness of the optimum contract is an immediate consequence of the convexity of the cost-function. Hermalin (1994) showed that if the cost function is linear $C(p) = pw_l + (1 - p)w_h$ at asymmetric equilibria may obtain. In the duopoly case at equilibrium one of the owners proposes stronger incentives to his manager than the rival owner. Such a possibility is ruled out in our case because $C(p)$ is convex. The unique Nash equilibrium is a symmetric equilibrium, where the two principals offer the same contract to their agent and where both agents choose the same level of effort.

2.4 Monopoly vs. duopoly

In this section we compare the optimum level of effort provided by agents under monopoly and duopoly when the principal chooses the optimum compensation scheme. Under which conditions will agents exert more effort when agencies compete with each other, i.e. in the duopoly case?

Let p^M and p^D be the equilibrium efforts under monopoly and duopoly respectively, and assume that assumption 1 is satisfied. We have:

$$p^M = \frac{\Delta\Pi}{2\gamma}$$

$$p^D = \frac{\Pi_{lh} - \Pi_{hh}}{2\gamma - (\Pi_{ll} - \Pi_{lh} - \Pi_{hl} + \Pi_{hh})}$$

$p^M > p^D$ if:

$$\frac{\Delta\Pi}{2\gamma} \geq \frac{\Pi_{lh} - \Pi_{hh}}{2\gamma - (\Pi_{ll} - \Pi_{lh} - \Pi_{hl} + \Pi_{hh})} \quad (5)$$

The managerial incentives and the manager's effort increase in the duopoly case – compared to the monopoly case - if the following conditions are satisfied:

1. $\Delta\Pi < \Pi_{lh} - \Pi_{hh}$, (6)
2. $\gamma \geq \frac{\Delta\Pi (\Pi_{ll} - \Pi_{lh} - \Pi_{hl} + \Pi_{hh})}{2 (\Delta\Pi - (\Pi_{lh} - \Pi_{hh}))}$ (7)

These conditions ensure that the equilibrium effort in the duopoly case exceeds the equilibrium effort in the monopoly case. This may happen in two situations. The first one is when $\Delta\Pi \geq \Pi_{lh} - \Pi_{hh}$: the entry of an inefficient firm (high cost) reduces the gain of a cost reduction. Therefore, the competing firms have less incentive to reduce their production costs. Consequently, they offer lower incentives to their managers who exert a lower level of effort. In the second situation $\Delta\Pi < \Pi_{lh} - \Pi_{hh}$: the entry of an inefficient firm (high cost) increases the gain of a cost reduction. In this case, the firm will offer stronger incentives if and only if the marginal cost of the effort grows at sufficiently rate $(C''(p^i) = \gamma \geq \frac{\Delta\Pi (\Pi_{ll} - \Pi_{lh} - \Pi_{hl} + \Pi_{hh})}{2 (\Delta\Pi - (\Pi_{lh} - \Pi_{hh}))})$. If this condition is not satisfied, firms are better off by proposing low incentives which will lead the manager to exert low effort. On the other hand if there is a strong increase of the marginal cost of effort, the owner's implementation cost of effort becomes larger both under monopoly and duopoly. The entry of low-cost firm always reduces the gain of a cost reduction ($\Delta\Pi \geq \Pi_{ll} - \Pi_{hl}$). Therefore the owner of the monopoly offers stronger incentives to his manager than duopoly owners. The reason is simple: Cournot competition reduces the output and consequently the gain of a cost reduction. Owners are therefore less inclined to propose high compensation for a cost reducing effort and consequently managers' efforts are weaker. As a result increased competition (in the form of duopoly vs. monopoly) has a negative effect on the manager incentives and on the effort level.

3. Experimental Design

The main purpose of our experiment was to test the above prediction, by comparing a monopoly situation to a duopoly situation, on the basis of a within subject analysis. We set a parametric version of the above model, for which we introduced additional simplifications in order to focus exclusively on incentive schemes and effort choices. Before presenting the predictions of the parametric version of our model, we outline the general feature of the experimental design.

3.1 General features

The experiment was organized in the experimental laboratory of LEEM, Montpellier, France². In each session, 20 student-subjects were randomly assigned either to the role of a principal (player X in the instructions) or an agent (player Y). Participants were privately informed about their assignment which was kept constant over the whole session. No subject participated in more than one session. In total 240 students participated in the experiment (12 sessions \times 20 subjects). All participants were involved both in the monopoly game and the duopoly game. Each session consisted therefore of two main sequences: in one of the sequences, participants played the monopoly game for 10 rounds and in the other sequence they played the duopoly game for 10 rounds. To control for ordering effects that could be induced by the introduction of the withdrawal of the competitive pressure, we ran two different treatments: the Monopoly-Duopoly treatment (MD thereafter) and the Duopoly-Monopoly treatment (DM thereafter). We organized six sessions per treatment. In treatment MD, after the practice rounds, subjects started the monopoly sequence followed by the duopoly sequence. In the DM treatment the order of the sequences was reversed. Specific instructions were provided at the beginning of each sequence. Furthermore, subjects have to answer a short questionnaire that allowed us to check their understanding of the rules of the game. After the first sequence, there was a short break during which the instructions for the next sequence were distributed (see the Appendix). Subjects could not communicate with each other during the break distributed.

Each treatment was preceded by a practice sequence. Because the duopoly game is much more complex than the monopoly game, we introduced the same practice sequence which consisted of 5 monopoly rounds in both treatments. This allowed us to check whether

² The computer program was realized by Dimitri Dubois.

subjects had the same familiarity with the decision tasks in both treatments, and started the real game with the same understanding of the game. The practice rounds also allow to control for learning effects which could be very different according to treatments (Kagel and Roth, 1995). Indeed, by omitting the preliminary sequence, subjects assigned to the MD treatment could more easily learn that those assigned to the DM treatment.

Table 1: Experimental design

<i>Treatment</i>	First sequence	Second sequence	Third sequence
<i>Treatment MD</i>	Training (5 periods)	Monopoly (10 periods)	Duopoly (10 periods)
<i>Treatment DM</i>		Duopoly (10 periods)	Monopoly (10 periods)

At the beginning of each round, each subject in the role of a principal was randomly matched with an agent. In each round of the duopoly sequence, each randomly formed player pair (a principal and an agent) was randomly matched with another pair (a principal and an agent). At the end of each round, new principal-agent pairs were randomly formed, and each such pair was randomly assigned to another pair. In the monopoly sequences, there was no interaction between the different pairs. Interaction was restricted to the principal and the agent of the same pair. Costs, payoffs, and outcomes were measured in ECU (experimental currency units). At the end of the experiment, each subject was paid in cash according to his cumulative payoff for one of the two sequences selected randomly (practice rounds were not paid out).

In each round, the principal could either be in a good state (“Green State” in the instructions) or in a bad state (“Blue State” in the instructions). As in the model, each round was divided into four stages:

In stage 1, the principal offered a contract to his agent for the current round. To simplify the principal’s task, the contract offer only determined the agent’s payment (w) for the “good state”. The principal could choose any contract offer ranging from 6 to 108 ECUs, with increments of 6 units: $w \in \{6, 12, 18, \dots, 102, 108\}$. Contract offers within a player pair where common knowledge only to the player pair.

In stage 2, the agent had to decide whether to accept or to reject the contract offer. In case of a rejection the agent’s payoff is zero and the principal is in the “bad state”.

In stage 3 the agent who accepted the contract offer had to choose the probability p that the “good state” obtains for the pair. The possible values for p ranged from 9% to 99% by increments of 9%, i.e. $p \in \{9\%, 18\%, 27\%, \dots, 90\%, 99\%\}$. The value of p chosen by the agent was not observable to the principal. To each possible value of p corresponds a cost of effort for the agent which is given in table 2. In the fourth stage players were informed about the realized state (for each player in the duopoly case) and the realized individual payoff of each member of their pair. Furthermore, at the end of each round, subjects received the following summary data: the principal’s contract offer, the agent’s acceptance decision, the realized state for the pair and the realized payoffs. Note that in the duopoly sequence the principal was also informed about the state realized for the rival pair.

Table 2: The cost associated with each value of p

p (%)	9	18	27	36	45	54	63	72	81	90	99
$C(p)$ (ECU)	0,2	1	2,2	3,9	6,1	8,7	11,9	15,6	19,7	24,3	29,4

3.2 Parametric setting

We set the following parameters in the experiment: $P(Q) = 100 - Q$, $c_h = 88$, $c_l = 76$. We chose $\gamma = 60$, so that the cost of effort function is $C(p) = 30p^2$. The monopoly profit is $\Pi_h = 36$ in the “bad state” (high cost) and $\Pi_l = 144$ if the “good state” (low cost). With these parametric settings the optimum compensation scheme offered by the principal in the monopoly case is $(w_l = 54, w_h = 0)$, and the optimum level of effort chosen by the agent is $p^M = 90\%$. Given the optimum compensation scheme, the agent earns zero if he rejects the offer. If he accepts the contract offer, his payoff depends on the realized state for his player pair. He earns $w - C(p)$ in the “good state” and $-C(p)$ in the “bad state”. Table 3 summarizes the various possible cases.

Table 3: Agent’s and Principal’s payoffs under monopoly

<i>State</i>	Agent payoff in case of refusal	Agent payoff in case of acceptance	Payoff of the principal
<i>Good</i>	0	$w - C(p)$	$144 - w$
<i>Bad</i>	0	$-C(p)$	36

The principal’s payoff depends on the sequence. In a monopoly round, he earns $144 - w$ in the “good state” and 36 in the “bad state”. In a duopoly round, principals’ profits depend not only on the state of their own pair, but also on the state of the rival pair. Table 4 summarizes the payoffs of the principal and the agent for each competing player pair identified as pair 1

(P1) or pair 2 (P2). While the agents' payoffs are the same as in the monopoly case, the principals payoffs depend on whether both firms are in the same state or not. We need to consider 4 possibilities: i) both firms are in the "bad state": each one has a profit equal to $\Pi_{hh} = 16$, ii) f both firms are in the "good state": each one makes a profit of $\Pi_{ll} = 64$. One firm is in the "good state" and her opponent if in the "bad state": the profit of the low-cost firm is $\Pi_{lh} = 144$. Finally if the opposite situation, the high-cost firm's profit is $\Pi_{hl} = 0$ when her rival has a low cost. The optimum duopoly compensation scheme offered by each principal is $(w_l = 42, w_h = 0)$, and the optimum effort level chosen by each agent is $p^D = 70\%$. Therefore, our model predicts that the entry of a new firm on the market reduces the incentives proposed by the owner to his manager who adjust her level of effort towards a lower level.

Table 4: Possible payoff in duopoly in the event of acceptance of the contracts

<i>State</i>		<i>Payoff of principal</i>		<i>Payoff of the agents</i>	
<i>P1</i>	<i>P2</i>	<i>Principal of P1</i>	<i>Principal of P2</i>	<i>Agent of P1</i>	<i>Agent of P2</i>
<i>Good</i>	<i>Good</i>	$64 - w_1$	$64 - w_2$	$w_1 - C(p_1)$	$w_2 - C(p_2)$
<i>Good</i>	<i>Bad</i>	$144 - w_1$	0	$w_1 - C(p_1)$	$-C(p_2)$
<i>Bad</i>	<i>Good</i>	0	$144 - w_2$	$-C(p_1)$	$w_2 - C(p_2)$
<i>Bad</i>	<i>Bad</i>	16	16	$-C(p_1)$	$-C(p_2)$

4. Experimental Results

In this section we present and discuss our main findings. All of our statistical tests require a 5% rejection threshold of the null hypothesis. We make use of the following abbreviations: KS for Kolmogorov-Smirnov, MWU for Mann Whitney Unilateral test, Wilcoxon for Wilcoxon signed rank test, t-test for Student test. M-MD identifies the monopoly sequence in the MD treatment. Similarly, D-MD identifies the duopoly sequence in the MD treatment. M-DM and D-DM are the obvious counterparts for the DM treatment. We start with the principals' contract offers before presenting the agents' decisions.

4.1. Contracts Offers

In this subsection we summarize the principals' decisions. The average contract offered by monopolistic principals is 55.6 in the MD treatment and 51.6 in the DM treatment, a non-significant difference (MWU, $p\text{-value}=0.521$) and which does neither differ from the theoretical prediction, i.e. contract $w^M = 54$ (t-test $p=0.474$ for MD and $p\text{-value} = 0.398$ for DM).

In the duopoly case, the average contract offer is 48.9 in the MD treatment and 45.3 in the DM treatment, a non-significant difference (MWU, p-value = 0.336). However average offers are significantly larger than the predicted contract $w^D = 42$ (t-test p-value=0.024 for MD and p-value=0.041 for DM): they exceed the predicted contract by 16.43% in the MD treatment and by 7.86% in the DM treatment.

Table 5: Average contract offer

Treatment	MD		DM	
	Monopoly	Duopoly	Duopoly	Monopoly
Sequence				
Prediction	54	42	42	54
G1	63,8 (14,6)	61,4 (12,1)	47,9 (11,4)	56,5 (9,0)
G2	48,4 (16,1)	46,0 (14,1)	50,3 (12,6)	57,1 (12,5)
G3	56,1 (11,5)	47,2 (9,3)	41,0 (15,7)	41,6 (14,4)
G4	57,0 (18,1)	47,8 (10,7)	44,5 (11,7)	56,8 (13,7)
G5	55,0 (10,5)	48,8 (8,4)	46,7 (10,2)	46,9 (7,6)
G6	53,3 (15,7)	42,2 (10,9)	41,3 (12,5)	50,8 (12,9)
Total	55,6 (14,4)	48,9 (10,9)	45,3 (12,4)	51,6 (11,7)

Result 1: On average, principals offer larger payments in the monopolistic environment than in the duopolistic environment.

Table 5 shows that the average contract in the monopoly sequence exceeds the average contract offer in the duopoly sequence for each of the six groups for both treatments. Principals propose a significantly larger compensation under monopoly than under duopoly in both treatments. Indeed, in the MD treatment the average contract offered by the monopolistic firm is significantly larger than the contract offered by a duopolistic firm (Wilcoxon one-sided p-value=0.027). In the DM treatment the average duopoly contract is significantly lower to the one offered by the monopoly (Wilcoxon one-sided p-value = 0.027).

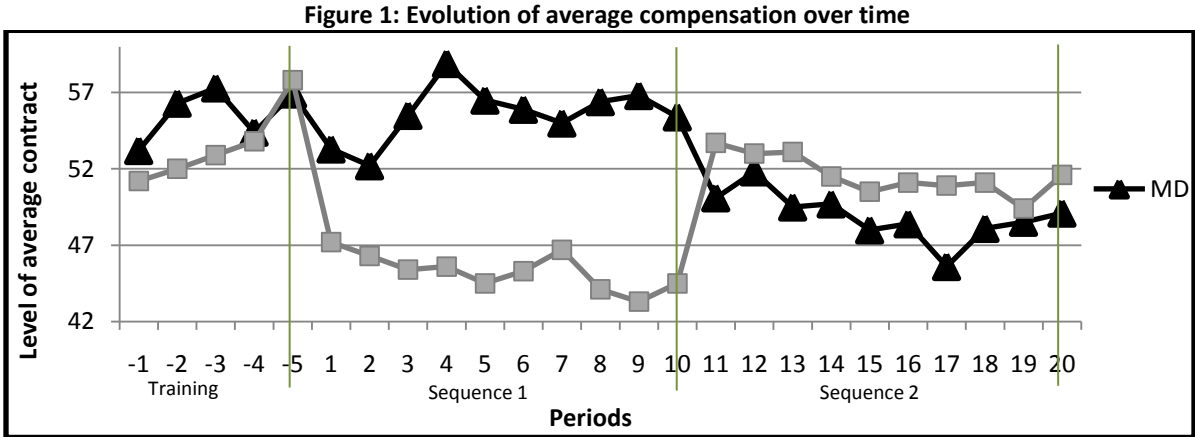


Figure 1 shows the evolution of the average contract over time for each treatment. The figure clearly shows that by moving from the monopoly to the duopoly condition (period 10 of the MD treatment), principals react immediately by offering a lower compensation to their agent. Symmetrically, after switching from the duopoly to the monopoly condition (period 10 of DM treatment), principals offer immediately a larger compensation to their agent. Furthermore over time the average contract offered by the monopolistic principal is significantly larger than the one offered by the principal exposed to competitive pressure in the duopoly condition (MWU p-value<0,001 for M-MD vs. D-DM and p=0,002 for D-MD vs. M-DM).

In accordance to our theoretical prediction we observe that principals propose a larger compensation to their agent (on average) in the monopoly condition than in the duopoly condition in both treatments. A reduction (increase) of the expected profit affects negatively (positively) managerial incentives. Principals react immediately to a change in their expected profit by revising their contract offers in the predicted direction.

Result 2: Consistent with our theoretical prediction the expected surplus share is favorable to the principal in the monopolistic environment. However in contrast to our theoretical prediction, the expected surplus share is more favorable to the agent in the duopoly condition.

Table 6: Agent's Expected Surplus Share

<i>Treatment</i>	MD		DM	
<i>Sequence</i>	Monopoly	Duopoly	Duopoly	Monopoly
Predictions	33,3%	30%	30%	33,3%
G1	47,9%	81,9%	71,4%	37,3%
G2	33,8%	41,1%	50,5%	39,1%
G3	38,2%	42,7%	34,9%	27,9%
G4	42,8%	45,4%	38,0%	39,5%
G5	36,5%	71,6%	42,0%	28,4%
G6	37,7%	33,7%	32,4%	33,8%
Total	39,5%	52,8%	44,9%	34,3%

Table 6 shows the agent's expected surplus share (ESS), i.e. the agent's expected net payment divided by the total expected surplus assuming that he chooses optimally the level

of effort³. For the monopolistic firm, the agent's ESS is 39.5% in the MD treatment and 34.3% in the DM treatment, an insignificant difference (MWU p-value=0.229). However, the ESS is significantly larger than predicted by our model, i.e. 33.3% (t-test, p-value=0.016).

In duopoly firms, the ESS averages 52.8% in the MD treatment and 44.9% in the DM treatment, a non-significant difference (MWU p-value=0.336). But as for the monopoly case, the ESS is significantly larger than predicted i.e. 30% (t-test p-value<0.001).

Finally, we also observe that the ESS is significantly larger in the duopoly environment than in the monopoly environment for both treatment (Wilcoxon one-sided p-value=0.027 for monopoly vs. duopoly in MD and in DM). Compared to the equal split benchmark, the ESS is significantly lower than 50% in the monopoly case (t-test, p-value<0,001) but significantly larger than 50% in the duopoly case (t-test, p-value=0,006).

We therefore conclude that in a monopolistic environment the expected surplus is shared in a way that favors the principal as predicted. However, when competition is introduced, the sharing of the expected surplus becomes favorable to the agent in contrast to the theoretical prediction.

In summary, in spite of the reduction of the average payment in duopoly, this payment is larger than the predicted payment and the surplus sharing is more favorable to the agent.

4.2. Agents' Decisions

Table 7: Rate of acceptance of contracts

<i>Treatment</i>	MD		DM	
	Monopoly	Duopoly	Duopoly	Monopoly
<i>Prediction</i>	100%	100%	100%	100%
G1	91,0%	100,0%	96,0%	99,0%
G2	85,0%	82,0%	86,0%	97,0%
G3	95,0%	96,0%	80,0%	83,0%
G4	88,0%	96,0%	93,0%	92,0%
G5	86,0%	85,0%	89,0%	95,0%
G6	76,0%	88,0%	93,0%	88,0%
Total	86,8%	91,2%	89,5%	92,3%

³ $ESS = \frac{p^*w - 30p^{*2}}{[p^*w - 30p^{*2}] + [p^*(144 - w) + (1 - p^*)36]}$

Table 7 shows the rates of acceptance of contract offers by agent-subjects. Theoretically all contracts should be accepted (since the participation constraint is always satisfied)⁴. Agents accepted 86.8% of the monopoly contract offers in the MD treatment and 92.3% in DM treatment, a non-significant difference (MWU p-value=0.148). The rate of acceptance of contracts offered by duopoly firms is 91.2% in the MD treatment and 89.5% in the DM treatment, which are not different (MWU p-value=0.627). But the key observation is that the rate of acceptance is not significantly different between the two sequences from the same treatment (Wilcoxon one-sided p-value=0.248 for monopoly vs. duopoly in DM and p-value=0.207 for monopoly vs. duopoly in MD). Approximately 10% of the contracts are rejected in each sequence, in accordance with earlier findings about contract offers ((Clark et al. (2010), Keser and Willinger (2000)).

Result 3: The acceptance probability of a contract offer is positively affected by the introduction of competition but not by its withdrawal.

We use a panel data regression in order to estimate the acceptance probability of a contract offer and to identify the variables that have a significant impact on the acceptance decision. The acceptance probability of subject i in period t is given by:

$$p(A_{it} = 1) = \frac{e^{z_i}}{1+e^{z_i}}$$

where $Z_i = \alpha + \beta_1 P_{it} + \beta_2 \Delta P_i + \beta_3 M + \mu_i + \varepsilon_{it}$

P_{it} is the payment of subject i in period t , ΔP_i and M are the dichotomous variables which indicates respectively the payment variation between period t and period $t-1$ (1 if the variation is strictly negative) and the sequence (1 for monopoly). μ_i is a normally distributed random variable that captures the individual random effect and ε_{it} is a standard random error term. The results of the random-effects panel regression are summarized in table 8. The Wald test shows that the models are globally significant.

⁴ $E(U^A) = pw_l - C(p) = pC'(p) - C(p) = \frac{\gamma}{2}p^2 > 0$.

Table 8: Logistic regression of the acceptance probability of contract offers

<i>Treatment</i>	MD	DM
<i>Nb. obs.</i>	1080	1080
<i>Dependent Variable</i>	Acceptance probability	
<i>Independent Variables</i>	Coeff. (SD)	Coeff. (SD)
P_{it}	0.154 (0.016)***	0.111 (0.014)***
ΔP_t	-0.800 (0.356)**	-0.840 (0.332)**
M	-1.197 (0.295)***	-0.198 (0.286)
Constant	-2.474 (0.798)***	-0.624 (0.684)

Wald $\chi^2(3)=125.85$, Prob> $\chi^2=0.0000$, Log likelihood=-211.551 for MD

Wald $\chi^2(3)=90.28$, Prob> $\chi^2=0.0000$, Log likelihood=-215.072 for DM

*** and ** denote two-tailed statistical significance at the 1% and 5% level, respectively.

An increase of the payment has a positive and significant impact on the acceptance probability. As the payment variation becomes larger (in the negative domain) the acceptance probability becomes lower. Indeed, the results indicate a positive relationship between payment and acceptance probability in both experimental treatments. On the other hand, a lower payment in the current period than the one offered in the previous period reduces the probability that the agent accepts the contract. The estimates also show that the sequence dummy is significantly and negatively correlated to the acceptance probability in treatment MD but not in treatment DM: by switching from monopoly to duopoly, with lower incentives, the probability that the agents accept the contract increases significantly, while moving from duopoly to monopoly, with higher incentives, does not affect the acceptance probability. Since agents accept lower payment in duopoly firms, they are sensitive to the competitive environment to which their principal is exposed.

We suspect that the main reason why agents reject contract offers is that they expect a more favorable offer. This is confirmed by a Logit estimate of the reject probability of the contract offer as a function of the ESS. The results of the random-effects panel regression are summarized in Table 9.

Table 9: Logistic estimates of the reject probability of contracts offers

<i>Treatment</i>	MD	DM
<i>Nb. obs.</i>	1200	1200
<i>Dependent variable</i>	Reject probability	
<i>Independent variables</i>	Coeff. (SD)	Coeff. (SD)
<i>PSE</i>	-1.090 (0.253)***	-1.108 (0.335)***
<i>Constant</i>	-1.903 (0.179)***	-2.769 (0.287)***

Wald $\chi^2(1)=10.94$, Prob> $\chi^2=0.0009$, Log likelihood= -309.997 for DM

Wald $\chi^2(1)=18.52$, Prob> $\chi^2=0.0000$, Log likelihood= -390.216 for MD

*** denote two-tailed statistical significance at the 1%.

The Wald test shows that the models are globally significant. An increase in the ESS has a negative and significant impact on the probability to reject the contract offer. This observation is in line with Anderhub et al. (2002) and Cochard and Willinger (2005) who found a similar result. Therefore, the agent's decision to accept or reject is based on the comparison of his net payment and the principal's payment: if the principal's payoff is comparatively too large the agent rejects the offer.

Table 10: Average effort level in accepted contracts

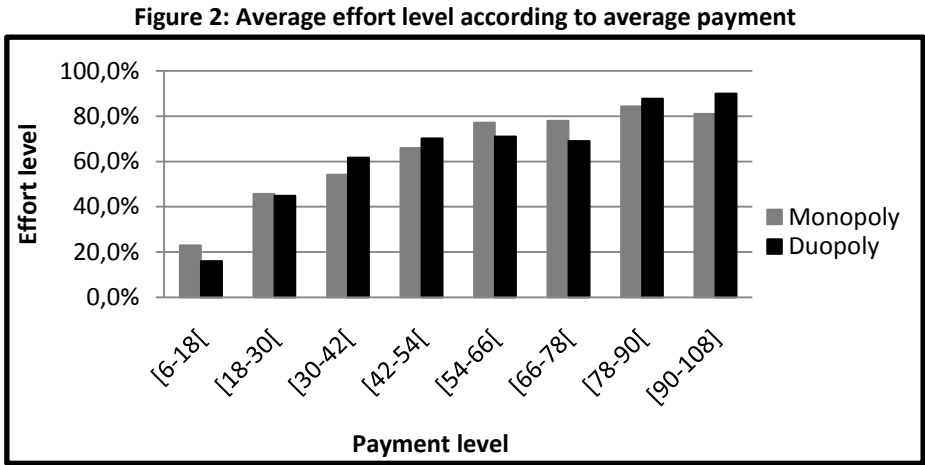
<i>Treatment</i>	MD		DM	
<i>Sequence</i>	Monopoly	Duopoly	Duopoly	Monopoly
<i>Prediction</i>	90%	70%	70%	90%
G1	60,2% (18,0)	68,3% (16,4)	69,4% (13,2)	76,9% (10,9)
G2	60,8% (15,5)	64,1% (18,4)	64,7% (18,0)	71,3% (14,5)
G3	70,4% (12,0)	65,9% (11,0)	55,5% (14,5)	66,7% (18,2)
G4	71,5% (21,1)	69,8% (10,9)	66,3% (16,7)	71,5% (13,6)
G5	79,6% (6,4)	77,7% (4,7)	74,8% (10,4)	75,9% (11,9)
G6	70,5% (12,5)	69,3% (11,5)	67,7% (8,7)	65,0% (15,4)
Total	68,8%	69,2%	66,4%	71,2%

Table 10 shows the average effort level (and standard error) chosen by the agents after accepting a contract. In monopoly, the average effort is 68.8% in the MD treatment and 71.2% in the DM treatment, a non-significant difference (MWU p-value=0.423) but these effort levels are significantly lower than the optimal effort, i.e. effort $p^* = 90\%$ for both treatments (t-test p-value<0.001 for both treatments). In duopoly, the average effort is 69.2% in the MD treatment and 66.4% in the DM treatment, which are statistically not different (MWU, p-value=0.521) nor from the theoretical prediction, i.e. effort $p^* = 70\%$ (t-test p=0.344 for MD and p-value = 0.113 for DM).

Result 4: The reduction of average payment after entry of a rival firm has no effect on the agent's average effort level. On the other hand, the increase of the average payment after exit of the rival firm increases significantly the average effort level.

The average effort level is not significantly different across sequences of the MD treatment (KS p-value=0.756). On the other hand, in the DM treatment the level of effort is significantly larger in the monopoly condition compared to the duopoly condition (KS p-value=0.049). The analysis of the evolution of the average effort over time confirms the absence of significant differences across sequences for the MD treatment (Wilcoxon one-sided p-value=0.878), but a significant one in the DM treatment (Wilcoxon two-sided p-value=0.006).

Therefore our data reflects an asymmetric reaction on the part of the managers: when the competitive pressure is relaxed, principals offer higher incentives because they have higher profit expectations and managers respond by providing higher effort. However, when competition is reinforced, principals offer lower incentives because of reduced profit expectations, but agents maintain their effort level.



Result 5: For a given level of payment, agents work harder in the duopoly environment than in the monopoly environment. The effort level is positively correlated to the payment and negatively to the payment variation.

Table 11 shows the results of a fixed-effects panel regression, with effort choice as the dependent variable.

Table 11: Determinants of the choice of effort level

<i>Treatment</i>	MD	DM
<i>Nb. obs.</i>	962	983
<i>NB. of subjects</i>	60	60
<i>Dependent variable</i>	<i>Effort</i>	
<i>Independent variables</i>	Coeff. (SD)	Coeff. (SD)
<i>Payment_{it}</i>	0.546 (0.039)***	0.604 (0.049)***
<i>ΔPayment_{it}</i>	-2.255 (1.113)**	-1.959 (1.249)***
<i>Monopoly</i>	-5.907 (0.916)***	-1.860 (1.096)**
<i>Constant</i>	44.577 (2.634)***	42.303 (2.529)***

Wald $\chi^2(3)=288.28$, Prob> $\chi^2=0.0000$, Log likelihood=-4134.539 for MD

Wald $\chi^2(3)=228.82$, Prob> $\chi^2=0.0000$, Log likelihood=-4307.894 for DM

*** and ** denote two-tailed statistical significance at the 1% and 5% level, respectively.

The results show that the effort level is strongly correlated to the contract payment in both treatments. For a given income, effort is significantly lower if the payment received in the previous period is higher than the payment in the current period. In contrast, if the payment is higher in the current period the agent increases her effort.

The estimates show also that the sequence dummy is significant and negatively correlated with effort in both treatments: for the same payment, agents work harder in the duopoly environment than in the monopoly environment.

Result 6: Agents tend to choose a level of effort that induces an equal sharing of the expected surplus between them and their principal, in both competitive conditions.

Table 12 reports the average payment, the effort level and the observed expected surplus share of the agent (ESSo thereafter) for accepted contracts. In contrast to the ESS the ESSo is calculated by taking into account the average effort level chosen by the agents and not the optimal effort level. The ESSo is not significantly different between monopoly and duopoly in both treatments (Wilcoxon one-sided p-value=0,463 for M-MD vs. D-MD and p-value=0,753 for M-DM vs. D-DM). Consequently, agents choose effort levels for which they expect a fair share of the surplus. Indeed, the average ESSo is not significantly different to egalitarian sharing i.e.: 50% (*t*-test p-value=0,080 for M-MD, p-value= 0,130 for D-MD, p-value=0,677 for M-DM p-value=0,996 pour D-DM).

Table 12: Average payment, effort level and ESSo in accepted contracts

<i>Treatment</i>	MD		DM	
	Monopoly	Duopoly	Duopoly	Monopoly
<i>Payment</i>	58,6	50,2	46,8	53,1
<i>Effort</i>	68,8	69,2	66,4	71,2
<i>ESSo</i>	54,16%	55,24%	50,01%	48,99%

Finally, both when he decides to accept or to reject a contract offer and when he decides about the level of effort, the agent compares his net payment to the principal's payment. He tends to refuse contract offers with unequal sharing and if he accepts a contract offer he tends to choose an effort level for which he expects an egalitarian sharing of the surplus with the principal.

5. Conclusion

The question that we tried to answer in this paper is the following: how do firms revise the incentives that they offer to their manager as a response to increased (reduced) competition and how do managers react to such a change? Neither the theoretical nor the empirical literature provides satisfactory answers to this question. The theoretical literature is ambiguous: several effects have been identified but the combined outcome of their interactions is unclear. The empirical literature is parsimonious and is confronted to obvious limitations of observability of the relevant data, such as effort. However there is some consensus about the existence of a monotonic relation between competition, incentives and effort: increased competition either lowers the incentives and the effort or increases both of them.

We contribute to the existing literature by providing experimental evidence on this issue. Our experiment is based on a simple model in which we compare a monopolistic firm to duopoly firms competing "à la Cournot". Each firm has an owner (the principal) and a manager (the agent). Principals offer contracts that pay a high bonus if the agent successfully reduces the firm's production cost. Agents choose a costly level of effort (equal to the success probability), unobservable to the principal, in order to reduce the cost.

Our key finding is that an increase of the competitive pressure (entry of a rival firm) reduces the incentives provided by the principals to their managers, but managers' reacts by

maintaining their level of effort instead of reducing it as predicted. This result tends to support Hart's idea of substitutability between incentives and competition: higher competition induces higher effort in spite of lower incentives. However we also find that this effect is asymmetric: when competition is reduced (exit of the rival firm), principals increase the incentives that they offer to their manager who increases his effort level.

Our finding tends to support the hypothesis that managers internalize to some extent the principal's concern about the competitive environment. Instead of adjusting simply their level of effort to the incentives implemented by the principal, managers also react to increased competition. While they share thereby the principal's objective, they are reluctant to accept unfair contracts. Indeed our data clearly shows that unfair contracts are rejected by agents, and when a contract is accepted agents adjust their effort level in such a way as to equalize the expected surplus share between them and their principal. Therefore as outside competition becomes more aggressive, managers are likely to maintain their efforts to reduce the firm's costs despite lower incentives, provided that the surplus is shared more equally with the firm owners. On the other hand, as the competitive pressure softens, managers care less about surplus sharing and respond to increased incentives by increasing their effort.

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Appendix: Instructions (translated)

General information

You are about to participate in an economic experiment on decision making. From now on, you are required to remain silent. If you have any question, please raise your hand, an assistant will answer your request.

This experiment consists of three sequences, one of which will be a training sequence. 20 participants are in this room : 10 participants will be in the role of player X and the other 10 in the role of player Y. Roles will be attributed on a random basis at the beginning of the experiment. Your computer screen will inform you about your role. All participants will keep the same role all along the experiment, that means for all three sequences. After each sequence there will a short break during which you will be required to remain seated in front of your computer. During the break, you will receive new instructions . You cannot discover the identity of the persons with whom you will interact, whatever your role. You will be able to communicate with the other participants only through your computer interface.

Payment for the experiment

During the experiment gains and losses will be measured in ECU; At the end of the experiment, one of the two sequences will randomly selected. The amount of ECU that you accumulated over the selected sequence will be converted into Euros. You may experience losses in some experimental rounds. However, the conversion rule of ECU's into Euros guarantees that you cannot lose money in this experiment. The conversion rule of the accumulated ECUs into Euros is the following :

$$\text{Payment in Euros} = 20 + 0,03 \times [\text{amount of ECUs} - \text{constant}]$$

The value of the constant is unknown at the beginning of the experiment, even for the experimenter. This value will be determined at the end of the experiment, and will be announced to you. The constant can take a different value for X players and for Y players. However the constant will be the same for all X players. Similarly, all Y players will have the same value for the constant. If the amount of ECUs that you accumulated over the chosen sequence is larger than the constant you will earn more than 20 Euros. If it is less than the value of the constant, you will earn less than 20 Euros.

Monopoly instructions

You are about to start a sequence of 10 periods. In each period, each player X will be anonymously and randomly matched with a Y player. New (X,Y) pairs will be formed randomly after each period. Each pair can either be in the “Green state” or the “Blue state”. The likelihood that a pair is in the “Green state” depends on the decisions of player Y. In the “Green state” player X makes a larger profit than in the “Blue state” : if the player pair is in the “Green state” player X earns 144 ECUs while if player pair is the “Blue state” player X earns 36 ECUs. In order to obtain these profit levels, player X and Y need to sign a contract, by following 4 steps. The rest of the instructions describes each of these steps.

Stage 1: Contract offer by player X : m

Player X offers a contract to player Y by which he sets the payment to player Y if the “Green state” obtains for the pair. This payment (noted **m** thereafter) will be between 6 ECU and 108 ECU, by increments of 6ECUs. So player X can choose $m = 6, 12, 18, \dots, 96, 102, 108$. The contract offered by player X to player Y within a player pair is known only by the members of the player pair.

Stage 2 : Acceptance or rejection of a contract

Player Y decides if he accepts or rejects the contract offered by player X. If he rejects the contract, the pair will necessarily end in the “Blue state”. In this case player Y earns 0 ECU and player X earns 36 ECUs. The pair moves therefore directly to stage 4.

Stage 3 : Choice of an action : p

If player Y accepts the contract offered by player X, he will have to choose an action (noted **p** thereafter). The value of p corresponds to the chance of obtaining the « Green state » for the player pair. Action p can take 11 different values , from 9% to 99%, by increments of 9 units. So, player Y can choose 9%, 18%, 27%, ..., 81%, 90% or 99%. Player X cannot observe the value of p chosen by player Y. To each value of p corresponds a cost (noted C thereafter) for player Y. The following table provides the cost, in ECUs, for each possible value of p.

Table A3. 1 : Cost of effort for each value of p

p (en %)	9	18	27	36	45	54	63	72	81	90	99
C(p) (ecu)	0,2	1	2,2	3,9	6,1	8,7	11,9	15,6	19,7	24,3	29,4

Stage 4 : Realization of the state and gains

- Case 1 – the contract offer is rejected : If player Y rejects the contract offered by player X, the player pair is in the “Blue state”, player Y earns 0 ECU and player X earns 36 ECUs.

- Case 2 – the contract offer is accepted : If player Y accepts the contract offered by player X, the state of the pair will be randomly determined. The computer system will draw a number between 0 and 100. If the number drawn is smaller or equal to the value of p chosen by player Y, the player pair will be in the « Green state ». If the number drawn is larger than the value of p chosen by player Y, the pair will be in the « Blue state ». Whatever the state of the player pair, player Y will pay a cost corresponding to the chosen value for p . If the “Green state” occurs for the pair, player X earns 144 ECUs minus the payment (m) transferred to player Y, and player Y earns m (the amount transferred by player X) minus C (the cost corresponding to the chosen value for p). If the “Blue state” occurs, player X earns 36 ECUs, and player Y loses C . The table below summarizes all possible gains for player X and player Y.

Table A3. 2 : Gains in case of acceptance

<i>State</i>	Gain of X	Gain of Y
<i>Green state</i>	$144 - m$	$m - C$
<i>Blue state</i>	36	$-C$

History: At any time you can hit the « history » button to access the record of past periods. The history file shows for each past period : the period number, the decision of player X (the amount m), the decision of player Y (the value of p for a Y player and “accept” or “reject” for an X player), the realized state, the gain of the period and the cumulative gain since the beginning of the sequence.

Example: Suppose that in stage 1 player X proposes $m = 48$ ECU to player Y.

- If player Y rejects the offer in stage 2, the pair is in the « Blue state », player Y earns 0 ECU and player X earns 36 ECUS. The pair goes to stage 4.
- If player Y accepts the offer in stage 2, the pair moves to stage 3 where player Y has to choose an action p . Suppose that he chooses $p = 54\%$. The cost corresponding to that value of p is $C = 8.7$ ECUs. Therefore, there is a 54% chance that the « Green state » occurs and 46% chance that the « Blue state » occurs. If the « Green state » occurs for the player pair, player X earns $144 - 48 = 96$ ECU and player Y earns $48 - 8.7 = 39.3$ ECUs. If the « Blue state » occurs, player X earns 36 ECUs and player Y loses -8.7 ECUs. For this example, the table below summarizes the possible gains in each state for each player in case of acceptance of the contract by player Y.

- **Table A3. 3 Gains in the example in case of acceptance**

<i>State</i>	Gain of X	Gain of Y
<i>Green state</i>	96 ecu (144 – 48)	39,3 ecu (48 – 8,7)
<i>Blue state</i>	36 ecu	-8,7 ecu

Duopoly instructions

You are about to start a new sequence of 10 periods. You keep the same role as in the previous sequence. In each period of the sequence, each player X will be randomly and anonymously matched with a player Y. Once all (X,Y) pairs are formed, each pair will be matched with another pair. For instance the pair (X_1, Y_1) will be matched with the pair (X_6, Y_6) , the pair (X_3, Y_3) will be matched with the pair (X_5, Y_5) , the pair (X_8, Y_8) will be matched with the pair (X_2, Y_2) ... At the end of each period new (X,Y) pairs will be formed, and each one will be randomly matched again with another pair. In each period player X can make a profit that depends upon an action chosen by player Y of his player pair, the state that occurs for his player pair and the state that occurs for the other player pair with which the pair is matched.

Each pair can either be in the "Green state" or the "Blue state". The likelihood that a pair is in the "Green state" depends on the decisions of player Y. In the "Green state" player X makes a larger profit than in the "Blue state". The profit of player X depends both on the state of his own pair and the state of the other pair with which it is matched. If both pairs are in the "Green state", each player X earns 64 ECUs. If both pairs are in the "Blue state" each player X earns 16 ECUs. If one of the pairs is in the "Green state" while the other one is in the "Blue state", player X of the pair in the "Green state" earns 144 ECUs and player X of the pair in the "Blue state" earns 0 ECU. In order to obtain these profit levels, player X and Y need to sign a contract, by following 4 steps. The rest of the instructions describes each of these steps.

Stage 1: Contract offers by players X : m

Each player X offers a contract to player Y of his pair by which he sets the payment to player Y if the "Green state" obtains for the pair. This payment (noted **m** thereafter) will be between 6 ECU and 108 ECU, by increments of 6 ECUs. The contract offered by player X to player Y within a player pair is known only by the members of the player pair.

Stage 2 : Acceptance or rejection of contracts

Each player Y decides if he accepts or rejects the contract offered by player X of his pair. If he rejects the contract, his pair will necessarily end in the "Blue state". In this case player Y earns 0 ECU and player X earns an amount that only depends on the state of the other pair. The pair moves then directly to stage 4.

Stage 3 : Choice of an action : p

If player Y accepts the contract offered by player X of his pair, he will have to choose an action (noted **p** thereafter). The value of **p** corresponds to the chance of obtaining the « Green state » for the

player pair. Action p can take 11 different values, from 9% to 99%, by increments of 9 units. So, player Y can choose 9%, 18%, 27%, ..., 81%, 90% or 99%. Player X cannot observe the value of p chosen by player Y. To each value of p corresponds a cost (noted C thereafter) for player Y. The following table provides the cost, in ECUs, for each possible value of p .

Table A3. 4 : Cost of effort for each value of p

p (en %)	9	18	27	36	45	54	63	72	81	90	99
$C(p)$ (ecu)	0,2	1	2,2	3,9	6,1	8,7	11,9	15,6	19,7	24,3	29,4

Stage 4 : Realization of the states and gains

- Case 1 – the contract offer is rejected : If in a pair player Y rejects the contract offered by player X the player pair is in the “Blue state”, player Y earns 0 ECU and the gain of player X depends only on the state that occurs for the other pair.

- Case 2 – the contract offer is accepted : If in a pair player Y accepts the contract offered by player X, the state of the pair will be randomly determined. Whatever the state of the player pair, player Y will pay a cost corresponding to the chosen value for p . The gains of the players depends on the states that occur in each pair.

➤ *If the two pairs are in the « Blue state », player X of each pair earns 16 ECUs and player Y of each pair loses C , the cost corresponding to the chosen value of p .*

➤ *If one of the pairs is in the « Blue state » and the other one in in the « Green state » :*

- *Pair in the « Blue state » : Player X earns 0 ECU and player Y loses C .*
- *Pair in the « Green state » : Player X earns $144 - m$ ECUs, with m the amount transferred to player Y of his pair. Player Y earns $m - C$, with m the amount transferred by player X of his pair, and C the cost corresponding to the value chosen for p .*
- *If the two pairs are in the « Green state », player X of each pair earns $64 - m$, with m the amount transferred to player Y in each pair, and player Y of each pair earns $m - C$, with m the amount transferred by player X of his pair, and C the cost corresponding to the value chosen for p by each one.*

Consider two pairs - P1 and P2 - matched together and formed by players X1, Y1 and X2, Y2, respectively. Note $m1$ the amount proposed by X1 to Y1 and $m2$ the amount proposed by X2 to Y2. The table below summarizes all the possible gains for each player of each pair, depending on the realized state for each pair.

Table A3. 5 : Gain possibilities in case of acceptance of contracts

State		Gains of X players		Gains of Y players	
P1	P2	X1	X2	Y1	Y2
<i>Blue</i>	<i>Blue</i>	16	16	-C	-C
<i>Blue</i>	<i>Green</i>	0	$144 - m2$	-C	$m2 - C$
<i>Green</i>	<i>Blue</i>	$144 - m1$	0	$m1 - C$	-C
<i>Green</i>	<i>Green</i>	$64 - m1$	$64 - m2$	$m1 - C$	$m2 - C$

At the end of a period each player can see on his computer screen the state that occurred for his pair and his individual gain. X players are also informed about the state that occurred in the other pair.

History: At any time you can hit the « history » button to access the record of past periods. The history file shows for each past period the following data : the period number, the decision of player X of his pair (the amount m), the decision of player Y of his pair (the value of p for a Y player and “accept” or “reject” for an X player), the realized state for his pair, the gain of the period and the cumulative gain since the beginning of the sequence. X players can also see for each period, the state that occurred for the other pair.

Example: Consider two pairs - P1 and P2 - matched together and formed by players X1, Y1 and X2, Y2, respectively. Note $m1$ the amount proposed by X1 to Y1 and $m2$ the amount proposed by X2 to Y2. Furthermore note $p1$ the value of the action chosen by Y1 and $p2$ the value of the action chosen by Y2. Assume that X1 proposes $m1 = 60$ ECUs to Y1 and that X2 proposes $m2 = 66$ to Y2. Suppose that Y1 accepts the contract offered by X1 and chooses $p1 = 63\%$ (at a cost of 11.9 ECU), and that Y2 accepts the contract offered by X2 and chooses $p2 = 45\%$ (at a cost of 6.1 ECU). The table below summarizes the possible gains for each player of each pair, depending on the realized state for each pair.

Table A3. 6 : Gain possibilities for the example (contracts are accepted)

States		Gains of X players		Gains of Y players	
P1	P2	X1	X2	Y1	Y2
<i>Blue</i>	<i>Blue</i>	16	16	-11,9	-6,1
<i>Blue</i>	<i>Green</i>	0	78 ($144 - 66$)	-11,9	59,9 ($66 - 6,1$)
<i>Green</i>	<i>Blue</i>	84 ($144 - 60$)	0	48,1 ($60 - 11,9$)	-6,1

<i>Green</i>	<i>Green</i>	4	-2	48,1	59,9
		(64 - 60)	(64 - 66)	(60 - 11,9)	(66 - 6,1)

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