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Theoretical and Experimental Approach to Organizational and Political Economics

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Contents

*This chapter was written in collaboration with Camelia Kuhnen from Kellogg School of Management at Northwestern University

†This chapter was written in collaboration with Jens Großer from Florida State University and Ernesto Reuben from Northwestern University

Preface

In this thesis I use theoretical and experimental approach to study topics in Organizational and Political Economics. The thesis consists of three chapters, each constituting an independent research agenda.

The first chapter, which is a joint project with Camelia Kuhnen, considers the impact of self-esteem, generated by privately received feedback about relative performance, on productivity. To the best of our knowledge, this is the first attempt to model and test the motivating role of self-esteem in competitive settings. We find out that feedback has both ex-ante and ex-post effects on productivity. The results suggest that in environments where monetary incentives are weak, moral hazard can be mitigated by providing feedback to agents regarding their relative performance, and by optimally choosing the reference peer group.

In the second chapter, which is a joint project with Jens Großer and Ernesto Reuben, we use experimental and theoretical approach to establish whether money can buy influence. Given the enormous amounts of money contributed to the legislators by lobbying groups each year, the lack of agreement as to how these transfers exactly benefit the lobbyists and the dispute about how strongly such contributions should be regulated, we find answering this question particularly important. We find out that if legislators and lobbyists interact repeatedly then lobbyists can achieve more favorable policy outcomes if they transfer a part of their wealth to the legislators. This holds even if such policies are against the interest of the majority of the society and lower legislator's chances in elections. Interestingly, we find little evidence of "strong" reciprocity and repeated interaction seems to be a necessary condition for the cooperative behavior to emerge.

In the last chapter of the thesis, I build a model of competitive labor market in order to find equilibrium incentives and the degree of cooperation when teamwork is optimal. I find out that in equilibrium better and less skilled workers separate and work in different firms. Highly skilled workers receive higher performance bonuses, work harder on their own task and are at the same time more teamwork oriented.

I owe immeasurable intellectual debt to my supervisor Pierpaolo Battigalli for constant support while working on the thesis. The papers have also benefited from the insightful comments and advice of the members of my thesis committee - Alberto Bisin, Sandro Brusco and Matthias Messner - as well as participants of NBER Behavioral Finance Meeting in Boston, International ESA Conference at Caltech, La Pietra- Mondragone Workshop and ESA European Meeting in Lyon. All remaining errors are mine.

I would also like to thank the Economics Department of Northwestern University for hospitality. My visit was not only very enjoyable and stimulating but also allowed me to meet my coauthors Camelia Kuhnen and Ernesto Reuben, who are a real pleasure to work with. A big credit goes to organizers and guest speakers of the Summer Institute in Behavioral Economics organized and sponsored by Russell Sage Foundation for introducing me to the field of Behavioral Economics.

Last but not least I would like to acknowledge the support I received from my family. I am grateful to my parents for supporting me throughout long years of education, my husband for never ending encouragement and comments on the numerous versions of the papers included in the thesis, and my children for inspiration and motivation to continue the search for more accurate description of the world around us.

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Rank Expectations, Feedback and Social Hierarchies*

Abstract

We develop and test experimentally a theoretical model of the role of self-esteem, generated by private feedback regarding relative performance, on the behavior of agents working on a simple effort provision task for a flat wage. We isolate the impact of learning one's rank in the group on one's output from any reputation, strategy-updating or peer monitoring effects.

Feedback has both ex-ante and ex-post effects on the productivity of workers and on the dynamics of social hierarchies. Agents work harder and expect to rank better when they are told they may learn their ranking, relative to cases when they are told feedback will not be provided. After receiving feedback, individuals who learn that they have ranked better than expected decrease their output but expect an even better rank in the future, while those who were told they ranked worse than expected increase their output and at the same time lower their rank expectations going forward. These effects are stronger in earlier rounds of the task, while subjects learn how they compare to their peers. This rank hierarchy is established early on, and remains relatively stable afterwards. Private relative rank information helps create a ratcheting effect in the group's average output, which is mainly due to the fight for dominance at the top of the hierarchy.

These results suggest that in environments where monetary incentives are weak, moral hazard can be mitigated by providing feedback to agents regarding their relative performance, and by optimally choosing the reference peer group.

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Therefore, social hierarchy effects on productivity may influence optimal team formation.

1.1 Introduction

Self-esteem has long been thought of in the psychology literature as a strong motivator of human behavior (Maslov (1943), McClelland, Atkinson, Clark, and Lowell (1953)). Recently, this concept has been introduced in theoretical models of economic choice (Benabou and Tirole (2002), Koszegi (2006)) as "ego utility". People derive utility from thinking of themselves as good, skilled or valuable according to some social criteria, and their actions are shaped by the desire to maintain high levels of self-esteem.

So far, the economics literature on ego utility has focused on understanding the role of self-esteem on behavior in non-competitive settings. However, ego utility may also affect strategic interactions, where self-esteem is determined by an individual's beliefs about his relative standing among his peers, and not necessarily by beliefs about absolute measures of his ability. In such settings, beliefs about relative rank are modified by the feedback that individuals receive about their relative performance. Therefore, ego utility is influenced not only by an individual's own actions, but also by those of other players. While these strategic considerations are similar to those studied in the tournaments literature[1], existing theory models do not capture the behavior of agents in settings where the benefit of being the most productive player is simply ego utility, or self-esteem. Moreover, there are no empirical or experimental accounts of behavior in such settings. We seek to address these two gaps in the literature.

Specifically, our goal is to understand the role of ego utility on productivity in competitive settings where participants receive private feedback about their relative standing. We isolate the ego utility effect from other reasons why feedback about rank may change behavior. For instance, feedback may influence productivity if compensation is performance-based, since people seem to care more about their relative, rather then objective level of wealth (Clark and Oswald (1996), Easterlin (1995), Luttmer (2005)). Feedback may also

[1]See Prendergast (1999) for a review.

change behavior if it provides information about the nature of the project (Seta (1982), Bandura (1986), Kluger and DeNisi (1996)). Moreover, if feedback is public, and thus the relative ranking is common knowledge among participants, peer monitoring or concerns for social status and reputation may influence the participants' behavior going forward (Kandel and Lazear (1992), Knez and Simester (2001), Falk and Ichino (2006), Mas and Moretti (2007)). To minimize the influence of these other channels through which relative rank information may impact actions, we employ a setting where participants receive a flat wage, the task that they work on does not involve changes in strategy or learning, and feedback is private and anonymous.

The theoretical model we develop and our experimental results imply that private feedback about relative ranking has both ex-ante and ex-post effects on the productivity of workers and on the dynamics of social hierarchies. Agents work harder and expect to rank better when they are told they may learn their ranking, relative to cases when they are told feedback will not be provided. After receiving feedback, individuals who learn that they have ranked better than expected decrease their output but expect an even better rank in the future, while those who were told they ranked worse than expected increase their output and at the same time lower their rank expectations going forward. These effects are stronger in earlier rounds of the task, while subjects learn how they compare to their peers in terms of output produced. This rank hierarchy is established early on, and it remains relatively stable later in the task. Private information regarding relative standing helps create a ratcheting effect in the group's average output. This ratcheting effect (working harder over time) is mainly due to the fight for dominance at the top of the hierarchy. Moreover, increasing the heterogeneity in the ability of members of the peer group leads to lower output from low ability individuals, but has no impact on the output of high ability workers.

Our premise that people's self-esteem depends on their relative standing among peers is supported by a large body of evidence. Research from social psychology shows that when effort is unobservable people work harder when they are provided with a social comparison criterion, for example with the average productivity of past participants (Szymanski and Harkins (1987), White, Kjelgaard, and Harkins (1995)). Thus, individuals are willing to exert more costly effort to avoid falling behind the average, and to be better than the average. In the context of a search experiment, Falk, Huffman, and Sunde (2006) show that low productivity subjects are more likely than high productivity ones to choose not to learn their rank in the group at the end of the task, consistent with the idea that a low rank decreases utility.

This paper contributes to the theoretical and experimental literature on ego utility, intrinsic motivation and peer effects. On the theory side, Benabou and Tirole (2002) focus on the effect of self-esteem on the behavior of people with time inconsistent preferences. They argue that self-confidence is valuable because it enhances motivation to act, and investigate a variety of intrapersonal strategies people may use to enhance their self-image. They show that people may handicap their performance (for example by exerting low effort), and use self-deception through selective memory or awareness management in order to maintain high self-perception about their ability. This keeps them motivated to undertake profitable endeavors in the future. Weinberg (1999) and Koszegi (2006), on the other hand, treat self-esteem as a consumption good and incorporate it directly in the utility function. They assume that individuals' utility is increasing with their perception of their own ability, which is updated in a Bayesian manner after receiving new relevant information.

These models, however, do not take into account the fact that in most real life situations people exert externalities on one another. Usually, one's self-esteem is not shaped in isolation but is also influenced by the actions of others. Thus, the predictions of extant theoretical models regarding people's reaction to relative rank information in the absence of monetary incentives are not clear. When feedback is provided, ex-ante concerns for self-image can increase effort, as agents seek to learn that they rank high. However, the prospect of receiving feedback can also lead to lower ex-ante effort, because of disappointment avoidance. As suggested by Koszegi (2006), agents with positive beliefs about themselves wish to preserve their self-esteem and may decide to avoid competing, because doing so reduces the informativeness of signals about ability obtained during the task. Ex-post effects of feedback are also difficult to predict based on existent theories. For instance, after receiving bad feedback about relative performance, people with self-image concerns could employ deception strategies as suggested in Benabou and Tirole (2002) in order to discard this information or interpret it to their advantage. They may give up competing if the perceived chances of winning in the future are minimal, or may engage in the task again because it is the only way to regain self-confidence (Koszegi (2006)). Extending these prior models, our theoretical framework applies to multi-agent settings and makes clear predictions about which of these effects should be observed in the data.

Related to the work on self-esteem is a large literature on the value of public recognition, or status. People care about social status as defined by their relative income (Frank (1984), Frank (1985)), they value public recognition independently of any monetary consequence and are willing to trade off material gains to obtain it (Huberman, Loch, and Onculer (2004)). The quest for status has labor market implications, for instance regarding wage and promotion schemes, or job search and sorting (Cowen and Glazer (2007)). Using survey and experimental data, Clark, Masclet, and Villeval (2006) find that status measured as one's rank in the income distribution has a more powerful effect on work effort than does the others' average income, suggesting that social comparisons are more ordinal than cardinal.

Peer monitoring has also been proposed as an effective incentive mechanism (Major, Testa, and Bylsma (1991), Kandel and Lazear (1992)). Performing well in front of peers seems to matter even when output does not have an impact on monetary payoffs (Knez and Simester (2001), Falk and Ichino (2006) and Mas and Moretti (2007)). The increase in output observed when people work along peers seems to come mainly from low-output individuals, who work harder in the presence of higher productivity workers (Seta (1982), Bandura (1986), Mas and Moretti (2007))

In contrast to these two streams of work on status seeking and peer monitoring effects, our focus is on the internal drive of individuals to rank well relative to others, and not on people's need for public recognition or reputation among peers. In line with prior evidence, we assume that people enjoy performing well relative to others even in situations when performance is private information, or when there are no future consequences via reputation or career concerns channels. A related driver of behavior to the one studied here is intrinsic motivation: people enjoy effortful endeavors, even in the absence of incentive pay, because completing such endeavors generates a sense of personal growth and fulfillment (e.g. Deci (1975)). Benabou and Tirole (2003) formalize the concepts of intrinsic and extrinsic motivation and show under which conditions the latter will "crowd out" or "crowd in" the former.[2] There is extensive evidence in the literature that external intervention (for example output-based pay or monitoring) crowds out intrinsic motivation and undermines productivity (see Deci, Koestner, and Ryan (1999) or Frey and Jegen (2001) for reviews). For instance, Gneezy and Rustichini (2000) show that piece rates lead to increased performance only if they are substantial and even piece rates as high as 10% may lead to a decrease in output as compared to a situation where no incentive pay is used. Since extrinsic motivators often turn out to have detrimental effects, finding the optimal level of incentive pay that would improve rather than impair productivity is not trivial. We are therefore considering an alternative incentive device - private information about one's relative position in the group - that can potentially reinforce intrinsic motivation in ego-driven individuals.

It is possible, though, that in environments where monetary incentives are strong enough to actually motivate people to work hard, they may crowd out the effect of feedback that we demonstrate here in a flat-wage environment. In a related paper, Eriksson, Poulsen, and Villeval (2008) measure output and effort levels across subject groups that face one of two variable compensation schemes — piece-rate or tournament pay— and find that releasing information about relative performance does not significantly influence the subjects' average output or effort in either pay condition.

Our results, however, suggest that in settings where monetary incentives are weak or non-existent, moral hazard can be mitigated by optimally providing feedback to agents regarding their relative performance. Ego utility, or self-esteem can be used as a motivator for productivity. In light of these findings, it is possible that by changing the reference peer group, a social planner or principal can benefit from the dynamics of social hierarchy effects on productivity. Rankings are commonly used in many environments – for example, in the labor market for corporate executives or fund managers, in educational in-

[2] A reduced-form approach to this topic is presented by Frey (1997). The interplay between the two types of incentives is generated by the assumption that extrinsic motivators (e.g. bonuses) convey information about the agent's ability or about the difficulty of the task, and hence influence the agent's intrinsic interest in making the project successful.

stitutions or sales departments. Institutions that publish rankings are usually concerned with the performance of their members. Therefore, understanding what impact rankings may have on performance is of key importance to the motivational politics of a modern firm.

1.2 Model

1.2.1 Setup

In our model two agents, i and j, work on similar tasks. Each individual output is observable and verifiable. The individual output depends on the worker's skill and on the amount of effort he has put into the task. We assume the following production function

$$y_i = a_i + e_i + \widetilde{\varepsilon}_i \tag{1.1}$$

where a_i represents the agent's innate ability level, e_i is the amount of effort that the agent has put into his task and the term $\widetilde{\varepsilon}_i$ is the realization of an exogenous transitory shock ($\widetilde{\varepsilon}_i \sim N(0, \sigma^2)$) independently and identically distributed across agents. The agent does not know his own ability, nor the ability of his opponent.

We assume that each agent's utility is increasing in his own output, since people enjoy knowing that they are productive (Deci (1975)). Moreover, we assume that the agent's utility depends also on how his output compares to that of the other agent, with utility decreasing in the output of the opponent. This assumption captures the empirical regularity that people enjoy performing better relative to others (e.g., Szymanski and Harkins (1987)). Importantly, agents work for a fixed wage, and do not receive pay linked to performance. The agent is also free to choose how much to care, or pay attention to the feedback about the opponent's output, and therefore about his own relative rank in this task. The intensity with which the agent chooses to care about the other person's output is captured by parameter $s_i \geq 0$. This assumption is similar to that of Benabou and Tirole (2002) that people may ignore information about output in order to preserve their self-esteem.

We assume that the agent's utility after he observes only his own output is equal to the level of his output y_i. If he also observes the output of his opponent his utility is equal to $y_i - y_j \ln\left(\frac{k}{k-s_i}\right)$, where $k > s_i$ is a parameter. Expression $\ln\left(\frac{k}{k-s_i}\right)$ is increasing in s_i. This means that, all else equal, the higher s_i the agent sets, the more he needs to produce to achieve a given level of utility from comparing his output to that of the other agent.

At the end of the working period each agent always knows how much he produced and he may also learn how much the other agent produced. In the beginning of the working period each agent knows the probability (denoted by p for agent i and q for agent j) with which he will get information about the output of his opponent. Working on the task is costly. Agent i, who will receive information about the output of the other agent with probability p, experiences the following disutility (cost of effort) while working:

$$c_i(a_i, e_i) = (\beta - \gamma a_i)\ln(e_i - ps_i) \tag{1.2}$$

where $\beta > 0$ and $0 < \gamma < 1$ are parameters. For the cost function to be well-defined, we assume that $\beta - \gamma a_i > 0$ and $e_i - ps_i > 1$[3].

Since $\gamma > 0$, we assume that effort is less costly for a more able worker. That is, being better skilled to do a task makes the job more enjoyable, while being less able makes working on the task more frustrating, stressful or disappointing.

Moreover, we assume that effort is less costly if agents set a higher standard for themselves (in other words, being more motivated makes the task less unpleasant), and also, if the probability of learning their rank is higher. This last assumption is technical and it assures that when $p = 0$, the standard set s_i by the agent does not change the cost function, since in that situation the agent will not actually learn their relative performance (so the agent will not be able to compare himself with his competitor).

Therefore, ex-ante an agent who does not know his own or his opponent's ability and expects to get feedback about the opponent with probability p has

[3]Always holds in equilibrium.

the following expected utility function:

$$E_i(u_i) = (1-p)\,E_i(y_i) + p\left(E_i(y_i) - E_i(y_j)\ln\left(\frac{k}{k-s_i}\right)\right) - (\beta - \gamma E_i(a_i))\ln(e_i - ps_i) \tag{1.3}$$

which is equivalent to

$$E_i(u_i) = E_i(a_i) + e_i - pE_i(y_j)(\ln k - \ln(k-s_i)) - (\beta - \gamma E_i(a_i))\ln(e_i - ps_i) \tag{1.4}$$

The endogenous reference standard s_i has two effects. As in Falk and Knell (2004), the benefits of getting feedback about relative performance, as well as the cost of producing output decrease with s_i. The latter assumption captures the positive motivational effect of goal setting. The same level of effort appears to be less costly when one works on ambitious and demanding tasks. The former assumption illustrates that the chosen standard s_i can be interpreted as a measure of how much the individual would be hurt by an increase in the output of the other player, or of how frequently he decides to compare himself to the other. The higher s_i is, the more ambitious is the goal set by agent i.

Agent i, therefore, faces the following problem:

$$\max_{e_i, s_i} E_i(a_i) + e_i - pE_i(y_j)(\ln k - \ln(k-s_i)) - (\beta - \gamma E_i(a_i))\ln(e_i - ps_i) \tag{1.5}$$

which gives the following first order conditions:

$$\begin{aligned} e_i &= \beta - \gamma E_i(a_i) + ps_i & (1.6)\\ s_i &= \frac{k(\gamma E_i(a_i) - \beta) + e_i E_i(y_j)}{\gamma E_i(a_i) - \beta + pE_i(y_j)} & (1.7) \end{aligned}$$

From equations (1.6) and (1.7) we get that:

$$\begin{aligned} e_i^* &= \beta - \gamma E_i(a_i) + p\left(k - E_i\left(y_j^*\right)\right) & (1.8)\\ s_i^* &= k - E_i\left(y_j^*\right) & (1.9) \end{aligned}$$

For simplicity, to avoid infinite hierarchies of beliefs, we restrict attention to the first order beliefs, that is, to beliefs about one's own ability ($E_i(a_i)$

and $E_j(a_j)$) and beliefs about ability of the other player ($E_i(a_j)$ and $E_j(a_i)$). Second order beliefs – that is, beliefs of player i about the beliefs of player j – are such that $E_i(E_j(a_j)) = E_i(a_j)$ and $E_i(E_j(a_i)) = E_i(a_i)$.

Also, $E_i(E_j(p)) = E_j(p) = E_j(E_i(q)) = E_i(q) = \frac{1}{2}$. Given these assumptions we get that agent i expects agent j to produce:

$$\begin{aligned} E_i\left(y_j^*\right) &= E_i\left(a_j + \beta - \gamma E_j(a_j) + q\left(k - E_j a_i - E_j(e_i^*)\right)\right) \\ &= E_i(a_j) + \beta - \gamma E_i(a_j) + \frac{k}{2} - \frac{1}{2}E_i a_i - \frac{1}{2}E_i\left(E_j(e_i^*)\right) \end{aligned} \tag{1.10}$$

Let $\overline{e}_i^* \equiv E_i(E_j(e_i^*)) = \int_0^1 e_i^*(p)f(p)dp$. Then combining equations (1.10) and (1.8) we get that:

$$e_i^* = \beta - \gamma E_i(a_i) + p\left(k - \left(E_i(a_j) + \beta - \gamma E_i(a_j) + \frac{k}{2} - \frac{1}{2}E_i(a_i) - \frac{1}{2}\overline{e}_i^*\right)\right)$$

After rearranging we get:

$$e_i^* = \beta + \frac{pk}{2} - p\beta + \left(\frac{p}{2} - \gamma\right)E_i(a_i) - p(1-\gamma)E_i(a_j) + p\frac{1}{2}\overline{e}_i^* \tag{1.11}$$

Taking expectations with respect to probability p in equation (1.11) we obtain:

$$\overline{e}_i^* = \beta + \frac{k}{4} - \frac{\beta}{2} + \left(\frac{1}{4} - \gamma\right)E_i(a_i) - \frac{1}{2}(1-\gamma)E_i(a_j) + \frac{1}{4}\overline{e}_i^*$$

which gives:

$$\overline{e}_i^* = \frac{1}{3}\left(2\beta + k + (1-4\gamma)E_i(a_i) - 2(1-\gamma)E_i(a_j)\right) \tag{1.12}$$

Combing equations (1.12) and (1.11) we obtain the formula for the equilibrium level of effort of agent i who has beliefs $E_i(a_i)$ and $E_i(a_j)$:

$$e_i^* = \frac{2p(1-\gamma) - 3\gamma}{3}E_i(a_i) - \frac{4p(1-\gamma)}{3}E_i(a_j) + \beta - \frac{2\beta p}{3} + \frac{2kp}{3} \tag{1.13}$$

Using equation (1.9) and (1.13) we obtain the equilibrium level of standard:

$$s_i^* = \frac{2(1-\gamma)}{3}E_i(a_i) - \frac{4(1-\gamma)}{3}E_i(a_j) + \frac{2}{3}(k-\beta) \tag{1.14}$$

In equilibrium agent i produces the following amount of output:

$$y_i^* = a_i + \frac{2p(1-\gamma)-3\gamma}{3}E_i(a_i) - \frac{4p(1-\gamma)}{3}E_i(a_j) + \beta - \frac{2\beta p}{3} + \frac{2kp}{3} + \widetilde{\varepsilon}_i \tag{1.15}$$

and ex-ante expects to produce:

$$E_i(y_i^*) = \frac{(2p+3)(1-\gamma)}{3}E_i(a_i) - \frac{4p(1-\gamma)}{3}E_i(a_j) + \beta - \frac{2\beta p}{3} + \frac{2kp}{3} \tag{1.16}$$

We use equations (1.13) - (1.16) to derive the main propositions in the paper.

1.2.2 Implications

Ex-ante effects

Our model predicts that feedback policy can influence both productivity and beliefs even before any information is revealed to the agents. In particular, agents who expect to receive information about their opponent's output with different likelihoods, other things being equal, will expect to rank differently and will produce different levels of output.

Proposition 1 *If the agent believes that his ability is relatively high (low) compared to the ability of the competitor then he will produce more (less) output and expect better (worse) relative performance when the likelihood of feedback increases.*

Proof. Using equation (1.15) we get that $\frac{dy_i^*}{dp} = \frac{2}{3}((1-\gamma)(E_i(a_i) - 2E_i(a_j)) + k - \beta)$. Since $\gamma < 1$, $\frac{dy_i^*}{dp} > 0 \Leftrightarrow E_i(a_i) > 2E_i(a_j) - \frac{k-\beta}{1-\gamma}$ and $\frac{dy_i^*}{dp} \leq 0 \Leftrightarrow E_i(a_i) \leq 2E_i(a_j) - \frac{k-\beta}{1-\gamma}$.

We measure relative performance using the difference in agents' outputs, $E_i y_i^* - E_i y_j^*$, and say that agent expects better relative performance when this

difference increases. The probabilities with which the agents receive feedback are not correlated, and thus we get:
$\frac{d\left(E_i\left(y_i^*\right)-E_i\left(y_j^*\right)\right)}{dp} = \frac{dE_i\left(y_i^*\right)}{dp} = \frac{2}{3}\left(\left(1-\gamma\right)\left(E_i\left(a_i\right)-2E_i\left(a_j\right)\right)+k-\beta\right)$
Since $\gamma < 1$, $\frac{d\left(E_i\left(y_i^*\right)-E_i\left(y_j^*\right)\right)}{dp} > 0 \Leftrightarrow E_i\left(a_i\right) > 2E_i\left(a_j\right) - \frac{k-\beta}{1-\gamma}$ and $\frac{d\left(E_i\left(y_i^*\right)-E_i\left(y_j^*\right)\right)}{dp} \leq 0 \Leftrightarrow E_i\left(a_i\right) \leq 2E_i\left(a_j\right) - \frac{k-\beta}{1-\gamma}$. ■

This proposition implies that giving subjects opportunity to compare themselves to others makes the sufficiently confident ones more productive and more optimistic about their relative position in the group, which is highly desirable from the principal's point of view.

Ex-post effects

Comparative statics allow us to predict how agents who initially do not know their relative position in the group adjust effort and beliefs about future rank as they change their perceptions of relative ability.[4] Different patterns in behavior and beliefs will occur after good and bad feedback, that is, after the subject learns that he ranked better or worse than he expected.

Proposition 2 *After receiving good (bad) feedback about own ability, i.e. after the agent learns that he is better (less) skilled than he expected, the agent's output will*

- *decrease (increase) if* $p < \frac{3\gamma}{2(1-\gamma)}$ *(sufficient condition is that* $\gamma > \frac{2}{5}$*)*
- *increase (decrease) if* $p \geq \frac{3\gamma}{2(1-\gamma)}$.

Proof. From equation (1.15) we get $\frac{dy_i^*}{dE_i(a_i)} = \frac{2p(1-\gamma)-3\gamma}{3}$ and
$\frac{dy_i^*}{dE_i(a_i)} < 0 \Leftrightarrow p < \frac{3\gamma}{2(1-\gamma)}$ and $\frac{dy_i^*}{dE_i(a_i)} \geq 0 \Leftrightarrow p \geq \frac{3\gamma}{2(1-\gamma)}$
Notice that since $p \leq 1$, if $\gamma > \frac{2}{5}$ then $\frac{dy_i^*}{dE_i(a_i)} < 0$. ■

Proposition 3 *If the agent learns that his competitor is better (less) skilled than he expected, he will decrease (increase) his future output.*

[4] Note that we do not explicitly model belief updating in this setting, that is, how agents use new information about their own or their competitors' performance to update beliefs about own and others' abilities.

Proof. From equation (1.15) we get $\frac{dy_i^*}{dE_i(a_j)} = -\frac{4p(1-\gamma)}{3} < 0$. ■

From Propositions 2 and 3 we learn that an agent will change his future output when the feedback he receives about his own and/or his opponent's ability is not in accordance with his current beliefs. For example, an agent who learned that he is higher in the productivity hierarchy (his own ability is higher and the ability of his opponent is lower) will increase his future output if $p \geq \frac{3\gamma}{2(1-\gamma)}$. For $p < \frac{3\gamma}{2(1-\gamma)}$, the direction of change in the output will depend on the strength of the effect of own ability relative to that of the competitor's ability.

The next proposition establishes formally how agent's beliefs change after he receives feedback about his relative position in the group.

Proposition 4 *When the agent's beliefs about relative performance are revised upwards (downwards), he expects better (worse) relative performance in the future.*

Proof. As in Proposition 1, we measure relative performance using the difference in agents' outputs, $E_i(y_i^*) - E_i(y_j^*)$, and say that agent expects better relative performance when this difference increases.

$$\frac{d\left(E_i\left(y_i^*\right)-E_i\left(y_j^*\right)\right)}{dE_i(a_i)} = \frac{dE_i\left(y_i^*\right)}{dE_i(a_i)} - \frac{dE_i\left(y_j^*\right)}{dE_i(a_i)}$$

$$E_i\left(y_j^*\right) = \frac{4}{3}(1-\gamma)E_i(a_j) - \frac{2}{3}(1-\gamma)E_i(a_i) + \frac{2\beta+k}{3}$$

$$\Rightarrow$$

$$\frac{d\left(E_i\left(y_i^*\right)-E_i\left(y_j^*\right)\right)}{dE_i(a_i)} = \frac{(2p+3)(1-\gamma)}{3} - \frac{2(1-\gamma)}{3} = \frac{(2p+1)(1-\gamma)}{3} > 0$$

$$\frac{d\left(E_i\left(y_i^*\right)-E_i\left(y_j^*\right)\right)}{dE_i\left(a_j^*\right)} = -\frac{4p(1-\gamma)}{3} - \frac{4(1-\gamma)}{3} = -\frac{4(1-\gamma)(1+p)}{3} < 0 \ ■$$

According to the model feedback also affects agents' motivation. An agent who got good feedback will become more ambitious in the future, in the sense that he will set more demanding goals for himself. He will have to rank better in the future (produce more relatively to his opponent) in order to maintain the same satisfaction level.

Proposition 5 *When the agent's beliefs about relative ability are revised upwards (downwards), he will choose a higher (lower) standard.*

Proof. Using equation (1.14) we obtain

$$\frac{ds_i^*}{dE_i(a_i)} = \frac{2(1-\gamma)}{3} > 0 \text{ and } \frac{ds_i^*}{dE_i(a_j)} = -\frac{4(1-\gamma)}{3} < 0$$

■

1.2.3 Total output - some implications

The previous propositions indicate that feedback about relative rank has ex-ante and ex-post effects on beliefs and productivity in setting where agents still learn where they stand in the rank hierarchy. It is therefore natural to ask what would be the effect of feedback in well-established teams, that is, in settings where workers' abilities and feedback policies are common knowledge. The following subsection addresses this question.

Common knowledge of abilities and feedback probability

Recall equation (1.8)

$$e_i^* = \beta - \gamma E_i(a_i) + p\left(k - E_i\left(y_j^*\right)\right)$$

and assume that there is common knowledge of abilities and feedback probability. We then get that in equilibrium

$$e_i^* = \frac{\beta(1-p) + pk(1-q) + p\gamma a_j + pqa_i - pa_j - \gamma a_i}{(1-pq)} \tag{1.17}$$

$$y_i^* = \frac{\beta(1-p) + pk(1-q) + (1-\gamma)(a_i - pa_j)}{(1-pq)} + \widetilde{\varepsilon}_i \tag{1.18}$$

Therefore, the principal who hires a pair of workers (i,j) and provides worker i with feedback with probability p and worker j with probability q expects the following level of total output

$$Y^*(i,j) = y_i^* + y_j^* = \frac{\beta(2-p-q) + qk(1-p) + pk(1-q)}{1-pq} + \frac{(1-\gamma)}{(1-pq)}\left(a_i(1-q) + a_j(1-p)\right) \tag{1.19}$$

Proposition 6 *For a given q, if agent i is good enough relative to agent j (that is, if $a_i \geq \frac{1}{q}\left(a_j - \frac{(k-\beta)(1-q)}{(1-\gamma)}\right)$) it is optimal for the principal to increase the intensity of feedback for worker i.*

Proof. $\frac{dY^*}{dp} = \frac{(1-q)}{(1-pq)^2}\left((k-\beta)(1-q) + (1-\gamma)(a_iq - a_j)\right)$

$\frac{dY^*}{dp} \geq 0 \Leftrightarrow a_i \geq \frac{1}{q}\left(a_j - \frac{(k-\beta)(1-q)}{(1-\gamma)}\right)$ ■

This proposition implies that a principal can extract more output from agents if he provides more frequent feedback to high ability workers. Feedback about relative rank is a cheap way to motivate the high types to work harder, since they enjoy learning that they did better than the competition. While our experimental analysis precludes us from having common knowledge of abilities and feedback probabilities, we can not test this proposition directly. However, it suggests that feedback can be optimally provided to agents of different types, to maximize effort provision when monetary incentives are weak or non-existent.

1.3 Experimental design

The ideal dataset for understanding the role of private feedback regarding relative rank on productivity would allow us to compare workers' output when such feedback is provided and when it is not provided, all other things being equal. It would also describe the workers' personal characteristics and rank expectations. It is hard, if not impossible, to obtain such data from the field and therefore we use a controlled experimental setting to test our theory.

In the experiment we ask subjects to solve simple multiplication problems (multiply one-digit numbers by two-digit numbers) during several identically structured rounds. Therefore, participants make real effort choices. We use this task for several reasons. First, no previous task knowledge is required and it is easy to explain. Second, task learning effects, which we would like to avoid, should be minimal. In other words, we expect that participants know how to solve multiplication problems before they come to the lab, and their ability to solve these problems does not improve during the duration of the task. Moreover, the score on this task depends on the subjects' ability as well as on their effort choice. Therefore, different subjects will end up with different scores, which will lead to dispersed rankings. Also, the subjects' ranks depend not only on their own (possibly unknown to them) abilities but also on the unknown skills and effort decisions of other participants. As a result, we are likely to find situations where the subjects' expectations are not confirmed by the received feedback. This allows us to study how this mismatch between expectations and reality affects future expectations and productivity. We are also able to assess whether this response differs when feedback is positive (i.e., the subject learns that he did better than expected) and negative (i.e., the subject learns that he did worse than expected).

In order for our data to be meaningful, it is necessary to control for the difficulty level of the multiplication problems. If randomly generated numbers were used to generate multiplication problems, and a participant solved more problems in round two than in round three this could mean two things. Either the person's effort remained the same across the rounds but the problems in period two were easier, or he worked harder in round two while the problems were equally difficult in both rounds. We generated 206 multiplication problems of the same difficulty level, as in Cromer (1974)[5] in order to avoid this possible confound.

Problems were presented to each subject on a computer screen. Each time the subject solved the multiplication correctly one point was added to his score and the next problem was presented. If the subject provided a wrong answer, the score remained unchanged and he was asked to solve the same problem again until answered correctly. By not allowing subjects to move on to the next question unless the previous one was solved, we avoid a situation where participants may strategically skip difficult problems looking for easy ones.

The experiment consisted of 18 rounds. Each of them had the same structure and three feedback conditions were possible. The conditions differed with respect to the probability with which the subject received feedback about his relative rank at the end of the round. This probability was either 0, 0.5 or 1. We refer to these as the "No", "Maybe" or "Sure" treatments, respectively. The feedback condition was determined randomly and independently for every subject at the beginning of each round.[6] Therefore, in the same round different subjects faced different feedback conditions.

The sequence of events in each round is shown in Figure 1.1. First, subjects were informed which feedback condition they were in. This information was consistent with what happened at the end of the period and subjects were aware of that. We informed subjects about the feedback condition in the beginning of each round because it allows us to study the ex-ante effect of

[5] Examples of problems used are: $89 * 4$, $76 * 9$, $73 * 8$.

[6] Using alternating messages within one session allows us to control for session effects.

feedback probability on rank, expected rank, output and effort choices.

Afterwards, subjects were asked to report their expected rank in that round.[7] Following that, subjects had 90 seconds to work on multiplication problems. For each subject, their score was displayed on the screen throughout the round and was updated after every correct answer (the score was reset to zero at the beginning of every round). After the 90 seconds passed, subjects were asked to asses how much effort they had put into the task that round. Answers were provided using a six point scale ranging from "no effort at all" to "a lot of effort".

In the final stage of each round, that lasted for fifteen seconds, each subject either saw the performance ranking or not, depending on the feedback condition they had been assigned to for that round. The ranking was determined by the current period scores of all subjects in the group. The subject that solved the highest number of problems would rank as number one, the one whose score was lower than scores of two other subjects would rank as number three, etc. Each subject could see the scores and ranks of all the participants but he could identify *only* his rank and score. Therefore each subject knew that nobody else could associate his identity to his actual rank and score.

The experiment was programmed using the z-Tree software (Fischbacher (2007a)). Subjects were given a written copy of the instructions (see Appendix) which they were asked to read before the experiment started. The task was also described verbally by the experimenter. Subjects practiced the task for one period, but feedback was not provided during that time. No external aids (calculators, scratch paper, etc.) were allowed. Subjects were recruited from Northwestern University using standard procedures. We conducted eight sessions, but one of them had to be excluded due to technical problems. We therefore present data from the remaining 54 subjects (24 male and 30 female), in seven sessions. Each of these subject groups consisted of

[7]We did not pay subjects if their rank expectations turned out to be correct at the end of the round, because doing so would have distorted behavior: all subjects would have declared that they rank last, solved zero problems, and achieved the last rank indeed. We understand the importance of incentive compatibility, and in other tasks where final compensation depends on output – and is not a flat wage like in the current experiment – paying people if they made the correct rank guess would certainly be desirable. However, as explained earlier, to understand how ego utility (i.e. liking to believe that we rank higher that others) changes behavior we are confined to a flat-wage environment.

six to nine people. Importantly, subjects received a fixed fee of $23 for their participation, independent of performance.

1.4 Experimental Results

1.4.1 Ex-ante effects of feedback

As predicted by Proposition 1, ex-ante information about the likelihood of receiving feedback at the end of the period about one's rank has a significant impact on both the subjects' expected rank, as well as on their actual output, measured as the number of multiplication problems solved correctly. These effects are illustrated in Fig. 1.2.

Output is 7.28% higher (11.35 vs. 10.58 solved problems per round, $p < 0.07$ in a one-sided mean comparison test), and the expected rank is better (4.16 vs 4.90, $p < 0.001$ in a one-sided mean comparison test) for participants who are in the "Maybe" feedback condition, than for those in the "No" feedback condition. There is no significant difference between the output or expected rank of subjects in the "Maybe" feedback condition versus "Sure" feedback condition.

Fig. 1.3 reveals significant gender effects on output and rank expectations, in each of the three feedback likelihood conditions. Men solve significantly more problems than women. Across all treatments, the average number of problems solved is 12.91 for men, and 8.69 for women ($p < 0.001$ in a one-sided mean comparison test), in line with the prior literature on gender and competitiveness (e.g. Gneezy, Niederle, and Rustichini (2003)). Also, men expect to rank better than women do (i.e. men report lower values for $ExpectedRank_t$). Across all conditions, men expect to receive a rank of 3.53, while women expect to receive a rank of 5.53. The difference is statistically significant ($p < 0.001$ in a one-sided mean-comparison test). This is consistent with prior experimental findings. For instance, Huberman, Loch, and Onculer (2004) observe that males seek status more than women, and Falk and Knell (2004) find that women have significantly lower aspiration levels than men regarding college education accomplishments.

The subjects' rank expectation and their actual rank are positively correlated, and this relationship becomes stronger in later periods. The Spearman rank correlation between $ExpectedRank_t$ and $Rank_t$ is 0.58 in the first six periods, 0.82 in periods seven through twelve, and 0.84 in periods thirteen through eighteen ($p < 0.0001$ in all cases). Therefore, as the task progresses, people get better at guessing their actual rank in the hierarchy.

1.4.2 Ex-post effects of feedback

Propositions 2, 3 and 4 imply that the feedback received regarding one's relative standing in the group has effects on the expectations of future rank and on the actual output produced in future rounds. We find evidence consistent with these predictions.

At the end of each round, subjects can receive one of three types of feedback regarding their relative ranking, depending on the relationship between their actual rank and the rank they expected to get. If $Rank_t > ExpectedRank_t$, feedback is negative, since subjects did worse than they expected. If $Rank_t < ExpectedRank_t$, feedback is positive, and if $Rank_t = ExpectedRank_t$, it is neutral. We use three indicator variables, $BadFeedback_t$, $GoodFeedback_t$ and $NeutralFeedback_t$ to capture these three types of events.

The regression models in Tables 1.1 and 1.2 show the role of received feedback on future output, expectations of rank, and actual rank. Doing better than expected in round $t-1$ (i.e. $GoodFeedback_{t-1}$=1) leads the subjects to expect a better rank in round t. Doing worse than expected (i.e. $BadFeedback_{t-1} = 1$) has the opposite effect, leading subjects to declare a worse expected rank (i.e. a higher value for $ExpectedRank_t$). Both of these effects are measured relative to receiving neutral feedback in Table 1, and relative to not getting any feedback at all in Table 2.

As predicted by Propositions 2, 3 and 4, while ranking information seems to make well-performing subjects think they will rank even better in the future, and badly-performing subjects think they will rank worse, the opposite actually happens. After receiving negative feedback, people solve more problems, and achieve a better rank. After receiving positive feedback, output is lower and the actual rank worsens. As above, these effects are measured relative to receiving neutral feedback in Table 1.1, and relative to not getting any feedback at all in Table 1.2. We control for the prior values of expected rank, output and actual rank to account for the mechanical effect that people who are top ranked can only move higher in the rankings, whereas people who are already at the bottom of the hierarchy can not rank any lower.

The likelihood of receiving feedback in the current round and the gender of the subject have similar effects on output and expected rank as shown earlier in the univariate analysis, and illustrated in Figures 1.2 and 1.3. If feedback is likely to be received – that is, the probability of seeing the ranking at the end of the period is not zero, as captured by the indicator variable $FeedbackLikely_t$ – then subjects expect and achieve better ranks, and the output is larger (however, the last effect is no longer statistically significant). Males expect better ranks than females, and solve more problems.

We also find evidence suggesting that the **ex-ante** dispersion in expected ability influences the agents' beliefs about relative rank, and their actual output, in the direction predicted by the model. Propositions 3 and 4 imply that the better agent i believes competitor j is, the worse is the rank expected by i, and the lower is the output produced by i. In our experiment, the number of men in the group is an exogenous manipulation of the beliefs of women participants regarding their relative ability. We base this argument on the results in Gneezy, Niederle, and Rustichini (2003) and Niederle and Vesterlund (2007) who show that women are less effective than men in competitive environments, and this effect is stronger in settings where women compete against men than in single-sex competitive environments. Hence, we proxy heterogeneity in the agents' expected ability by the gender composition of our subject groups. As shown by the results in Table 1.3, we find that the number of men in the group matters for the productivity of women, but not for that of men. Women's expected and actual ranks are worse, and their output is lower, the more men there are in the group, as predicted by Propositions 3 and 4.

1.4.3 Hierarchies and the fight for dominance

The experimental evidence so far indicates that feedback about rank can impact the dynamics of rankings. But these effects should be less important once the performance hierarchy is established. Indeed, as shown in Table 1.4, when we estimate the same regression models as in Table 1.1 for rounds 1-9 and 10-18 separately, we find that $GoodFeedback_{t-1}$ and $BadFeedback_{t-1}$ influence strongly the subjects' rank expectations in the early rounds, but these effects are no longer statistically significant during later rounds. In other words, feedback about relative performance in a particular round does not influence a subject's expectations about where he will stand in the hierarchy in the future, once the hierarchy is determined.

In light of this suggestive evidence, we test more formally whether stable hierarchies do get formed, and if so, how soon it happens. Fig. 1.4 shows evidence that hierarchies indeed emerge, and that effort is sustained even after the social dominance order is established. First, the data indicate that output grows over time. This could in part be due to learning effects (i.e. participants find better ways to do multiplications), and in part due to a competition or ratcheting effect that is caused by people's desire not to lose their status in the hierarchy. We revisit these two effects at the end of this section.

Moreover, we find that the standard deviation of output increases over time, consistent with subjects expending the appropriate effort levels needed to maintain their rank (i.e. high effort for top-ranked individuals, and low effort for bottom-ranked ones). The standard deviation of expected rank also increases in later rounds, suggesting that people's expectations "fan out" as they learn about their relative performance. Early on, subjects have similar priors about their relative ability, but as they get feedback regarding their output level, posterior beliefs about rank became more heterogeneous, in accordance with the group's diversity in abilities.

Another way to illustrate that hierarchies form early on and remain relatively stable is to see whether people who were at the bottom of the ranking in the early rounds of the task tend to stay at the bottom in later rounds, while people who started by being at the top of the ranking will stay at the top. For each participant we calculated their average rank in the first six, middle six and last six rounds of the task. We will refer to these as the early, middle and late stages of the task. For each of theses three stages, we assigned subjects to one of three rank performance bins: low, middle and high, depending on their average rank during the six rounds that comprised the stage. Thus, subjects in the low rank performance bin in a particular stage are those in the bottom third of the performance distribution, as determined by how their average rank compared to the average rank of the others in their peer group. Subjects in the high rank performance bin are those in the top third of the performance distribution as measured by their average rank during that stage.

Figures 1.5 and 1.6 show how people transition across rank performance bins as the task progresses. Fourteen of the seventeen (82%) of the individuals who were in the bottom third of the rank hierarchy during rounds 1 through 6 end up in the same low rank performance bin during rounds 7 through 12, and also during rounds 13-18. Of the twenty-one subjects who were in the top third of the rank hierarchy during the first six rounds, eighteen (86%) are still top performers during rounds 7 through 12, and fifteen (71%) remain at the top during rounds 13-18. Thus, while there are instances where subjects move up and down the hierarchy, most people stay in the same rank performance bin they had in the first six rounds of the task. This indicates that by the end of the first six rounds the hierarchy is already established.

While people's ranks do not change much once the hierarchy is formed, the average output of the group increases, as shown in Figure 1.4. Does this increase come from top performers working harder to maintain their top rank, or by people in the middle or low end of the hierarchy who want to get better rankings? The answer to this question is relevant for optimal team formation and dynamics. If the increase in output comes from people at the top of the ranking fighting for dominance, and not from people at the bottom trying to get a better rank, then it may be efficient to reshuffle peer groups by assigning bottom performers to new teams. There, they have a chance to be higher up in the ranking, and will expend effort to preserve their newly-acquired position, thus increasing the total output produced.

Figure 1.7 shows that the ratcheting effect observed in average output comes mainly from subjects who were at the top or in the middle of the hierarchy in the first six rounds. Individuals who ranked in the bottom third of the hierarchy early on have a slower rate of productivity increase relative to the other participants. Therefore, the increase in productivity that is shown in Figure 1.4 comes mainly from high productivity subjects who fight to maintain or improve their rank. A recent quote[8] by Vijay Singh, who was the number

[8]http://www.brainyquote.com/quotes/quotes/v/vijaysingh183223.html

one player in the Official World Golf Rankings in 2004 and 2005, illustrates this ratcheting effect: "I'm playing pretty good now, but my ranking doesn't say that. I'm number two."

An alternative interpretation of the increase in output over time seen in Figure 1.7 is that people simply get better at solving multiplication problems as the task progresses, and those that had better performance earlier on learn faster. This interpretation is unrelated to ego utility or to the ratcheting effect (that is, strategically choosing to work harder in order to obtain a good rank). To investigate this alternative explanation, we obtain a measure of how difficult it is for subjects to solve multiplication problems. We calculate the cost of effort ($CostOfEffort_t$) per multiplication problem as the ratio of declared effort to output produced by each subject in each round. We average this quantity across the three performance categories (early top, middle and bottom performers). For learning to explain the patterns in Figure 1.7, it should be the case that the rate of change in output and the rate of change in the cost of effort over time are negatively related. In other words, early top performers will increase their output at a faster pace relative to bottom performers because their cost of effort decreases at a faster pace over time. As the data in Table 1.5 show, we do not find this to be the case.

The output of early top performers increases at twice the rate over time as that of early bottom performers ($\frac{\Delta Output}{\Delta Round}$ is 0.21 and 0.11 for these two categories, respectively). The cost of effort, however, decreases faster over time for bottom performers ($\frac{\Delta CostOfEffort}{\Delta Round}$ is -0.01 for bottom performers and -0.004 for top performers).[9] Therefore, learning effects (i.e. the task getting easier over time) can not be the sole explanation for the increase in output of those ranking well early on, since the task seems to get easier faster for early bottom performers. Hence, ego utility – as shown by our model and previous empirical results – can be a driver of output and lead to ratcheting at the top of the hierarchy, a pattern illustrated by the data in Figure 1.7 and Table 1.5. Throughout the task, early top performers declare higher effort levels relative to early bottom performers (4.40 versus 4.02, on a scale from 1 to 6), produce

[9] The average rate of change in output, and in the cost of effort over time are estimated by regressing $Output_t$ and $CostOfEffort_t$ on $Round_t$, for participants in each of the three early performance categories.

higher output (14.90 versus 6.65 multiplication problems per round) and have a lower cost of effort (0.30 versus 0.61). All of these differences are statistically significant ($p < 0.01$).

1.4.4 Additional Evidence

In every round of the experiment, after the work (multiplication) phase but before feedback phase, we ask subjects to assess, on scale from 1 to 6, how hard they worked in the current round. Before we discuss this data we need to make a couple of comments.

First of all, notice that these are self-reported and highly subjective measures of effort. Given that effort is unobservable, there is no incentive-compatible mechanism that we could have used to obtain objectively valid measures of effort. We cannot be certain that subjects report or even try to report effort truthfully and do not pick a random number instead. Finally, there is a problem with interpretation. We don't know whether the values reported by the subjects correspond to effort (e_i) or cost of effort ($c(e_i)$) and our model makes clear, however different, predictions for those two different measures.[10]

Data reveals that feedback probability has significant effect on reported effort level. Subjects who know that they will receive feedback with probability 1 or 0.5 report that they worked significantly harder than those who know they will not receive any feedback (4.44 (for $p = 1$) and 4.35 (for $p = 0.5$) vs 4.04 (for $p = 0$)). There is no significant difference in effort when subjects receive feedback with probability 0.5 and 1.

Group composition has significant effect on effort levels reported by women. As shown in Table 1.3, the more men in the group the less hard women report they worked. This suggests that women choose to exert less effort when

[10]Given the production function $y_i = a_i + e_i + \widetilde{\varepsilon}_i$, all the propositions regarding output level y_i hold also for effort e_i without any major changes. This implies that effort should be increasing in feedback probability, decrease after good feedback and increase after bad feedback. Different predictions hold for cost of effort ($c(e_i)$). Plugging equations (1.8) and (1.9) into the cost of effort function (equation (1.2)) we obtain that in equilibrium cost of effort is equal to

$$c_i(a_i, Ea_i) = (\beta - \gamma a_i) \ln (\beta - \gamma E_i(a_i))$$

This expression is independent of $E_i(a_j)$ and p which suggests that in equilibrium receiving good or bad feedback about the opponent as well as feedback likelihood should have no effect on the reported effort measures.

competing against men which is in line with the literature about gender and competitiveness.

Tables 1.1 and 1.2 indicate that subjects report to work less hard in the current round if they received feedback in the previous one. There is no effect of good and bad feedback on reported effort relative to receiving neutral feedback.

1.5 Conclusion

We propose that individuals' utility is influenced by private information regarding their relative performance. This hypothesis implies that feedback about rank has effects on both productivity and on the dynamics of the rank hierarchy in groups of workers doing similar tasks. These predictions are supported by experimental evidence. To separate our theory from alternative explanations as to why rank information changes behavior, we employ an experimental setting where subjects receive a flat wage for working on a simple multiplication problem solving task, and where there can not exist reputation, strategy-learning or peer monitoring effects.

We find that agents increase output, and expect to rank better, if they think feedback is likely. After receiving feedback, those who got better ranks than expected will decrease output, but expect even better ranks in the future, while the opposite is true of people who ranked lower than expected. The productivity hierarchy is established early on in the task, and there is a ratcheting effect of rankings on output. People at the top of the hierarchy early on work harder over time to maintain that position, while people at the bottom do not change their productivity level as much.

Therefore, our results suggest that in competitive settings productivity and beliefs are influenced by privately observed information about relative position in the group hierarchy. Importantly, the effects of private rank feedback on output are comparable to those of peer monitoring mechanisms documented in prior work. Mas and Moretti (2007) find that a 10% increase in average co-worker productivity is associated with 1.7% increase in a worker's effort. By optimally arranging the mix of workers in each shift, the firm in their sample could improve productivity by 0.2%. Similarly, Falk and Ichino (2006) find that a 10% increase in a peer's output results in a 1.4% increase in a given individual's effort. We find that giving people an opportunity to compare themselves to others (by increasing the probability of feedback from 0 to 0.5) raises individual output on average by 7.28%, a sizeable effect compared to that of peer monitoring.

In light of our findings, it is natural to ask whether an optimal feedback policy exists. In other words, we would like to know whether organizations can increase their total output through optimal feedback provision, perhaps by changing the timing and content of information released to workers or by revealing information to certain individuals only. Even though the current experimental setup does not allow us to directly compare such complex feedback policies, our results have several implications for improving productivity. Those implications should be taken with caution, as their external validity remains to be examined in future work.

For instance, the principal could take advantage of the ex-ante effect of feedback likelihood on effort provision. Our model suggests that an organization could produce more if it used different feedback likelihood policies for agents of different skill. Feedback should be given more frequently to agents who either believe that they have, or actually posses, relatively high ability. To prolong the effectiveness of relative rank information, the principal could either provide noisy feedback to slow down the learning of one's rank in the hierarchy, or reshuffle work groups once the hierarchy is established and known. Since in more homogeneous groups incentives are preserved for all members while in heterogeneous groups members split into top performers, who keep fighting for high ranks, and bottom performers, who compete much less, reshuffling may allow low-rank workers to climb the hierarchy in another group, and as a result, to generate more output. Finally, the principal could manipulate the beliefs of the agents. Both the model and the data suggest that if competitors appear to be too tough, an agent's performance deteriorates. Therefore, improving workers' beliefs about their relative ability may have a positive impact on productivity.

Appendix to Chapter 1

Appendix: Instructions

Welcome to our experiment on economic decision making!

The study will last about 60 minutes, during which you will participate in a 45-minute experiment, and will fill out some questionnaires. Your task during the experiment is to solve multiplication problems. Each time you provide a correct answer one point is added to your score. Your score is refreshed in each period and you are going to play for 18 periods.

In each of the periods:

1) You will be told what information you will receive at the end of the period regarding your rank in the group. Your rank is based on the number of correct answers provided by you and the other participants. You will see one of the following three statements on the screen, selected at random for each one of the participants in each period:

"You WILL see the ranking this period."

In this case, for sure you will see the rank information at the end of the period.

"You MAY see the ranking this period."

In this case, there is an equal chance that you will or will not see the rank information at the end of the period.

"You WILL NOT see the ranking this period."

In this case, for sure you will not see the rank information at the end of the period.

2) You will be asked to estimate your rank in the group, before seeing any of the multiplication problems.

Your rank is determined by your score in the current period. If you have the highest score (i.e. nobody solved more multiplication problems than you did), you will rank as number 1. If there is only one person who solved more problems you will rank as number 2, and so on.

Therefore, if you expect that x people will have higher score than yours, please type in a number equal to $x + 1$ as your expected rank and press the "Submit" button.

Example: You expect that 5 people will do better than you. Type in 6 and press "Submit".

3) You will be presented with multiplication problems to solve.

In each period you will have 90 seconds during which you can work on the multiplication problems. To provide an answer, type it in the box and press "Submit".

If your answer is correct a point will be added to your score and you will see another multiplication problem.

If your answer is incorrect, your score will remain unchanged and you will see the message "Incorrect. Please try again". You will be asked to solve the same problem again. Only after you provide correct answer the program will move on to the next multiplication problem.

4) You will be asked to report the level of effort you have put into doing the task during that period.

Check the appropriate field that reflects how much effort you have put into doing the task, ranging from "no effort at all" to "a lot of effort", then press "Submit".

5) You may see how you have ranked relative to others during the period, depending on what you were told in the beginning of the period (see (1))

If the ranking information is provided to you this round, you will have 15 seconds to see it. The ranking is presented in such a way that every participant can identify only his/her own score. In other words, your exact ranking for that period will be known to you only. No other participant can see how you ranked that period.

Example: There are 10 participants. You solved 3 problems and five people did better than you. The screen that you will see may look like this

This period is over!

Ranking in this period:

Rank	Name	Score
1	.	10
1	.	10
3	.	9
4	.	8
5	**You**	**3**
5	.	3
5	.	3
5	.	3
9	.	1
9	.	1

In case you do not see the ranking you will be asked to wait for 15 seconds for the experiment to continue.

Then, the experiment moves on to the next period and all the stages are repeated. In the end of the experiment we will ask you to fill in a short questionnaire.

Payment

You will receive a total of **$23** in cash for your participation in our study.

Practice periods

You will have a chance to practice this task for one period. We encourage you to type in at least one correct and one incorrect answer so that you know how to behave in both cases. You will not see any ranking information in the practice period.

Appendix: Tables and Figures

Figure 1.1: Sequence of events in a round.

Figure 1.2: Feedback likelihood, output and expected rank

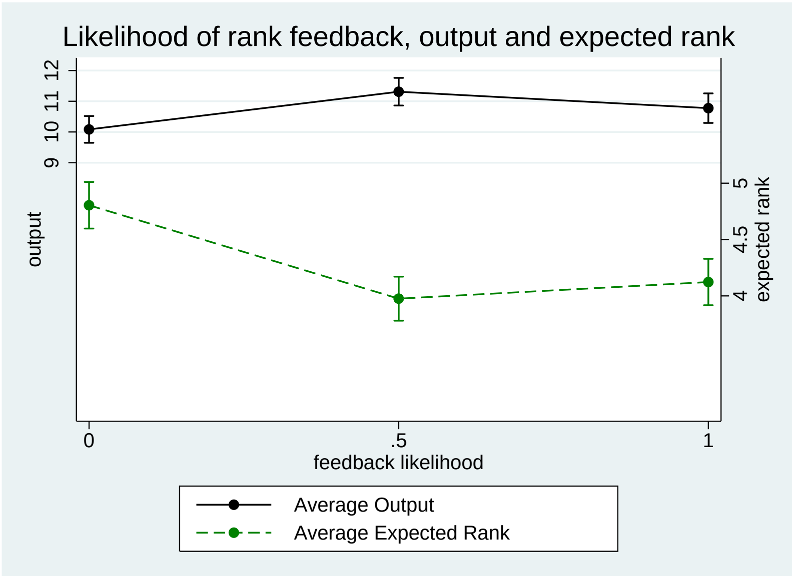

Figure 1.3: Feedback likelihood, output and expected rank, by gender

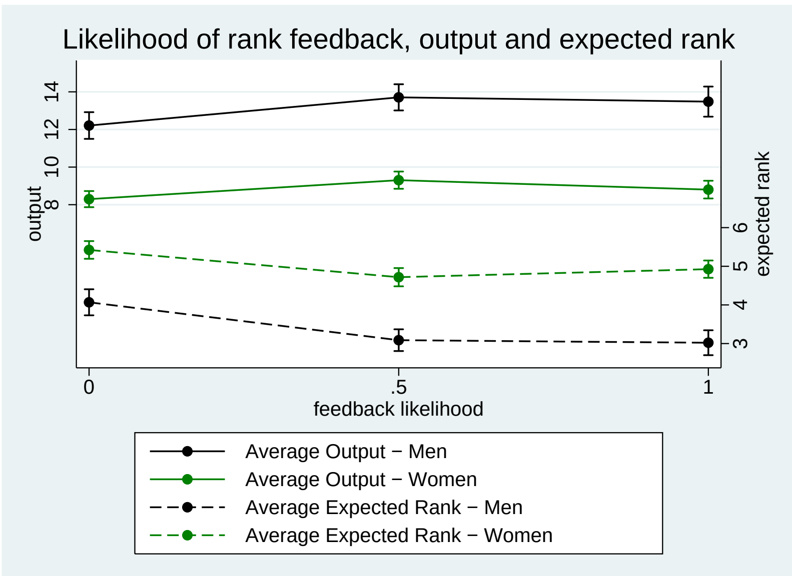

Figure 1.4: Output and expected rank, by round

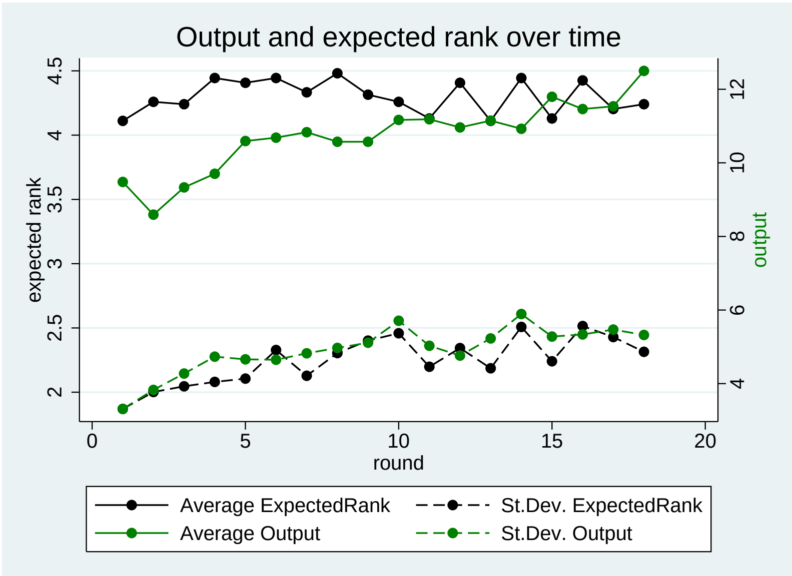

Figure 1.5: Transitions across ranks: rounds 1-6 to rounds 7-12.

	Low7-12	Medium7-12	High7-12
Low1-6	14/17	3/17	0/17
Medium1-6	5/16	10/16	1/16
High1-6	0/21	3/21	18/21

Figure 1.6: Transitions across ranks: rounds 1-6 to rounds 13-18.

	Low13-18	Medium13-18	High13-18
Low1-6	14/17	3/17	0/17
Medium1-6	4/16	10/16	2/16
High1-6	0/21	6/21	15/21

Figure 1.7: The average output produced each round by subjects who were at the top, in the middle or at the bottom of the rank hierarchy during the first six rounds.

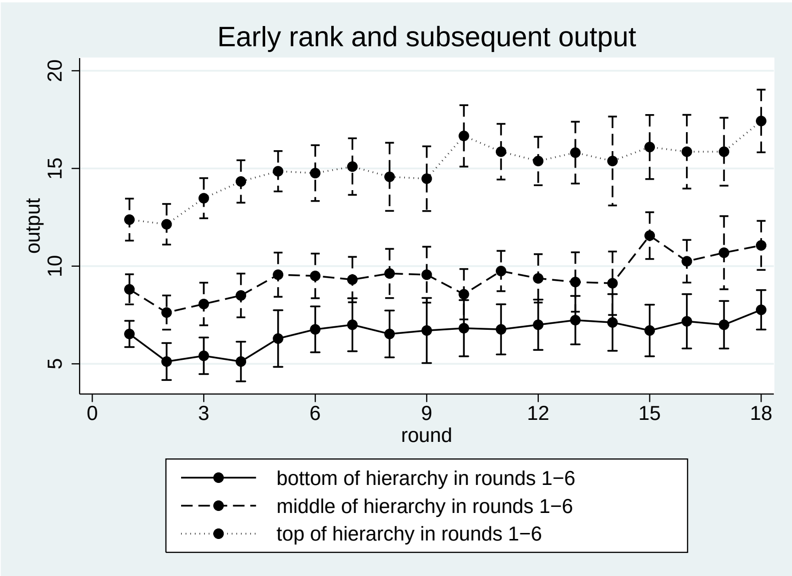

Table 1.1: The ex-post impact of feedback on estimated rank, actual rank, output and effort. $Output_t$ is the number of multiplication problems solved correctly by the subject in round t. $ExpectedRank_t$ is the rank that the subject expects to get in round t, as declared in the beginning of the round. $Rank_t$ is the actual rank achieved by the subject in round t. $Effort_t$ is subjective, self-reported measure of how hard subject worked in round t. Low values for $ExpectedRank$ and $Rank$ indicate better rank expectations, and actual rank, respectively (e.g. the top performing subject has $Rank = 1$). $ExPostFeedback_t$ is an indicator variable equal to 1 if the subject received relative ranking feedback at the end of round t. $GoodFeedback_t$ is an indicator variable equal to 1 if the subject received positive feedback at the end of round t, i.e. when $Rank_t < ExpectedRank_t$. $BadFeedback_t$ is an indicator variable equal to 1 if the subject received negative feedback at the end of round t, i.e. when $Rank_t > ExpectedRank_t$. $FeedbackLikely_t$ is an indicator variable equal to 1 if the probability the subject will receive feedback on relative ranking is 0.5 or 1 (i.e. if the subject is in the "Maybe" or "Sure" feedback treatment). $Male$ is an indicator variable equal to 1 if the subject is male. $Round_t$ is the round number. The reference category is given by observations where subjects received neutral rank information at the end of the prior round ($NeutralFeedback_{t-1} = 1$). T-statistics are in parentheses.

	$Output_t$	$ExpectedRank_t$	$Rank_t$	$Effort_t$
	Coef./t	Coef./t	Coef./t	Coef./t
$GoodFeedback_{t-1}$	–0.76	–0.50	0.63	0.01
	(–2.55)**	(–4.56)***	(3.54)***	(0.14)
$BadFeedback_{t-1}$	0.74	0.54	–0.38	0.12
	(2.19)**	(4.17)***	(–2.26)**	(0.96)
$ExPostFeedback_{t-1}$	–0.12	0.23	–0.07	–0.25
	(–0.36)	(1.49)	(–0.44)	(–2.32)**
$FeedbackLikely_t$	0.56	–0.55	–0.31	0.41
	(1.52)	(–2.81)***	(–1.79)*	(3.95)***
$Output_{t-1}$	0.75			
	(13.43)***			
$ExpectedRank_{t-1}$		0.79		
		(13.52)***		
$Rank_{t-1}$			0.66	
			(10.15)***	
$Effort_{t-1}$				0.53
				(11.13)***
$Male$	1.35	–0.39	–0.69	0.31
	(3.33)***	(–2.19)**	(–2.63)**	(3.35)***
$Round_t$	0.05	–0.01	–0.00	0.00
	(3.79)***	(–1.49)	(–0.20)	(0.67)
Adj. R^2	0.664	0.701	0.540	0.341
No. of obs	918	918	918	918

Robust standard errors clustered by subject
Session fixed effects included
$^{*}p < .10, ^{**}p < .05, ^{***}p < .01$

Table 1.2: Ex-post impact of feedback on estimated rank, actual rank, output and effort – alternative specification for models in Table 1. The reference feedback category is given by observations where subjects did not receive relative rank information at the end of the prior round ($ExPostFeedback_{t-1} = 0$). T-statistics are in parentheses.

	$Output_t$ Coef./t	$ExpectedRank_t$ Coef./t	$Rank_t$ Coef./t	$Effort_t$ Coef./t
$GoodFeedback_{t-1}$	–0.88	–0.27	0.56	–0.24
	(–3.08)***	(–1.54)	(3.50)***	(-2.30)**
$BadFeedback_{t-1}$	0.62	0.77	–0.45	–0.13
	(2.26)**	(5.17)***	(–2.66)**	(-1.18)
$NeutralFeedback_{t-1}$	–0.12	0.23	–0.07	–0.25
	(–0.36)	(1.49)	(–0.44)	(-2.32)**
$FeedbackLikely_t$	0.56	–0.55	–0.31	0.41
	(1.52)	(–2.81)***	(–1.79)*	(3.95)***
$Output_{t-1}$	0.75			
	(13.43)***			
$ExpectedRank_{t-1}$		0.79		
		(13.52)***		
$Rank_{t-1}$			0.66	
			(10.15)***	
$Effort_{t-1}$				0.53
				(11.13)***
$Male$	1.35	–0.39	–0.69	0.31
	(3.33)***	(–2.19)**	(–2.63)**	(3.35)***
$Round_t$	0.05	–0.01	–0.00	0.00
	(3.79)***	(–1.49)	(–0.20)	(0.67)
Adj. R^2	0.664	0.701	0.540	0.341
No. of obs	918	918	918	918

Robust standard errors clustered by subject
Session fixed effects included
$^{*}p < .10, ^{**}p < .05, ^{***}p < .01$

Table 1.3: Impact of heterogeneity in subjects' competitive abilities on their estimated rank, actual rank and effort. Heterogeneity in the ability to compete is proxied by the gender mix in each subject group. The sample is split by the subjects' gender (Panel A: Women, Panel B: Men). $MenInGroup_t$ and $GroupSize_t$ are the number of male subjects, and the total number of subjects in the group, respectively. $Round_t$ is the round number. $Output_t$ is the number of multiplication problems solved correctly by the subject in round t. $ExpectedRank_t$ is the rank that the subject expects to get in round t, as declared in the beginning of the round. $Rank_t$ is the actual rank achieved by the subject in round t. Low values for $ExpectedRank$ and $Rank$ indicate better rank expectations, and actual rank, respectively (e.g. the top performing subject has $Rank = 1$) $Effort_t$ is subjective, self-reported measure of how hard subject worked in round t.

	Panel A: Women Only				Panel B: Men Only			
	$Output_t$	$ExpectedRank_t$	$Rank_t$	$Effort_t$	$Output_t$	$ExpectedRank_t$	$Rank_t$	$Effort_t$
	Coef./t	Coef./t	Coef./t	Coef./t	Coef./t	Coef./t	Coef./t	Coef./t
$MenInGroup_t$	–1.10	0.37	0.60	-0.31	0.25	–0.20	–0.10	0.14
	(–2.59)**	(1.69)*	(2.68)**	(–3.27)***	(0.32)	(–0.50)	(–0.25)	(1.45)
$GroupSize_t$	0.42	0.29	0.19	0.10	–1.33	0.66	0.63	–0.16
	(0.97)	(1.25)	(0.86)	(0.88)	(–1.13)	(1.20)	(1.18)	(–1.39)
$Round_t$	0.11	0.01	0.01	–0.02	0.22	–0.02	0.00	0.00
	(4.57)***	(0.72)	(0.88)	(–1.78)*	(5.53)***	(–1.00)	(0.17)	(0.33)
Constant	7.85	1.47	1.56	4.45	20.75	–0.92	–1.33	5.21
	(2.97)***	(1.06)	(1.10)	(5.05)***	(2.46)**	(–0.32)	(–0.47)	(6.47)***
Adj. R^2	0.157	0.192	0.240	0.130	0.096	0.067	0.064	0.029
No. of obs	540	540	540	540	432	432	432	432

Robust standard errors clustered by subject

$^{*}p < .10, ^{**}p < .05, ^{***}p < .01$

Table 1.4: The ex-post impact of feedback on estimated rank, actual rank, output and effort, for rounds 1-9 (Panel A) and 10-18 (Panel B). $Output_t$ is the number of multiplication problems solved correctly by the subject in round t. $ExpectedRank_t$ is the rank that the subject expects to get in round t, as declared in the beginning of the round. $Rank_t$ is the actual rank achieved by the subject in round t. Low values for $ExpectedRank$ and $Rank$ indicate better rank expectations, and actual rank, respectively. $Effort_t$ is subjective, self-reported measure of how hard subject worked in round t. $ExPostFeedback_t$ is an indicator variable equal to 1 if the subject received relative ranking feedback at the end of round t. $GoodFeedback_t$ is an indicator variable equal to 1 if the subject received positive feedback at the end of round t, i.e. when $Rank_t < ExpectedRank_t$. $BadFeedback_t$ is an indicator variable equal to 1 if the subject received negative feedback at the end of round t, i.e. when $Rank_t > ExpectedRank_t$. $FeedbackLikely_t$ is an indicator variable equal to 1 if the probability the subject will receive feedback on relative ranking is 0.5 or 1. $Male$ is an indicator variable equal to 1 if the subject is male. $Round_t$ is the round number.

	Panel A: Rounds 1-9				Panel B: Rounds 10-18			
	$Output_t$	$ExpectedRank_t$	$Rank_t$	$Effort_t$	$Output_t$	$ExpectedRank_t$	$Rank_t$	$Effort_t$
	Coef./t	Coef./t	Coef./t	Coef./t	Coef./t	Coef./t	Coef./t	Coef./t
$GoodFeedback_{t-1}$	0.08	–0.73	0.25	0.10	–1.70	–0.22	1.03	–0.05
	(0.19)	(–4.19)***	(0.94)	(0.68)	(–3.82)***	(–1.12)	(4.26)***	(-0.30)
$BadFeedback_{t-1}$	1.20	0.89	–0.48	0.12	0.40	0.24	–0.32	0.13
	(2.71)***	(4.98)***	(–1.84)*	(0.89)	(0.79)	(1.23)	(–1.36)	(0.64)
$ExPostFeedback_{t-1}$	–0.39	0.09	0.05	–0.23	0.17	0.31	–0.18	–0.28
	(–1.08)	(0.70)	(0.24)	(–2.23)**	(0.34)	(1.39)	(–0.76)	(–1.66)
$FeedbackLikely_t$	0.41	–0.31	–0.26	0.36	0.75	–0.75	–0.37	0.45
	(1.39)	(–1.82)*	(–1.52)	(3.68)***	(1.43)	(–3.10)***	(–1.61)	(3.20)***
$Output_{t-1}$	0.81				0.70			
	(16.60)***				(10.42)***			
$ExpectedRank_{t-1}$		0.82				0.77		
		(16.74)***				(10.64)***		
$Rank_{t-1}$			0.69				0.63	
			(10.35)***				(8.64)***	
$Effort_{t-1}$				0.54				0.52
				(8.53)***				(9.66)***
$Male$	0.85	–0.35	–0.59	0.23	1.80	–0.42	–0.79	0.38
	(2.20)**	(–2.63)**	(–2.07)**	(2.45)**	(3.73)***	(–1.88)*	(–2.91)***	(3.37)***
$Round_t$	0.08	–0.01	–0.02	0.02	0.06	0.00	0.00	0.02
	(1.66)	(–0.73)	(–0.94)	(1.26)	(1.78)*	(0.04)	(0.15)	(1.61)
Adj. R^2	0.665	0.717	0.526	0.34	0.657	0.697	0.547	0.35
No. of obs	432	432	432	432	486	486	486	486

Robust standard errors clustered by subject
Session fixed effects included
$^{*}p < .10, ^{**}p < .05, ^{***}p < .01$

Table 1.5: Ratcheting effect or learning?

Subjects are divided into three categories (top, middle and bottom performers) depending on their rank in the hierarchy during the first six rounds of the task, as in Figure 1.7. $Effort_t$ is an input provided by each subject at the end of each round, before the ranking information is shown. $Output_t$ is the number of multiplication problems solved correctly by each subject in each round. $Cost\ of\ effort_t$ is calculated as $\frac{Effort_t}{Output_t}$. The average rate of change in output and in the cost of effort over time are captured by variables $\frac{\Delta Output}{\Delta Round}$ and $\frac{\Delta CostOfEffort}{\Delta Round}$, respectively, and are estimated by regressing $Output_t$ and $Cost\ of\ effort_t$ on $Round_t$ for subjects in each of the three early performance categories.

Ranking in rounds $1-6$	*Average declared effort per round*	*Average output per round*	*Average cost of effort per round*	$\frac{\Delta Output}{\Delta Round}$	$\frac{\Delta CostOfEffort}{\Delta Round}$
Top of hierarchy	4.40	14.90	0.30	0.21	-0.004
Middle of hierarchy	4.38	10.17	0.44	0.16	-0.01
Bottom of hierarchy	4.02	6.65	0.61	0.11	-0.01

2

The Price of Low Taxes: An Experimental Study of Lobbying and Redistributive Politics[†]

Abstract

Using theoretical and experimental approach we test the hypothesis that interest groups can buy influence through monetary contributions to the policy makers. We find evidence that in settings of repeated interaction lobbyists are able to influence legislators' policy decisions in spite of no formal contracts, no communication and no information exchange. We find very little evidence of strong reciprocity from the candidates.

2.1 Introduction

The number of interest groups, active lobbyists as well the amounts spent on lobbying continue to grow every year. In 2007 a total of $2.83 Billion was spent on lobbying in United States. The number of lobbyists in 2008 rose to 15,963[1]. Those numbers have followed a rising trend for a long time. Total contributions from Political Action Committees (PACs) to Federal Candidates

[†]This chapter was written in collaboration with Jens Großer from Florida State University and Ernesto Reuben from Northwestern University

[1]data from http://www.opensecrets.org/lobby/index.php last checked on December 3, 2008

reached \$346,479,477 in election cycle 2008[2] which is by far not a small number. There is no doubt that the transfers from interest groups to candidates sum up to enormous amounts of money. However, there is no firm agreement about how financial contributions from lobbyists to legislators exactly benefit the lobbyists and we seek to address this gap in literature. Using an experimental set up, we are able to assess whether interest groups can directly exert influence on the policy makers' decisions through unconditional monetary transfers.

Most interest groups have economic issues at heart and carry out heavy research on the matters of their interest. They look for solutions that would serve their goals and improve welfare of their members. However, as they lack the legislative power, they need to convince policy makers to take a favorable course of action and implement desired laws and policies. One way that lobbyists exert influence is through information provision. Legislators make decisions about a wide range of complex issues and do not have enough resources to specialize in each one of them. Therefore, they lack the depth of knowledge that interest groups have and may be interested in learning from them. In our paper we abstract from the issues of information transition. An interested reader can refer to Potters and van Winden (2000) who provide theoretic and experimental analysis of lobbying through information. Other papers that model lobbying as strategic information transmission include Ainsworth (1993), Austen-Smith (1993), Austen-Smith (1995), Austen-Smith and Wright (1992), Lohmann (1995), Potters and van Winden (1992), and Rasmusen (1993).

Our focus is instead on another type of lobbyists' activity - monetary contributions to parties and candidates. While contributions from corporations, trade organizations and labor unions to federal candidates were outlawed long ago, there are still legal ways through which organized groups can support candidates financially. Political Action Committees (PACs) are organizations that collect money from individuals and under Federal Election Campaign Act from 1974 are allowed to legally contribute to political candidates and parties. The maximum allowed contribution per candidate and per political party is regulated by the law, but only at the federal level. At the state level the size

[2] data from http://www.opensecrets.org/pacs/index.php last checked on December 3, 2008

of the support is unlimited (this is referred to as "soft" money).

Members of the interest groups and policymakers justify the monetary transfers as means to get access to legislators (Grossman and Helpman 2001; Hansen 1991) and to prove credibility. By putting money where their mouths are interest groups send a message that the issues they raise are important and economically relevant. They are therefore more likely to get attention and respect of the policy maker. Policy makers are more likely to trust the information they get if it is backed up with money as it signals that the interest group used adequate resources for research instead of coming up with ideas that are not thoroughly analyzed. As mentioned earlier, theoretical and experimental evidence confirms that it could be reasonable for interest groups to pay for an opportunity to meet with policy maker in order to provide him with information and distort his views. But is it all?

Another alternative explanation is that those contributions buy direct influence. We hypothesize that by supporting a policy maker financially, the lobbyist buys his sympathy and can influence his decision even when access, credibility and information transmission issues are absent. Verifying whether this hypothesis is indeed true is very hard if not impossible using field data. The ideal dataset for understanding the role of monetary contributions on policymaker's decisions would allow us to compare legislator's decisions under different contribution levels, all other things being equal. Therefore, we used controlled laboratory environment to test the hypothesis that money buys direct influence.

The experiment was conducted at Northwestern University using standard procedures. Given that lobbyists are active in practically all areas of policy making, there are many ways in which the experiment could be framed. In our set up we chose tax rate as policy of interest for its simplicity, ease of explanation and economic relevance. In reality, most countries exhibit poor majorities. In particular, top 1% earn disproportionate amounts with share of income equal to 16% before taxes and 14% after taxes. Earnings of top 20% amount to 54% of total income before taxes and 50% after taxes. Given such evident disproportions one may wonder why the majority does not redistribute more from the rich. After all everybody, independent of the income, has equal power to elect legislators. One of the reasons could be that more equal redistributions would destroy incentives to work. However, as Krugman said "there is very little evidence that taxing capital gains would actually hurt the economy". Another reason could be tracked down to income mobility. Even poor want low taxes in case they become rich tomorrow. However, mobility is not higher in low-taxing USA than in high-taxing Scandinavian countries (Bowles and Gintis 2002). Alternatively, maybe rich are able to achieve lower redistribution through monetary transfers? Interest groups can transfer money to policymakers in many ways, both legally (as discussed earlier) as well as illegally (through bribes, gifts, future jobs, etc). Contracts involving such an exchange of favors (money for preferred policy) could not be formally enforced but there is room for informal enforcement, for example through "strong" reciprocity or repeated interaction.

In the experiment subjects act in one of two different roles. They are either candidates who decide on policy (tax rate) and later run in elections; or they are voters. Out of four voters one is rich and has the possibility to transfer any part of his resources to the candidates before they choose the policy. He, therefore, represents the lobbyist in the experiment. Transfers are unconditional and do not oblige candidates to take any particular action. Candidates have no way of spending the money while in the lab (so votes in the elections cannot be bought with it). After the transfers are made, candidates make binding announcement regarding the chosen policy. Then voting and elections take place and the policy of the candidate who won is implemented.

If monetary contributions do not buy influence, then no transfers should be made to the candidates and candidates driven by the desire to win elections should announce the tax that is preferred by the majority (so by poor voters). If we find evidence of positive transfers followed by the policies more favorable for rich voter (lobbyist) we can interpret it as support for the hypothesis that money buys influence.

Our data reveals that, under some conditions, financial contributions indeed buy influence. Rich voter through monetary contributions is able to significantly change the announced and implemented policy to one that benefits him even though it hurts the majority in the society. This suggests that money does not only buy access and credibility as claimed by lobbyists and legislators but it also buys influence. However, the relationship between transfer and chosen policy is present only in partners treatments so when rich voter can form long lasting relationship with candidates. This result is in line with what we observe in real life where most of the lobbying goes to the incumbent candidates with whom the interest group had a chance to interact in the past. The possibility of extending the relationship to more than one period seems to be crucial for the lobbying to be effective. In strangers treatment (in each period different subjects out of candidate pool are active and different voter from the pool of voters is rich) while transfers are not significantly different from those in partners treatment, we find out that they have no impact on the chosen policy. Comparing strangers and partners treatments we find little evidence of strong reciprocity - reciprocity driven candidates should be equally responsive to transfers in both conditions which is not the case. Our data hints that monetary transfers buy influence through repeated interaction.

When long-term relationships are possible we find evidence that the candidates are influenced not only by the size of transfer they received but also by the size of transfer that was made to their opponent, with the chosen policy being less favorable for the lobbyist if he transfers more to the opponent. The best strategy for the lobbyist seems to be to lobby equally both candidates. Such strategy is in line with theoretical predictions (Grossman and Helpman 2001) and strategies that most lobbyists follow in the real world. Two top contributors in election cycle 2007-2008 contributed almost equal amounts to both republicans and democrats. National Association of Realtors has spent $3,729,400 out of which 57% went to democrats and 43% to republicans. AT&T Inc has spent $2,813,700 with 45% of the amount going to democrats and 55% going to republicans (see www.fec.gov).

The rest of the paper is structured as follows: in section 2 we explain the experimental design and equilibrium predictions. In section 3 we present the results of the experiment and section 4 concludes.

2.2 Experimental design and equilibrium predictions

In this section we first describe the game subjects played in the experiment, for which we then derive the equilibrium predictions. The game is designed to capture in a simple way a situation in which a minority of affluent individuals have the opportunity to use monetary transfers to influence redistributive policies. Finally, we describe in detail the different treatments and we give an overview of the experimental procedures.

2.2.1 The lobbying game

Consider the following three-stage game with $i = 1, \ldots, n \geq 3$ voters and two political candidates, $j = A, B$. Each voter i has an initial capital endowment, $e_i \geq 0$, where $\overline{e} \equiv \frac{1}{n}\sum_{i=1}^{n} e_i$ denotes the average endowment. We assume that there is one *rich* voter, R, who has $e_R > \overline{e}$ and $n-1$ *poor* voters, $i \neq R$, who have $e_{i \neq R} < \overline{e}$ each.

In the first (or *lobbying*) stage, R has the opportunity to transfer money amounts, $l_{R \to j} \geq 0$, to each candidate j, respectively, with the only restriction that $0 \leq l_R \leq e_R$, where $l_R \equiv l_{R \to A} + l_{R \to B}$. Importantly, these transfers do not change the decision space of candidates and voters in the following stages. In particular, candidates have no obligations towards R when being lobbied.

In the second (or *tax competition*) stage, the two candidates choose redistributive tax rates, $t_j \in [0, 1]$, which determine the degree to which voter R must share her capital endowment with the poor voters. Specifically, if candidate j's tax rate applies, each voter i's after-tax endowment is given by $e_{i,t_j} \equiv e_i + t_j(\overline{e} - e_i)$. In the extreme case of no redistribution, $t_j = 0 \Rightarrow e_{R,t_j=0} = e_R$ and $e_{i,t_j=0} = e_i, \forall i \neq R$, and at the other extreme of full redistribution, $t_j = 1 \Rightarrow e_{i,t_j=1} = \overline{e}, \forall i$. The candidates make their decisions using the following three-step procedure: candidate j chooses her tax rate first, and candidate $-j \neq j$ chooses her tax rate after observing t_j. Thereafter, the two candidates simultaneously and independently either accept the current pair of tax rates, (t_j, t_{-j}), or opt for a change at a cost $c = c_A = c_B > 0$. If both accept, the game proceeds to the third stage. If at least one candidate asks for a change, the three-step procedure is repeated until eventually a pair of tax rates is accepted by both candidates.

In the third (or *election*) stage, the accepted tax rates, t_A and t_B, compete in simple majority elections (with random tie breaking), in which voters simultaneously and independently can either vote for candidate A or for candidate B (abstention is not an option). The winning candidate, w, receives a strictly positive reward, $r > c$, and her tax rate, t_w, determines the the voters' after-tax endowments. The loser's (normalized) reward is zero and her tax rate is of no consequence.

Then, candidate j's payoff is

$$\pi_j = l_{R \to j} - C_j + \begin{cases} r & \text{if} \quad V_j > V_{-j} \\ r/2 & \text{if} \quad V_j = V_{-j} \\ 0 & \text{if} \quad V_j < V_{-j} \end{cases}, \tag{2.1}$$

where C_j denotes j's total costs of tax rate changes and V_j and V_j denote the total number of votes for j and $-j$, respectively. Moreover, voter R's payoff is given by

$$\pi_R = e_R - l_R + t_w(\overline{e} - e_R), \tag{2.2}$$

and each voter $i \neq R$'s payoff is given by

$$\pi_{i \neq R} = e_i + t_w(\overline{e} - e_i). \tag{2.3}$$

2.2.2 Equilibrium predictions

We proceed in the reverse order of the stages ('backwards induction') to derive our subgame-perfect Nash equilibrium predictions, and we assume that all players are self-interested with respect to their monetary payoffs. Moreover, we use iterated elimination of weakly dominated strategies as equilibrium refinement in each stage of the game. This gives:

Proposition 7 *In the unique subgame-perfect Nash equilibrium in weakly dominant strategies, voter R does not transfer any money amounts to the candidates, $l_R^* = 0$, both candidates immediately choose and accept full redistribution, $t_A^* = t_B^* = 1$, and all voters randomize their votes between the two identical tax rates.*

Proof. In each stage, we use iterated elimination of weakly dominated strategies as a Nash equilibrium refinement. Then, in the election stage each voter votes sincerely: that is, if $t_j < t_{-j}$, voter R votes for candidate j and each voter $i \neq R$ votes for candidate $-j$; and if $t_j = t_j$, all voters randomize their votes between the two candidates. This is because voter i's payoff is higher if she votes sincerely than if she votes insincerely in cases where her vote is pivotal, that is, if n is odd (even) when there are $\frac{n-1}{2}$ votes $\left(\left[\frac{n-1}{2}\right]\right.$ and $\left[\frac{n-1}{2}\right]$ votes, respectively$\left.\right)$ for the two candidates by the other voters $-i \neq i$. In all other cases her vote is not pivotal and her payoff does not dependent on her vote decision. Thus, voting sincerely weakly dominates voting insincerely. Each candidate anticipates the voters' decisions in the election stage. Then, in the tax competition stage the two candidates choose $t_A^* = t_B^* = 1$ immediately, and both accept this pair of tax rates immediately. These tax rates weakly dominate any smaller tax rates, $t_j' < 1$, because t_j' yields the same payoff for j as t_j^* if $t_{-j} < t_j'$, it yields a lower expected payoff than t_j^* if $t_{-j} = t_j'$, and it yields a lower payoff than t_j^* if $t_{-j} > t_j'$.[3] Moreover, $t_A^* = t_B^* = 1$ are chosen and accepted immediately, because not doing so costs $c > 0$. Anticipating $t_A^* = t_B^* = 1$ in the second stage, voter R chooses $l_R = 0$ in the lobbying stage because transfers do not prevent full redistribution determined in subsequent stages and, thus, lobbying would only reduce R's payoff ■

Note that these predictions hold for each period if the game is repeated finitely. Moreover, giving up the refinement of iterated elimination of weakly dominated strategies would yield many subgame-perfect Nash equilibria, hence, would substantially reduce the power of our predictions. In Section 2.3 we investigate whether our equilibrium refinement is justified by the experimental results.

2.2.3 Experimental design

Participants in the experiment repeatedly play the lobbying game for 30 periods. In all cases, participants are randomly divided into groups. In each group there is an electorate of $n = 4$ voters (one rich voter and three poor

[3]Observe the similarity between our tax competition stage and Bertrand games that model price competition between firms (cf. Motta 2004).

voters) and at least two candidates. Every period, voter R receives an endowment of $e_R = 130$ points and each poor voter receives an endowment of $e_{i \neq R} = 10$ points.[4] Consequently, in the full-redistribution equilibrium described in Proposition 7, all voters end up receiving the average endowment $\overline{e} = 40$ points. Candidates receive a reward of $r = 20$ points if they win the election and the cost of changing their submitted tax rate is $c = 1$ point. In addition, in order for candidates and voters to receive comparable earnings in the experiment, candidates received a fixed payment of 25 points per period independent the electoral results. Hence, given that there are no transfers, both candidates choose a tax rate of 1, and voters randomize their vote, candidates can expect on average 37.5 points per period. The roles of candidate or voter are randomly assigned among the participants at the beginning of the experiment and stay constant throughout the 30 periods.

We use two treatment variations. First, we vary the ability of the rich voter to transfer money to the candidates. Specifically, all participants play 15 periods of the game as described above. We refer to these periods as the *Lobbying* treatment. In remaining 15 periods, participants play the lobbying game but without the lobbying stage. We refer to these periods as the *No-Lobbying* treatment as rich voters are not able to transfer money to the candidates.[5] The No-Lobbying treatment servers as a control that allows us to evaluate whether candidates deviate from a tax rate of 1 due to transfers by voter R or due to other reasons. In order to control for order effects, roughly half the participants play first the No-Lobbying treatment and then Lobbying treatment, and the other half play first the Lobbying treatment and then the No-Lobbying treatment.

The second treatment variation corresponds to the ability of voters and candidates to keep track and reciprocate the actions of others across periods.

[4]Note that although this distribution is very unequal—25% of the electorate possess 81.25% of all resources—it is not far from some of the income distributions of various countries. For example, in both Brazil and in South Africa, the income of top 30% of the population corresponds to about 75% of the national income (see, http://go.worldbank.org/6F2DBUXBE0).

[5]Note that, as voter R does not transfer any money amounts to the candidates in the equilibrium described in Proposition 7, the predictions for the No-Lobbying treatment are essentially the same: both candidates immediately choose and accept full redistribution and all voters randomize their votes between the two identical tax rates.

Table 2.1: Number of groups in each treatment and sequence

Sequence \ Matching	Partners	Strangers
No-Lobbying → Lobbying	8	5
Lobbying → No-Lobbying	9	6

Participants play either in the *Partners* treatment, where voters always interact with the same candidates and the voter R is always the same participant, or in the *Strangers* treatment, where candidates and the participant who plays as voter R change every period. Specifically, in the Partners treatment, groups consist four voters and two candidates. Before the first period is played, candidates are randomly assigned to be either 'Candidate 1' or 'Candidate 2' and voters are assigned to be either rich or poor. Candidates keep the same label and voters keep the same role throughout the experiment. In the Strangers treatment, groups consist of four voters and a pool of participants from which candidates are drawn. Specifically, at the beginning of *each period*, two participants are randomly selected from this pool (each with equal probability) to be a candidate. Again, candidates are labeled as 'Candidate 1' or 'Candidate 2', but in this case, these labels are randomized such that the same participant does not receive the same label in two consecutive periods. Similarly, in each period, the role of voter R is randomly assigned among the four voters, each with equal probability. In the experiment, the average size of the pool of potential candidates was 6.45 participants (with standard deviation of 1.29, a median of 6, a minimum of 4, and a maximum of 8).[6] The 2×2 experiential design along with the number of groups in each treatment is summarized in Table 2.1.

Note that given the assumption of self-interested and fully rational individuals, the predicted behavior described in Proposition 7 holds for both the Partners and Strangers treatment. However, this might not be the case if candidates reciprocate the transfers of voter R. Given the inability of candidates and voters to keep track of each other's actions in the Strangers treatment, we consider that if candidates exhibit reciprocal behavior then it must be due to

[6]Differences in the size of the pool were due to different number of participants showing up for the experiment.

non-strategic motivations—that is, it is not motivated by the expectation of future interaction (for examples see Fehr and Gächter 2000). In the Partner's treatment, constant labeling and repeated interaction between the various parties can allow for more strategic forms of reciprocity. In particular, in line with Kreps, Milgrom, Roberts, and Wilson (1982), both voter R and the candidates could use tit-for-tat type of strategies to coordinate in an equilibrium in which rich voters transfer some money to candidates and they reciprocate by coordinating on a lower tax rate. Thus, by comparing behavior across the Partners and Strangers treatments, we are able to identify the relative importance of these forms of reciprocity in explaining any deviations from full redistribution.

In both treatments, all participants are informed of the matching scheme. Furthermore, in order to give voters and candidates the same learning opportunities in both treatments, we provide all participants in a group with the following information in each period (in the strangers treatment, this even includes the non-selected participants from the pool of potential candidates): the amount transferred by voter R to each candidate, the tax rate chosen by each candidate, and the total number of votes received by each candidate.

The experiment was conducted in the laboratory of the Kellogg School of Management in Northwestern University. In total, 217 students participated and were paid at an exchange rate of 50 points for one US dollar. Participants earned on average \$21.27. The detailed experimental procedures and the instructions are available in Appendix 2.4.

2.3 Results

First we present data on tax and transfer levels in different treatments (Lobbying, No-Lobbying, Partners, Strangers) and identify differences between them. Then we look for the determinants of tax, transfer and voting decisions to further understand the impact that financial lobbying can have on political decisions.

2.3.1 Taxes and transfers in different treatments

Transfers

Data reveals that many rich voters decide to make transfers to the candidates. They transfer something to at least one of the candidates 43% of the time. The average total transfer (sum of transfers made to both candidates) in a given period is equal to 13.84 points but there is large variance between how much candidates transfer with standard deviation equal to 24.13 points and maximum total transfer equal to the whole endowment of 130 points. There is no significant difference between average individual transfers in strangers and partners treatments (8.055 for strangers vs. 6.184 for partners, $p = 0.4942$ in a two-sided mean comparison test).

As stated in Proposition 7, in equilibrium no transfers should be made because under rationality and self-interest assumptions transfers cannot have any effect on the policy. However, if rich voter assigns positive probability to the proposition that candidates have a taste for reciprocity and announce lower taxes following a transfer or if the interaction is repeated sufficient number of times, then cooperation can turn out to be an equilibrium outcome, as shown in the seminal paper by Kreps, Milgrom, Roberts, and Wilson (1982).

Taxes

In the absence of lobbying, rational self-interested candidates, who compete in elections, should announce 100% tax rate in order to attract as many votes as possible (Proposition 7). Fig. 2.1 illustrates that in the no lobbying (NL) parts taxes on average are very high and quickly converge to the equilibrium 100% level. The slightly lower taxes in the initial periods of the experiment are mistakes resulting from lack of experience. We observe them only if no lobbying part occurred first in the experiment. If no lobbying part occurred second so after subjects had some prior experience with similar environment, tax rates are at the equilibrium (that is 100%) level from the very first period (compare Fig. 2.2 and Fig. 2.3).

Taxes could be lower in the lobbying part of the experiment for various reasons. First of all, if we relax the assumption that candidates are self-interested, it may be optimal for them to reciprocate the transfers in form of lower taxes. Evidence of strong reciprocity, so willingness to repay gifts even in anonymous one-shot encounters with genetically unrelated strangers when such behavior is against rationality and material self-interest was found for example by Fehr and Gächter (2000) and Fehr, Fischbacher, and Gächter (2002). Moreover, even non reciprocal and purely self-interest driven candidates can find it profitable to announce lower taxes and establish a lasting cooperative relationship with rich voter (Kreps, Milgrom, Roberts, and Wilson 1982). In particular, it may be beneficial for both the rich voter and candidates to establish a relationship in which rich voter transfers a part of his endowment to the candidates and they in return coordinate on lower taxes.

We have already noted that transfers are the same in strangers and partners treatment. Therefore, if strong reciprocity drives the behavior of the candidates there should be no difference in taxes between strangers and partners treatment. If subjects are driven by self interest and reciprocate for strategic reasons then the taxes should be lower in partners treatment because only in this treatment reputation building and long term cooperation is possible.

In partners treatment, in the parts of the experiment when lobbying is possible, we find out that in all periods the average winning tax rate is lower than in strangers treatment (see Fig. 2.4). On average the winning tax is equal to 86.3137% in partners treatment and 97.5758% in strangers treatment. The difference is significant with $p = 0.011$ in a one-sided mean comparison test. This result suggests that the possibility of forming long term relationships is important determinant of how successful lobbying will be. Even though there is no significant difference in transfers between strangers and partners treatment, the taxes differ significantly.

The average winning tax rate of 97.5758% in L part of strangers treatment is very high and close to "selfish" equilibrium level of 100% . Indeed we find out that in strangers treatment winning tax rate is not affected by the possibility of lobbying (97.909 vs. 97.576 $p = 0.7967$ in a two-sided mean comparison test) and average tax rate is only slightly lower when lobbying is possible (95.651 vs. 92.636 $p = 0.0718$ in a one-sided mean comparison test, $p = 0.1435$ in a two-sided mean comparison test). This is illustrated in Fig. 2.5.

In partners treatment, when all subjects are active and keep the same roles throughout the experiment, both average and winning tax rates are on average significantly lower when rich voter can transfer points to the candidates as compared to the situation when he cannot make such transfers (see Fig. 2.6). The winning tax rate drops from 97.412 to 86.313 % ($p = 0.0135$ in a one-sided mean comparison test) and average tax rate drops from 94.912 to 81.814 % ($p = 0.0068$ in a one-sided mean comparison test).

These results suggest that the possibility of building long term relationship between rich voter and candidates is necessary for lobbying to be effective. We will now turn to understand in more detail the determinants of transfers and taxes and how they differ in strangers and partners treatment.

2.3.2 Transfer and Tax Determinants

While candidates respond to the possibility of lobbing in partners treatment there is no significant response in strangers treatment. We already have some evidence that this difference in candidates' behavior cannot be caused by differences in transfer size because if anything, voters transfer more in strangers treatment. We further find out that correlation between transfers and taxes in given period is much stronger and significant in partners treatment (the Spearman rank correlation between Tax_t and $Transfer_t$ is -0.5953, $p < 0.0001$) than in strangers treatment (Spearman's rho=-0.1045, $p = 0.0578$) suggesting that the size of transfer has stronger impact on candidate's tax decision when subjects repeatedly interact with the same people.

In order to get a more complete picture of tax rate determinants we run regressions presented in Table 2.2. In partners treatment, we find out that the higher the amount transfered to the candidate the lower the tax. Taxes are also affected by the amount that was transfered to their competitor suggesting that not only the absolute but also relative size of lobbying matters. Transfers in the previous period have significant but opposite effect showing that candidates respond to changes in transfers made to them and others. Further, candidates' tax announcements are highly correlated with each other as well as with previous announcements.

In strangers treatment we do not find any significant tax determinants. Neither the size of current or previous transfer received by the candidate or his opponents influences his tax decision. This is independent of whether we look only at the subjects' own experience (so what happened in the rounds when they were active) (middle column in Table 2.2), or all the observations that subjects make (they are following the progress of the game on their screens at all times, also when they are inactive) (right hand side column in Table 2.2). This further confirms that our subjects are not driven by strong reciprocity as they do not pay any attention to the size of transfers received or the history of the game when setting the tax.

There is intuitive explanation for why in strangers treatment candidates are not inclined to respond to higher transfers with lower taxes. First of all, they cannot be punished for not reciprocating the transfer with more favorable tax. The rich voter could only punish (that is not transfer anything) in the next, and not current, period, however he has only 25 % chance of being rich in the following period. Even if he is rich again, than he still does not know whether the candidate he is facing is the one he played with in the previous period because the identities of the players are kept private. Secondly, cooperation is harder to achieve because there is no way to build up a reputation. All candidates would have to cooperate and reciprocate the bribes and given that there is only little probability of being asked to play again there is large temptation to announce low taxes preferred by majority and collect the benefits from winning the election.

Since the size of transfer does not influence the tax in strangers treatment we want to see whether voters learn this as time passes by and consequently decrease the amount given to the candidates. Fig. 2.7 as well as Table 2.4 show that transfers decrease over time. We do not find any other significant determinants of transfer size in strangers treatment (see Table 2.4). Voters do not change the size of the transfer in response to previously announced tax rates, they decrease the transfer over time and also transfer significantly less to the candidates if lobbing occurs in part two of the experiment i.e. after they had some prior experience with the environment. Transfers made to the candidates are again highly correlated (Spearman's rho = 0.7040, $p < 0.0001$).

Table 2.3 presents transfer determinants in partners treatment. Higher taxes lead to lower future transfers (punishment). Transfers are higher if lobbying occurred in the second part of the experiment suggesting that having some experience with the environment subjects realize that a substantial rather than symbolic transfer is needed to persuade the candidates to forgo winning benefits and announce more favorable tax. Transfers to the players are highly correlated (Spearman's rho = 0.7946, $p < 0.0001$) which is a very rational strategy given that candidates are sensitive not only to the absolute but also relative size of the transfer they receive (and they announce significantly higher taxes when the other candidate received higher transfer).

2.3.3 Wealth Effects

So far we have shown that in partners treatment rich voters, by transferring a part of their wealth to candidates, are able to influence candidate's tax decision. The question that remains is whether the decrease in taxes is enough to compensate for the cost of transfers, that is whether it pays off for the rich voter to lobby. As illustrated in Figure 2.8 we find out evidence to the contrary. Rich voter's earnings are significantly lower when lobbying is possible both in partners treatment (42.329 vs. 39.949, $p = 0.0977$ in a one-sided mean comparison test) and in particular in strangers treatment (41.882 vs. 26.073, $p = 0.0019$ in a one-sided mean comparison test).

2.4 Conclusion

In our experimental set up we find evidence that supports proposition that through lobbying rich members of the society are able to influence legislators' tax decisions in settings of repeated interaction (in spite of no formal contracts). We find very little evidence of "strong" reciprocity from the candidates as monetary transfers do not have significant influence on tax rates in one-shot relations. Also in spite of lobbying being successful, it is not profitable for the rich and candidates are the ones that benefit from it most.

To the best of our knowledge, this is the first experimental approach to understand the impact of lobbying through monetary contributions and we see a lot of potential for future research within this framework. We mention a few of possible extensions of the experiment in the following paragraphs.

We find out that it is hard for the candidates in our experiment to coordinate on lower taxes. In the experiment the only tool to foster cooperation is the possibility to change the tax rate after the announcement of the competitor. In real life situations candidates and / or lobbyists can communicate relatively easily and it would be interesting to verify in controlled experimental set up how such communication influences the policy outcomes. We suspect that verbal, even if not binding, promises and agreements foster the relationship between legislators and lobbyist and further decrease taxes.

Another difference between our experiment and real life is that the subjects are endowed with their income and pure luck decides who is rich and who is poor. In real life, on the other hand, wealth usually comes as a result of and is a symbol of hard work. Therefore, in reality legislators may consider full redistribution less fair and also appreciate transfers more. This leads to a hypothesis that deserves empirical verification, namely that transfers are more effective, even in one-shot interactions, when income is earned through hard work.

An interesting and related question is whether legislators announce policies that favor the rich in order to receive something from them in return later. Maybe only a prospect of receiving a transfer from the rich is enough to distort policies from those preferred by poor majorities. An environment very similar to the one used in this paper would help us understand such concerns. If we ask the policy makers to announce the taxes first and then allow rich people to contribute to the legislators, will they express their gratitude?

Lobbying plays a very important role in modern politics and huge amounts of money are transferred to the legislators each year. This work suggests that monetary transfers have economic impact even if they do not involve any formal contracts. Understanding this process in full detail is therefore relevant from economic stand point and surely deserves further investigation.

Appendix to Chapter 2

Experimental procedures and instructions

Experimental procedures

The computerized experiment was conducted in 2008 in the laboratory of the Kellogg School of Management of Northwestern University. Recruitment was done from the school's pool of experimental participants, which consists almost exclusively of Northwestern undergraduate students. The 217 participants signed up to the experiment using the school's recruitment website. The experiment was computerized and programmed with z-Tree (Fischbacher 2007b), and it lasted around one hour. In each session there were between eight to twelve participants. All participants in a session played either the Partners or the Strangers treatment and one of the two sequences: either Lobbying→No-Lobbying or No-Lobbying→Lobbying.

After their arrival, participants were asked to take a seat in the laboratory. Once everyone was seated, participants were given the IRB consent form in which they agree to participate in the experiment. Thereafter, they were given the instructions (available below) followed by a few questions designed to check their understanding of the game. Participants were told that the experiment consisted of two parts and were first given the instructions to part 1, which described either the Lobbying or the No-Lobbying treatment (depending on the sequence being played). after playing the 15 periods of part 1, instructions were distributed for part 2. After playing part 2, participants answered a short debriefing questionnaire after which they were paid their earnings and dismissed.

Below is a sample of the instructions used in the experiment. It corresponds to the Lobbying treatment with Strangers matching when it was played as part 1. The instructions for other treatments are very similar and are available upon request.

Instructions

General

You are participating in an experiment on economic decision making and will be asked to make a number of choices. If you follow the instructions carefully, you can earn money. At the end of the experiment, you will be paid your earnings in cash.

You are not allowed to communicate with other participants. If you have a question, raise your hand and we will gladly help you.

During the experiment your earnings will be expressed in points. Points will be converted to US dollars at the following rate: **50 points = $1.00**.

The experiment is strictly anonymous: that is, your identity and actions will not be revealed to others and the identity and actions of others will not be revealed to you.

At the beginning of the experiment, participants will be randomly assigned to different roles. Four of you will be assigned to the role of a **voter** and the rest will be assigned to the role of a **candidate**. You will keep the same role during the entire experiment.

The experiment consists of two parts. In the following paragraphs you will find the instructions for part one. The instructions for part two will be given to you once part one has ended.

Part 1 - Instructions

Part 1 of the experiment consists of 15 periods. As payment for this part, you will receive the sum of your earnings over the 15 periods. Each period is divided into four stages. They are described in detail below. For convenience, when appropriate, we describe the voter's decisions on the left column and the candidates on the right column.

Voters	Candidates
Stage one	**Stage one**

In stage one, voters learn what their endowment in this period is. In each period, **one** of the four voters is randomly selected to receive an endowment of **130 points**. For convenience we refer to this voter as voter130. The three remaining voters receive and endowment of **10 points**, we refer to them as voter10.

Stage two

In stage two, voter130 decides how many points to transfer to candidate 1 and to candidate 2. He can choose any amount from his/her endowment (between 0 and 130 points). Voter10s do not make any transfers. Once voter130 makes a decision, the amount transferred to each candidate will be seen by all voters on the screen.

Stage three

In stage one, all candidates receive an endowment of **20 points**. In addition, candidates learn whether they are active of inactive in this period. In each period, **two** candidates are randomly selected to be active. They will be randomly labeled as candidate 1 and candidate 2. Note that candidate 1 and 2 will be **different** participants in every period. In a given period, only active candidates make decisions and have the opportunity of earn additional points. Candidates that are inactive can follow the progress of the experiment on their screens.

Stage two

In this stage, candidate 1 and candidate 2 are informed of the amount of points they received from voter130. They will also be informed of the number of points transferred to the other active candidate.

Stage three

In this stage, voters are informed of the percentage chosen by candidate 1 and by candidate 2.	In stage three, candidate 1 and candidate 2 each choose a percentage between 0% and 100%. The precise procedure by which they arrive to their choice is described in detail in the next page.
Stage four In stage four, voters cast a vote in favor of candidate 1 or in favor of candidate 2. The candidate with more votes wins and his/her chosen percentage is used to determine the voters' earnings in this period. In case of a tie, a candidate is randomly selected to be the winner. They way in which the winning percentage determines the voters' earnings, is described in detail below.	**Stage four** In this stage, candidates are informed of the voting outcome and on whether they won or lost. Candidates that win receive **20 additional points** as earnings in this period. Candidates that lose do not receive additional points.

Choosing a percentage

In this section we describe the procedure used by candidate 1 and candidate 2 to choose a percentage. The procedure is divided in steps:

Step 1: Candidate 1 chooses a percentage, which is communicated to candidate 2.

Step 2: Candidate 2 chooses a percentage, which is communicated to candidate 1.

Step 3: Candidate 1 decides either to accept or to change his/her percentage. If candidate 1 accepts, the procedure ends and the two percentages are communicated to the voters. If candidate 1 changes his/her percentage, the new percentage is communicated to candidate 2 and the procedure continues to step 4.

Step 4: Candidate 2 decides either to accept or to change his/her percentage. If candidate 2 accepts, the procedure ends and the two percentages are communicated to the voters. If candidate 2 changes his/her percentage, the new percentage is communicated to candidate 1 and the procedure goes back to step 3.

Note that the procedure does not end until one of the two candidates decides to accept.

Costs of changing percentage: There is a small cost of changing the percentage in step 3 or 4. Each time a candidate chooses to change his/her percentage it costs that candidate 0.5 points from his/her endowment.

Wining percentage and voters' earnings

The earnings of voters in each period are determined by the percentage chosen by the winning candidate. Specifically the earnings, in points, of voter10s are given by the following rule:

$$\text{earnings} = 10 + [\text{percentage}] \times 30$$

And the earnings, in points, of voter130 are given by the following rule:

$$\text{earnings} = 130 \text{ - } [\text{percentage}] \times 90 \text{ - } [\text{transfer to candidate 1}] \text{ - } [\text{transfer to candidate 2}]$$

To illustrate how earnings are calculated we provide below a series of examples.

Example 1: Suppose voter130 decides not to transfer any points to both candidates. In this case, the voters' earnings for different winning percentages are given in the table below.

Percentage	Earnings of voter130		Earnings of voter10s	
0%	**130 points**	= 130 - 0.00 × 90	**10 points**	= 10 + 0.00 × 30
25%	**107.5 points**	= 130 - 0.25 × 90	**17.5 points**	= 10 + 0.25 × 30
50%	**85 points**	= 130 - 0.50 × 90	**25 points**	= 10 + 0.50 × 30
75%	**62.5 points**	= 130 - 0.75 × 90	**32.5 points**	= 10 + 0.75 × 30
100%	**40 points**	= 130 - 1.00 × 90	**40 points**	= 10 + 1.00 × 30

Example 2: Suppose now that voter130 transfers 15 points to candidate 1 and 25 points to candidate 2. In this case, the voters' earnings for different winning percentages are given in the table below.

Percentage	Earnings of voter130		Earnings of voter10s	
0%	**90 points**	= 130 - 0.00 × 90 -15 -25	**10 points**	= 10 + 0.00 × 30
25%	**67.5 points**	= 130 - 0.25 × 90 -15 -25	**17.5 points**	= 10 + 0.25 × 30
50%	**45 points**	= 130 - 0.50 × 90 -15 -25	**25 points**	= 10 + 0.50 × 30
75%	**22.5 points**	= 130 - 0.75 × 90 -15 -25	**32.5 points**	= 10 + 0.75 × 30
100%	**0 points**	= 130 - 1.00 × 90 -15 -25	**40 points**	= 10 + 1.00 × 30

Candidates' earnings

The earnings of the candidate who wins are given by:

earnings = 20 + 20 + [transfer from voter130] - [costs incurred when choosing a percentage]

The earnings of the losing candidate are given by:

earnings = 20 + [transfer from voter130] - [costs incurred when choosing a percentage]

Here are a couple of examples.

Example 1: If a candidate changes his/her percentage four times, receives 5 points from voter130, and wins the election, his/her earnings equal: **43 points** = 20 + 20 + 5 - 4 × 0.5.

Example 2: If a candidate changes his/her percentage four times, receives 25 points from voter130, and loses the election, his/her earnings equal: **44.5 points** = 20 + 25 - 1 × 0.5.

Appendix: Figures and Tables

Figure 2.1: Taxes over time - No Lobbying

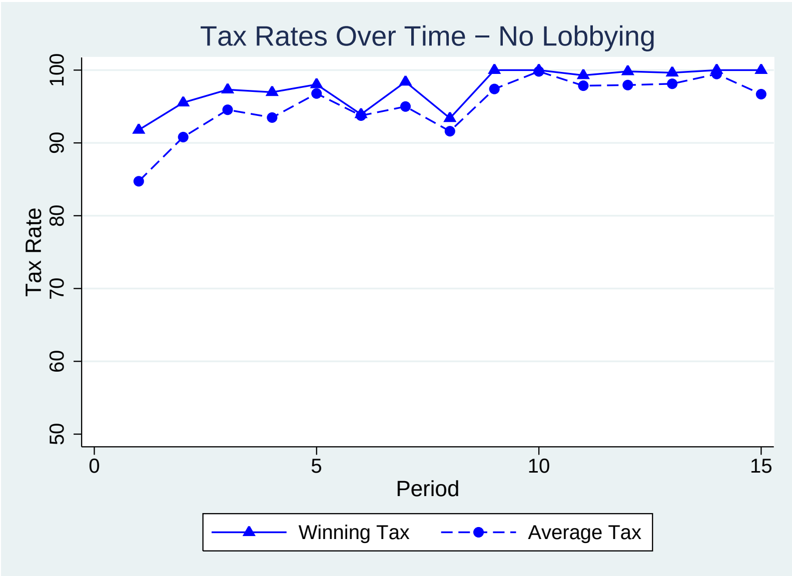

Figure 2.2: Taxes over time - No Lobbying, Part 1

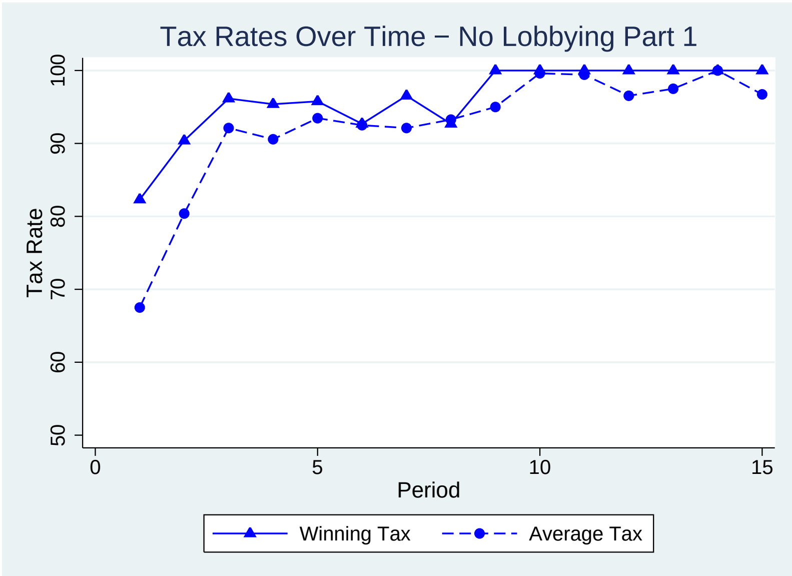

Figure 2.3: Taxes over time - No Lobbying, Part 2

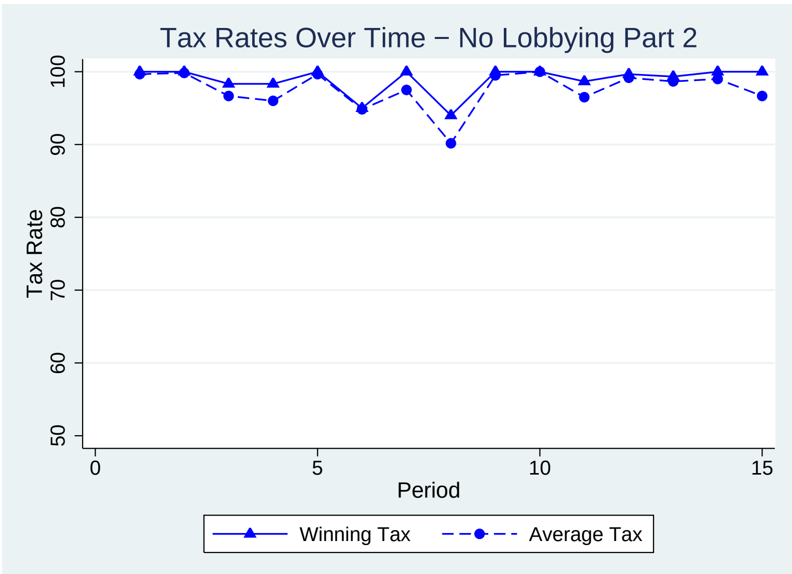

Figure 2.4: Taxes over time in Lobbying Part - Partners vs Strangers

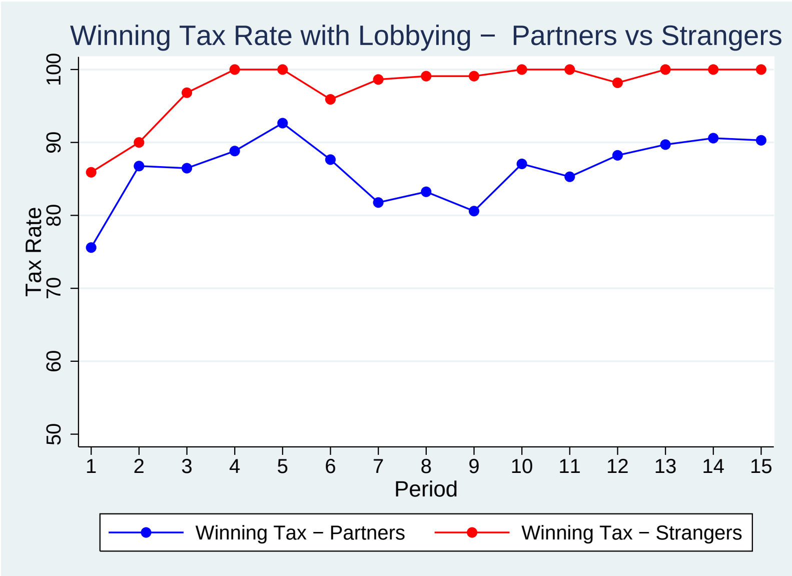

Figure 2.5: Lobbying and Taxes over time - Strangers

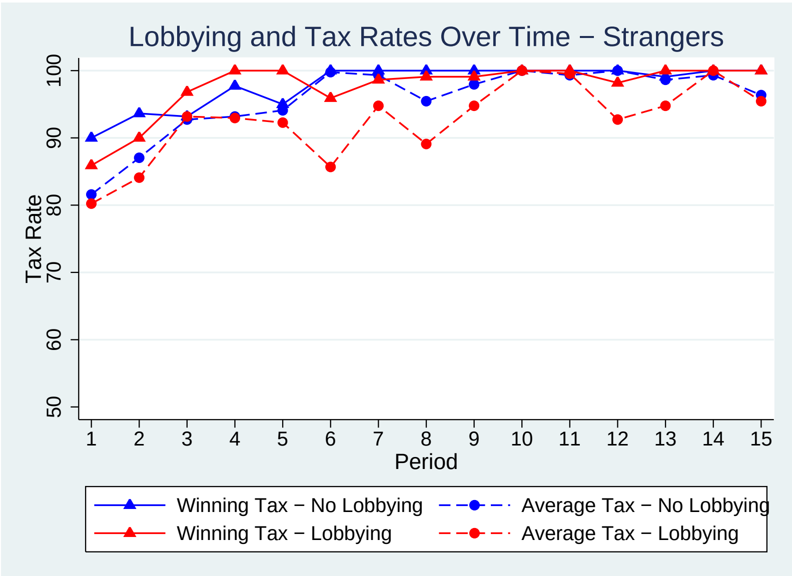

Figure 2.6: Lobbying and Taxes over time - Partners

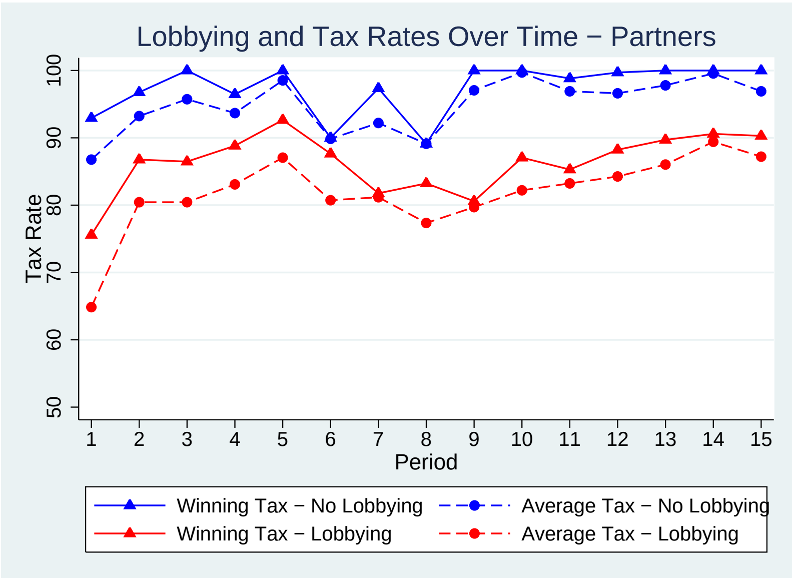

Figure 2.7: Lobbying and Taxes over time - Partners

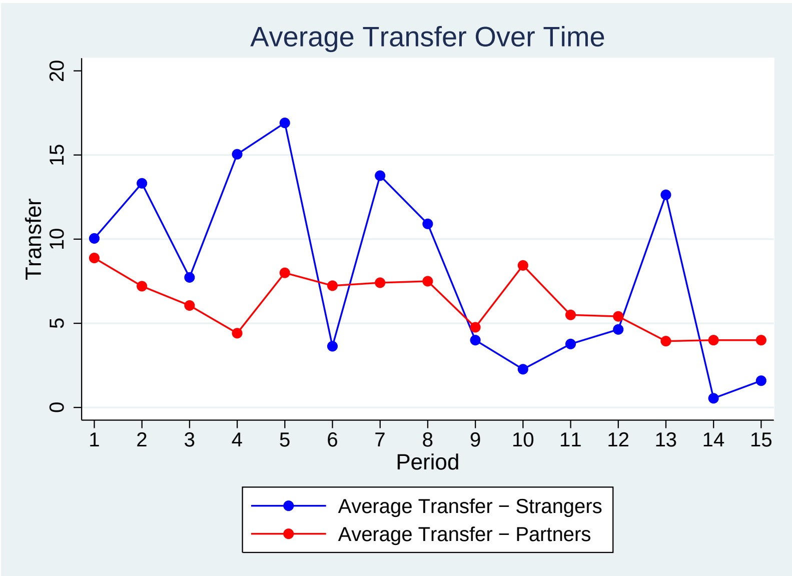

Figure 2.8: Voters' profits

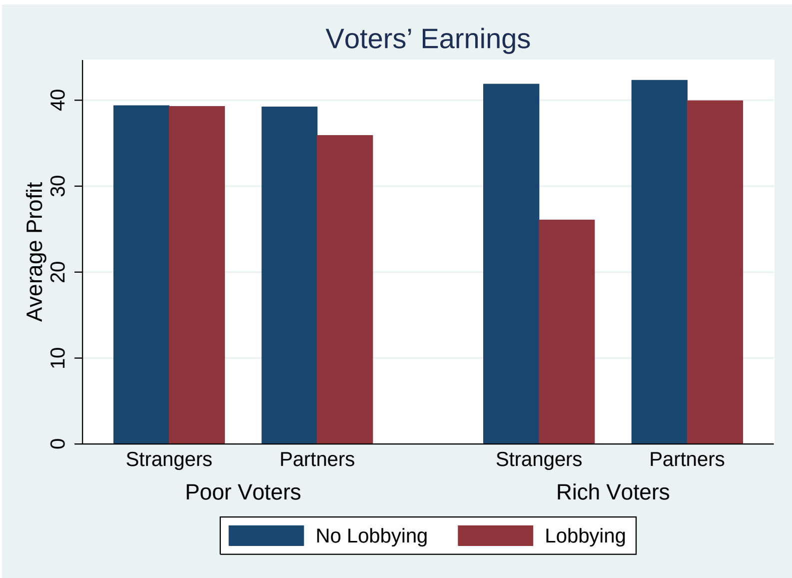

Table 2.2: Tax determinants in partners and strangers treatment. Tax_t is the tax announced by the candidate in round t. $TaxOther_t$ is the tax announced by the competing candidate in round t. $Transfer_t$ is the amount of points transferred to the candidate in round t and $TransferOther_t$ is the amount that was transferred to the other candidate in round t. $PreviousTax$ is the amount transferred by the voter to the candidate the last time he was active as a rich voter (which is not necessarily in the previous round). $PreviousTaxOther$ is the amount transferred by the voter to the other candidate the last time he was active as a rich voter. $AverageTransfer_{t-1}$ is the average of the transfers made to the candidates in the round $t-1$. $AverageTax_{t-1}$ is the average of the tax announcements made in round $t-1$. The regression in the middle column, Tax_t - Strangers, takes into account only candidate's own experience so the rounds in which he was actively making decision. The regression in the right column, Tax_t - Strangers* takes into account all the observations that candidate makes (inactive candidates follow the progress of the experiment on the screens) so it allows for the candidate's decision to be influenced by the experience of others and what happened when he was inactive.

	Tax_t - Partners Coef./t	Tax_t - Strangers Coef./t	Tax_t - Strangers* Coef./t
$Transfer_t$	–0.59	0.15	-0.05
	(–3.81)***	(0.64)	(0.45)
$TransferOther_t$	0.36	–0.22	-0.02
	(2.28)**	(–1.06)	(0.77)
$Transfer_{t-1}$	0.26	–0.15	
	(1.67)*	(–1.00)	
$Transferother_{t-1}$	–0.29	0.14	
	(–1.90)*	(0.59)	
$TaxOther_t$	0.56	–0.03	0.07
	(14.10)***	(–0.13)	(0.18)
Tax_{t-1}	0.08		
	(1.84)*		
$Taxother_{t-1}$	0.06		
	(1.27)		
$PreviousTax$		–0.43	
		(–1.51)	
$PreviousTaxOther$		0.01	
		(0.08)	
$AverageTransfer_{t-1}$			-0.02
			(0.77)
$AverageTax_{t-1}$			0.07
			(0.32)
$Round$	0.03	0.84	0.21
	(0.12)	(1.33)	(0.46)
Overall R^2	0.5952	0.0553	0.015
No. of obs	476	107	308

$^{*}p < .10, ^{**}p < .05, ^{***}p < .01$
Subject fixed effects included

Table 2.3: Transfer determinants in partners treatment. $Transfer_t$ is the amount of points that rich voter transferred to a given candidate in round t. Tax_{t-1} is the tax level that this candidate announced in round $t-1$. $TaxOther_{t-1}$ is the tax level that the other candidate announced in round $t-1$. $TransferOther_t$ is the amount of points that rich voter decided to transfer to the other candidate in round t. *Part* is equal to 1 if lobbying (L) occurred before no lobbying part (NL) in the experiment and it is equal to 2 if L occurred after NL.

	$Transfer_t$ Coef./t
Tax_{t-1}	–0.05
	(–3.46)***
$TaxOther_{t-1}$	0.01
	(0.61)
$TransferOther_t$	0.46
	(11.00)***
$Transfer_t$	0.16
	(3.44)***
$TransferOther_{t-1}$	–0.15
	(–3.19)***
Round	–0.08
	(–1.08)
Part	3.78
	(2.19)**
Adj. R^2	0.589
No. of obs	476

$^{*}p < .10, ^{**}p < .05, ^{***}p < .01$
Subject fixed effects included

Table 2.4: Transfer determinants in strangers treatment. $TotalTransfer_t$ is the sum transferred to both candidates by rich voter in round t. $AverageTax_t$ is average of the tax announcements made by active candidates in round t. $PreviousTotalTransfer$ is the sum of the transfers to both candidates that the subject made when he was last active as a rich voter. $TotalTransfer_{t-1}$ is the sum of the transfers to both candidates made in round $t-1$. $Part$ is equal to 1 if lobbying (L) occurred before no lobbying part (NL) in the experiment and it is equal to 2 if L occurred after NL.

	$TotalTransfer_t$ Coef./t	$TotalTransfer^*_t$ Coef./t
$AverageTax_t$	–0.13	
	(–1.31)	
$AverageTax_{t-1}$		–0.23
		(–1.64)
$PreviousTotalTransfer$	–0.18	
	(–0.87)	
$TotalTransfer_{t-1}$		0.05
		(0.68)
$Round$	–2.65	–1.08
	(–3.96)***	(–2.02)**
$Part$		–51.83
		(–2.11)**
Overall / Adj. R^2	0.002	0.556
No. of obs	38	154

$^{*}p < .10,^{**} p < .05,^{***} p < .01$
Subject fixed effects included

3

Sorting of heterogenous agents when teamwork is optimal

Abstract

The aim of this paper is to analyze the impact of competition on the structure of incentive schemes and the degree of cooperation within the firms. Firms in our model want to employ teams of two workers, each of whom decides how much effort to exert on his own task and how much to help his teammate. Workers differ in their innate abilities. Their type as well as effort exerted are unobservable to everybody but themselves. We show that if equilibrium exists it is separating and high ability workers, in order to distinguish themselves from less able workforce, choose the incentive schemes that strongly rely on their own as well as their teammate's performance. They work harder on their own task and are more team-oriented than less skilled workers. Our paper stresses the sorting role of the incentives and provides rationale for the emergence of different corporate cultures.

3.1 Introduction

Teamwork is nowadays a very common work practice. A recent European survey found that 31 per cent of all manufacturing organizations had implemented team-based work (Benders, Huijgen, and Pekruhl (2001)). A 1994 survey of U.S. firms found that in 64% of the responding establishments, at least half of the core workers were involved in employee problem-solving groups, work teams, job rotation, or combinations of these practices (Locke, Kochan, and

Piore (1995)). A large body of literature, both theoretical (Itoh (1991)) as well as empirical (for example Hamilton, Nickerson, and Owan (2003), Ichniowski, Shaw, and Prennushi (1997), Kocher, Strauß, and Sutter (2006)), confirms that teamwork improves firms performance and increases productivity compared to situations where each agent specializes in his own task.

Firms try to encourage teamwork using teamwork promoting policies and incentive schemes such as group bonuses. What is interesting is that we see a lot of heterogeneity in the intensity of these tools among firms, even within the same industry (Kosfeld and von Siemens (2007)). In our paper we find out theoretical justificatin for such heterogeneity.

There are some advantages and disadvantages to teamwork from the point of view of the employee. Most people exhibit taste for variety and welcome task diversification and so teamwork as well. On the other hand, when workers are heterogenous in skill then engaging in team production adds uncertainty about ability of the teammate. Highly skilled people may want to refrain from teamwork and prefer to concentrate on their own tasks when they expect that their teammates will not be as productive as they are. Low ability workers on the other hand may prefer to base a larger part of their work and income on teamwork expecting to benefit from the output of better skilled colleagues. However, it is also possible that in a competitive labor market firms are able to design incentives that screen workers to different firms based on their level of ability. If this is the case, then the uncertainty issue is absent - worker's can perfectly foresee that when they choose the contract that is designed for them they will be working with equally skilled colleagues. Therefore, whether low ability or high ability workers would be more teamwork oriented remains an open question which we aim to answer.

Firms in our model can employ teams of two workers. Following Itoh (1991) we assume the cooperation between the employees takes the form of agent i helping agent j accomplish a task. Therefore, the agents in our model have to decide how hard to work on their own task and on the task of their colleague. Since the employer cannot easily observe effort levels, he gives the worker a stake in his own and in his teammate's output to motivate him to work on both tasks. Consequently, the wage contracts we consider in our model consist of a fixed wage, an individual performance bonus, and a teammate's performance bonus. It is important to notice that such a contract exposes each agent to risks associated with the unknown innate abilities of her teammates. As we will later on see the beliefs about the teammate's type play an important role in determining the equilibrium contracts.

The heterogeneity of the workforce can lead to adverse selection problems and the unobservability of effort to moral hazard. Problems related to adverse selection, moral hazard and teamwork naturally arise in the employer - employee situations. In real world at the time of contracting the employers usually do not know the worker's basic skill or training. And after the contract is signed they cannot observe how much effort he puts in his tasks. In order to include those very realistic features of labor markets and keep our work tractable we will combine moral hazard and adverse selection in the spirit of Laffont and Tirole (1986). By doing so we capture the idea that firms are aware of the impact of the incentives on worker effort choice. In particular, they can infer what levels of effort workers are likely to take under a given contract. This in turn will allow us to use the techniques of adverse selection to solve the model. We will follow the logic similar to the one used in the well known model of insurance market by Rothschild and Stiglitz (1976). Our analysis is, however, more complex. We incorporate bi-dimentional workers' effort choices and introduce the dependence between workers output and the type of teammate he is matched with. The teammate type plays an interesting role because the beliefs about the teammates type enter the expected utility of a player. In other words, workers are influenced by the beliefs they hold about the potential coworkers when making their employment decisions.

In our model we assume that both workers and firms are fully rational. It turns out that both types cannot be pooled under one contract in equilibrium. If an equilibrium exists it is separating and more skilled workers, not surprisingly, work harder on their task and are attracted to firms that offer higher own performance bonuses. What is less obvious is that highly skilled workers will also work harder on their teammate's task and their contract will have higher teammate's performance bonus. This result is driven by the fact that workers realize that separation takes place in equilibrium and so they are able to foresee the ability of colleague they will be matched with in a particular firms. This result is in line with the observation of Hamilton, Nickerson, and

Owan (2003) who find out that high-ability workers are more likely to join teams than their less skilled colleagues. The production levels are higher in the firms that employ high ability worker and both the incentive and sorting effect of performance pay contributes to it.

Our paper also contributes to the literature on corporate cultures by showning that ex ante identical firms can exhibit different corporate cultures as a result of wage competition for heterogenous workers. Employees in some firms will be more hard working and more teamwork oriented than in others. Other papers like Kosfeld and von Siemens (2007) and Rob and Zemsky (2002) show that different corporate cultures can result from different choice of incentives in otherwise identical firms when workers derive more or less utility form cooperation depending on their type or previous experience. We on the other hand show that different corporate cultures can arise even when workers do not exhibit different attitudes towards cooperation and they only differ in their productivity parameter. We stress the interesting role that sorting and information play and describe the impact that they have on the emerging incentive schemes.

Our paper also stresses the sorting role of variable pay and contributes to a rather limited literature on this topic. Sorting, also called self-selection, is consistent with many facts (see Paarsch and Shearer (2000), Lazear (2000), Lazear (2005)) but the existing literature concentrates mostly on the incentive role of variable pay. Prendergast (1999) surveys the work on incentives in firms and concludes that incentives are important, but the sorting effect of pay-for-performance contracts is equally important as incentive effect while the overwhelming focus is placed on the latter. He also points out that many of the predictions of the incentive theory are not borne out in the data and could be potentially explained by sorting effects. A recent experimental study (Dohmen and Falk (2001)) has shown that output is indeed much higher in the variable pay schemes (piece rate, tournament, and revenue sharing) compared to the fixed payment scheme but this difference is largely driven by productivity sorting. Eriksson and Villeval (2004) confirm that there is a concentration of high skill workers in performace pay firms. In other words, firms that use performance pay may observe higher production levels not because by giving high powered incentives they motivate workers to exert a lot of effort, but because they attract highly skilled workforce in the first place. Workers who know that they are skilled for the job and as a result are likely to achieve high production levels choose to work for the firms that condition pay on the performance. They will also work harder than they would have under a fixed wage, but the effect of sorting should not be underestimated.

Given how much focus and research has been done on the incentive role of the pay for performance contracts the lack of the papers that study sorting effects is surprising. The previous papers that analysed segregation of workers differing by skill (for example Kremer and Maskin (1996), Saint-Paul (2001), Grossman (2004)) do not focus on the impact of the structure of incentives offered in the market on the decision of the worker to accept or reject employment. Instead they assume complete information about worker type and aim to understand why firms may prefer segregated to symmetric job assignment. The only theoretical paper that the author is aware of that deals with worker heterogeneity, multitasking and effects of competition among employers on sorting via compensation design is a paper by Kosfeld and von Siemens (2007) in which the authors show that in a competitive equilibrium selfish and conditionally cooperative workers will self-select into different firms: while selfish workers don't exert team effort and receive strong incentives, conditional cooperators provide team effort and their incentives can be muted. Our paper differs from theirs in definition of worker heterogeneity. Kosfeld and von Siemens (2007) driven by recent experimental results (Fehr and Schmidt (2004)) study the impact on incentives of the worker heterogeneity in the sense of the personal attitude towards teamwork. In particular, they assume that selfish players do not derive any utility from teamwork while conditionally cooperative players derive extra non monetary utility when they are matched with somebody who will reciprocate if they decide to help. Our definition is different and leaves the psychological issues aside. We are going to assume that workers differ in their innate abilities so some workers are more productive than others. The implications of psychologically motivated differences like those in Kosfeld and von Siemens (2007) could of course be studied on top of our analysis.

3.2 Model of the economy

We will now provide a formalized model of the examined labor market.

3.2.1 Players

In our labor market model there are two sets of players - many risk averse agents (also called workers or employees) and more than two identical risk neutral principals (also called firms or employers) who can enter the market and compete for the agents. The agents differ in skill and variance of output produced if they are hired by a firm. For simplicity we will assume that there are two different types of worker and we will denote the workers by $i, j \in I \equiv \{H, L\}$, where H stands for highly skilled worker and L for less skilled worker. Workers' types are private information. Each worker knows his own type, but other workers and the employer cannot observe it. Each firm needs to hire teams of two employees to complete certain tasks. There are no capacity constraints in the sense that firms can employ any number of teams.

3.2.2 Production and wages

Each employed agent has a well-defined task to perform. Each individual output is observable and verifiable. The individual output depends on worker's skill, the amount of effort he has put into the task and the amount of help he received from his teammate. It is given by

$$y_i = \theta_i + b_i + h\left(\theta_j + c_j\right) + \varepsilon_i \tag{3.1}$$

where $\theta_i > 0$ represents the agent's innate ability. Each agent is either a highly skilled worker θ_H or less skilled worker θ_L. Highly skilled workers are more productive, so we assume $\theta_H > \theta_L$. Each agent makes a two dimensional choice of effort $(b_i, c_i) \in \mathbb{R}_+^2$, where b_i represents the level of effort that he has put into doing his own task and c_i is the effort put into the task of the colleague. h represents the total effect that the support of the teammate has on the production level of the worker. We assume that helping others is not more productive than working on one's own task and that helping is not destructive, so $0 \leq h \leq 1$. It is reasonable to assume that worker's effort is less productive on the task of the teammate than on his own for the number of reasons. For example he may be better trained at performing his own task or there may be communication costs involved in teamwork. The last term ε_i is the realization of some exogenous transitory shock, $\varepsilon_i \sim N(0, \sigma^2)$ independently and identically distributed across agents of the same type. This implies that the output is vulnerable to some variation that is unknown to everybody. [1]

The fact that worker's output increases merely because he works in a team, that is even if his teammate decides not to exert any effort to help him, deserves a comment and justification. There is a rich literature on peer effects trying to understand the impact peers may have on each other performance. The justification for assumption that workers are more productive if they work in pairs rather than alone can found for example in the work by Falk and Ichino (2006) who provide clean evidence of such peer effects.

The principal observes only y_i and has no knowledge about the workers' types and effort decisions. Total output is the sum of individual outputs. The price of output is normalized to one.

Fulfilling her own task and helping colleague the agent incurs a disutility

$$C_i(b_i, c_i) = \frac{b_i^2 + c_i^2}{2} \tag{3.2}$$

which we call the cost of effort. In accordance with a large body of literature on the benefits of teamwork we assume that it is advantageous to induce workers to help each other and this cost structure captures the benefits of helping effort. Under this cost specification, the efforts are technologically independent, so increasing effort on one task does not increase the marginal cost of effort on the other task. This corresponds to the assertion by behavioral scientists that job enlargement and enrichment can motivate workers to work hard. Therefore, allocating a given total effort to more than one task involves lower disutility and we say that workers have a taste for variety.

Industrial psychologists argue that people indeed exhibit a taste for variety,

[1] We would obtain the same results, with only minor changes in the proofs, if we assumed that the output produced by low ability worker is more variable, that is $\sigma_L > \sigma_H$.

that is, monotonous tasks are perceived as less pleasant and involve quicker exhaustion than more variable tasks. Inducing teamwork is one way to react to a taste for variety. When we allow workers to work on more than one task we are able to increase their total effort. This leads, on average, to higher production levels, which is beneficial from the point of view of the firm.

This is not the only possible specification of the cost of effort that could be used. In fact many multitasking models presuppose that there are negative externalities between the tasks introduced through cost function that takes the functional form $\frac{(b_i+c_i)^2}{2}$. With this cost function, agents care only about the sum of effort exerted. Helping others is costly to the agent, because it crowds out efforts spent on his own task and thus lowers his own output. Which of the cost structures is more appropriate is an empirical question to which definite and clear-cut answers have not yet been provided. For the purposes of this paper the first specification is more convenient, because, as will become clear in the analysis of the model, it allows us to focus on the separation according to skill, leaving aside technologically driven externalities.

As we have already mentioned, cooperation can be beneficial to the firm. However, it is not in the interest of the worker to exert any kind of costly effort. Unless the employer links worker's compensation to the level of effort that this worker exerts, the worker will always prefer to shirk. In our case, the effort is unobservable to the employer and therefore the compensation scheme cannot be based on it. Nevertheless, the output of the task, which is informative about effort is observable and can be used in the compensation scheme. We restrict attention to the contracts $T = (\alpha, \beta, \gamma)$ that are linear. The wages are going to take the following form:

$$w_i = \alpha + \beta y_i + \gamma y_j \tag{3.3}$$

where α is the fixed wage component, β is the individual incentive component and γ is the group/teamwork incentive component and $\alpha, \beta, \gamma \in \mathbb{R}_+$.

Using linear compensation scheme in the static framework may seem controversial. As Mirrlees (1974) has shown linear incentives can be suboptimal. In particular, in the static setting the principal can achieve almost first best offering the following incentive scheme: he pays a fixed wage when output is above some threshold and punishes with very low wage when output falls below this threshold. This scheme works because with normal distribution output is much more likely to be small when the agent shirks. However, intuitively, punishing for very rare events does not seem to be an adequate incentive to motivate effort. Moreover, it is more difficult to analyse analitically. We motivate using the linear incentive scheme instead of this "two-wage" scheme in the following way. First of all, notice that "two-wage" scheme does not implement first best with heterogenous workforce. Better skilled workers will always prefer the contract designed for poorly skilled workers because it has a lower threshold. As a result they will also exert less then optimal effort. Second, since individual efforts are not observable freeriding can occur. Effort choice under such payment scheme is complicated decision that depends on the beliefs about teammate's type and chosen effort levels. Basicaly all effort levels, by which we mean all possible divisions of labor on the tasks, that satisfy individual rationality could be sustained as an equilibrium and so we could imagine a very unhealthy working environments to arise. For example, it could happen that one worker works harder on both tasks, while he recieves the same compensation as his colleague. Since firms put a lot of emphasis on things like corporate culture, intrinsic motivation and healthy relationships between their emplyees we can hardly imagine a firm using such a compensation scheme if it wants to implement teamwork. Finally, we can easily interprete our problem as dynamic. In particular, imagine that there is a number of periods in which agents make their effort choices, in each period they learn what the output of the task was. The principal, however, learns the output only in the last period and compensates his employees then. In such a case "two-wage" scheme does not necessarily implement first best because of the gaming behavior of the employees. In particular workers, given the observation of previous output realizations may stop providing effort because either they have already passed the threshold or due to unlucky events there are no chances that they are going to meet it. If we imagine that b_i and c_i are not one time effort choices but a sum of efforts in a given time period then by the argument provided by Holmstrom and Milgrom (1987) we can safely restric our attention to linear wage schemes and with linear wages there are no reasons for gaming behavior.

3.2.3 Preferences

The profit of the risk-neutral principal is defined as output net of wages. The expected profit from employing a pair of workers i and j under contract $T = (\alpha, \beta, \gamma)$ is:

$$\pi_{i,j}(T) = (1 - \beta - \gamma)(Ey_i + Ey_j) - 2\alpha \tag{3.4}$$

Following the framework used in Holmstrom and Milgrom (1987), we assume that risk averse agent i has a CARA (constant absolute risk aversion) utility function:

$$U_i = -\exp\left\{-r(w_i - C_i(b_i, c_i)\right\}, \tag{3.5}$$

where r is the CARA coefficient. The worker's expected utility when he accepts a contract $T = (\alpha, \beta, \gamma)$ is

$$V_i \equiv -E_i \exp\left\{-r(\alpha + \beta y_i + \gamma y_j - C_i(b_i, c_i)\right\} \tag{3.6}$$

It is known that if we are using CARA utility function and the output is normally distributed $Y \sim N(E(Y), Var(Y))$ then

$$E\left\{\exp\left\{-rY\right\}\right\} = \exp\left\{-r\left[EY - \frac{r}{2}var(Y)\right]\right\} \tag{3.7}$$

Therefore, we can rewrite the expected utility of an agent of type i who is paired with a worker of type j under contract $T = (\alpha, \beta, \gamma)$ as:

$$V_i(T) = -\exp\left\{-r[\alpha + \beta E_i y_i + \gamma E_i y_j - \frac{b_i^2 + c_i^2}{2} - \frac{r}{2}(\beta^2 + \gamma^2)\sigma^2]\right\} \tag{3.8}$$

and his certainty equivalent wealth as:

$$CE_i(T) = \alpha + \beta E_i y_i + \gamma E_i y_j - \frac{b_i^2 + c_i^2}{2} - \frac{r}{2}(\beta^2 + \gamma^2)\sigma^2 \tag{3.9}$$

The utility of the unemployed worker is normalized to -1. Employers seek to maximize their profits and workers to maximize their utilities.

3.2.4 Timing

The model considers the following sequence of actions. *In stage one*, firms can simultaneously enter the market at zero cost announcing the contracts to all the workers. (There are more than two such potential entrants.) Each firm can announce *only one* contract from the set of all available contracts $\mathbf{T} \equiv \{(\alpha, \beta, \gamma) : \alpha, \beta, \gamma \in \mathbb{R}_+\}$. *In the second stage*, after having observed all the offered contracts, workers simultaneously choose either to remain unemployed, and earn their reservation utility, or to work for one of the firms. In case two firms offer contracts that give the same utility, the employee chooses one of them at random. In addition each worker who has accepted a contract decides how much effort to put to his task and how much to help his colleague under the chosen contract. Finally, firms operate with all the workers they have attracted and production, wages and profits are realized. The profits of the firms that have not entered or entered but did not attract any workers are equal to zero.

3.2.5 Equilibrium concept

We solve the model using backward induction procedure. We do that in two steps. First, we find Bayes Nash Equilibria of the second stage of the game to see what kind of contracts will be accepted and the effort levels chosen in the equilibrium. Second, given the employees equilibrium strategies we establish what kind of contracts firms offer in the equilibrium. In order to do that, let's first define the equilibrium concept starting with the description of the equilibrium behavior of the workers.

We model workers' interactive behavior as a Bayesian game. As in other models of adverse selection, worker's contract selection choices can reveal information on their preferences. We assume that the beliefs are symmetric across workers and firms and denote by $\rho_k \in [0, 1]$ the probability with which firms and workers believe that a worker who accepts contract T_k from the set of all offered contracts, $\mathbf{T}^o \subseteq \mathbf{T}$, is a highly skilled worker. Such beliefs can be formed for all possible sets of offered contracts. Let $p_{i,k} \in [0, 1]$ denote the type dependent probability with which the worker of type i accepts a contract T_k when a set of contracts $\mathbf{T}^o$ was offered on the market. Let $(b_{i,k}, c_{i,k}) \in R^2_+$

be the effort levels that the worker of type i would (given his beliefs ρ_k) choose if he worked in a firm that offered a contract T_k. Workers can specify effort levels for all kinds of contracts offered. In a competitive equilibrium, workers' strategies and beliefs must form a perfect Bayesian equilibrium given all possible sets of offered contracts.

Definition 8 *(Equilibrium Behavior of the Workers) Workers behave optimally given a set of offered contracts $\mathbf{T}^o$, if their beliefs ρ_k and type-dependent strategies $(p_{i,k}, b_{i,k}, c_{i,k})$ form a Perfect Bayesian Equilibrium. In other words:*

(i) workers' type-dependent effort choices $(b_{i,k}, c_{i,k})$ maximize their expected utility given their beliefs $\rho_{i,k}$

$$\forall i \ \forall k \quad (b_{i,k}, c_{i,k}) \in \max_{b_i, c_i} CE_i(T_k|\rho_k)$$

(ii) workers' acceptance decisions maximize their expected utility given their beliefs ρ_k and the effort equilibrium behavior as described in (i)

(iii) beliefs are consistent with workers' acceptance decisions and Bayes' rule if the contracts are on the equilibrium path (i.e. are accepted with strictly positive probability by at least one type)

Intuitively, workers' optimal behavior can be described in the following way. Upon observing all the offered contracts workers form beliefs about the structure of workforce that each contract is going to attract and calculate their optimal effort choices under each contract. Even though the types of workers are unobservable, the decision to choose a particular contract may reveal some information about the worker type. This allows workers to form beliefs about other worker types given their acceptance decisions. Knowing the effort choices and having the beliefs about the type of their teammate under each offered contract, workers are able to compare the expected payoffs corresponding to each contract and they choose the one that maximizes their utility. The beliefs corresponding to equilibrium contracts have to be confirmed by the equilibrium acceptance decisions and have to be in accordance with Bayes' rule. For the contracts that are never accepted beliefs are undetermined and can be chosen arbitrarily.

The analysis of a competitive equilibrium is based on Rothschild and

Stiglitz (1976) and the equilibrium can be formally described as in the following definition

Definition 9 *(Competitive Equilibrium) The equilibrium is described by the set of offered contracts* $\mathbf{T}^*$*, that given the optimal behavior of workers (as described above in Definition 8), satisfy the following:*

(i) $\forall T_k \in \mathbf{T}^* \ (p_i)_k > 0$ *for at least one type of the worker*

(ii) $\pi_{i,j}(T_k) \geq 0 \ \forall T_k \in \mathbf{T}^*$ *given the beliefs* ρ_k

(iii) $\nexists T_l \in \mathbf{T} \setminus \mathbf{T}^*$ *that if offered would attract at least one type of the worker and make a positive profit.*

In other words, in equilibrium no irrelevant contracts (by which we mean contracts that are never accepted) are offered by the firms. All the offered contracts have to give non negative profits, otherwise firms would be better off not offering them at all. A set of equilibrium contracts is an equilibrium if and only if there does not exist a contract outside the equilibrium set of contracts, that if offered attracts workers and yields a positive profit.

It is useful to see how the equilibrium contracts would look like if the workers' types and efforts were observable.

3.3 The Full-Information Benchmark - First Best Contracts

In the first best, the principals are able to observe and verify agents' types and effort levels. Employer's expected profit from employing the i-type worker to work in a team under contract $T = (\alpha, \beta, \gamma)$ is $\pi_i = (1 - \beta - \gamma)(\theta_i + b_i + h(\theta_i + c_i))) - \alpha$. Suppose that the agent's type is revealed when he accepts the job offer and employer can perfectly monitor the executed effort. Then firms are able to condition their offers on the worker's type (offer one type of contract, call it T_L^{FB}, only to the low ability workers and another contract, call it T_H^{FB}, only to high ability workers) and can also formulate the contracts that specify effort levels. We use the subgame perfect Nash equilibrium concept (SPNE) to determine the equilibrium outcome.

Proposition 10 *In any SPNE with observable worker types and efforts, both types of workers accept contract* $T_i^{FB} = (\theta_i + b_i + h(\theta_i + c_i), 0, 0)$, $i = H, L$. *Firms earn zero profits and both types of workers choose the same effort levels* $b_H = b_L = 1$ *and* $c_H = c_L = h$. *In addition, a high-ability worker gets a larger utility than a low-ability worker,* $V_H(T_H^{FB}) > V_L(T_L^{FB})$, *and it is efficient for the two ability types to participate* $V_i(T_i^{FB}) > -1$ *for* $i \in \{H, L\}$.

Proof. The above proposition follows from standard risk-sharing and competition arguments. ■

In other words, at the first best when the principal can observe worker's skill and the level of effort there is no need to use risky bonuses (which are disliked by the risk averse worker) and the whole compensation can be paid through riskless wage component α. Competition among firms leaves employers with zero profits and workers earn wages which are equal to the profits from their production.

We have formulated the optimal contracts when the principal verifies both the worker type and his choice of effort. These contracts, however, are not feasible when the effort of the employees is not known to the employer. Even if the effort levels were observed, but the innate ability was not, we still would not be able to implement the first best contracts, because they would violate incentive compatibility. Therefore, let's now move on to analyze the optimal contracts when the worker's type and the effort he exerts are his private information.

3.4 Hidden-information and hidden-action contracts

3.4.1 Second stage equilibrium strategies of the workers

We begin the analysis at the end of the game, when workers after having observed the set of offered contracts $\mathbf{T}^o$ form their beliefs ρ_k and make effort and employment decisions. Workers choose the effort levels as to maximize their expected utility given their beliefs. This boils down to solving the following set of optimization problems. For $\forall T_k \in \mathbf{T}^o$ workers choose $(b_{i,k}, c_{i,k})$ such that

$$(b_{i,k}, c_{i,k}) \in \arg\max_{b_i, c_i} CE_i(T_k|\rho_k) \tag{3.10}$$

From the first order conditions, we obtain

$$\begin{aligned} b_{i,k} &= \beta_k \\ c_{i,k} &= h\gamma_k \end{aligned} \tag{3.11}$$

The effort selection problem is independent of the worker type and the beliefs that workers hold. Under the same incentive scheme both types of worker choose the same effort levels. Therefore efforts are solely determined by the incentive scheme. Nevertheless, workers' heterogeneity and beliefs still play very important role in the choice of contract. In other words, the fact that under the same contract workers would choose the same effort levels does not necessarily imply that in equilibrium both types of worker will be working equally hard. Due to the heterogeneity in productivity or beliefs, it may be optimal for different types of workers to choose distinct incentive schemes. In particular one can expect that high ability workers who expect to have on average higher output will be willing to have a higher proportion of the compensation paid in the own performance bonus than less skilled workers. By the same logic, workers who expect to be working with better skilled teammates are willing to accept higher levels of teamwork bonus. In this paper, it is our aim to find out whether such separation of types can occur, what would be the properties of the contracts that could achieve separation and what would be the resulting type specific effort levels. The particular set up used here will allow us, from now on, to shift the focus of attention away from the moral hazard and solve the model using the techniques used in handling adverse selection models.

It is useful to rewrite the profit of the firm from employing a pair of workers of type i and j where $i, j \in \{H, L\}$ under contract $T_k = (\alpha, \beta, \gamma)$ as

$$\pi_{i,j}(T_k|\rho_k) = (1-\beta-\gamma)(E_{\rho_k}(\theta_i+\theta_j)(1+h)+2\beta+h^2\gamma)-2\alpha \tag{3.12}$$

and the certainty equivalent of the worker of type i as:

$$\begin{aligned} CE_i(T_k|\rho_k) &= \alpha+\beta(\theta_i+\beta+h(E_{\rho_k}\theta_j+h\gamma))+\gamma(E_{\rho_k}\theta_j+\beta+h(\theta_i+h\gamma))- \\ &\quad -\frac{\beta^2+h^2\gamma^2}{2}-\frac{r}{2}(\beta^2+\gamma^2)\sigma^2 \end{aligned} \tag{3.13}$$

After the workers formed their beliefs and made hypothetical effort choices for each offered contract, they are ready to make payoff comparisons between the contracts. In equilibrium, each type of worker is going to compare all the options he has (including not working at all) and choose the one that from his point of view gives him the highest payoff. In other words, he is going to accept a contract that given his beliefs ρ_k maximizes his utility, provided that it gives higher utility than remaining unemployed. If there is more than one such contract the worker randomly picks one of them. If there are no contracts that satisfy participation constraint, worker remains unemployed. Let N be the number of firms, then formally we can describe the set of accepted contracts, $\mathbf{T}^a$, as a collection of contracts T_k^a where $k = 1, ..N$ such that given the beliefs ρ_k, for at least one of the types:

$$T_k^a \in \arg\max_{T_k \in \mathbf{T}^o} CE_i(T_k|\rho_k) \tag{3.14}$$

such that

$$CE_i(T_k^a|\rho_k) \geq 0$$

We have now a complete knowledge of how workers make their employment decisions. We still need to describe how firms decide what contracts to propose.

3.4.2 First stage of the game

When designing the contracts, firms realise that they do not act in isolation and that there are other players whose behavior is going to influence their final payoff. These players are both the employees and the other firms with which the firm competes for workers. Firms need to form conjectures about the behavior of these other players and then react to it optimally. In equilibrium firms correctly anticipate the behavior of employees and other firms, and given these conjectures they offer contracts that maximize own profits. We have already established how the workers are going to react to all possible combinations of offered contracts in the second stage. Now we are going to make use of this information and study the interaction between firms and their contract design problem.

Zero profit condition

The first thing to observe is that competition for workers is going to leave zero profits to the employers. Firms in order to operate have to attract the workers. Workers, on the other hand, are going to chose only the firms that offer the best contracts. Therefore, until all profit is spent on wages, firms will always have an incentive to announce a contract that is more attractive to the worker than the one of the competing firm. By doing so they can "steal" the workers from the competitor and guarantee ability to carry out production. In other words, only when firms are left with no more resources to spend on wages, no profitable deviation on the side of the firms exists and the offered contracts can be sustained in the equilibrium. In what follows we are going to prove formally that in the equilibrium all contracts that are accepted leave zero profits to the employer.

First note that in equilibrium, each contract offered and accepted earns a nonnegative profit. Firms offering loss-making contracts can do better by not entering the market. Therefore, all contracts are weakly profitable in the equilibrium.

Proposition 11 *Any contract accepted by a pair of workers (i, j) in the equilibrium, leaves zero profits to the employer. Therefore, the contract that attracts a worker of type i and a worker of type j in the equilibrium has to satisfy the following condition, which we call zero profit condition*

$$\alpha = \frac{1}{2}(1-\beta-\gamma)((1+h)(\theta_i+\theta_j)+2\beta+2h^2\gamma) \tag{3.15}$$

Proof. We will first show that if at least two firms attract the same type of workers they cannot make positive profits in the equilibrium. Then we will argue that if only one firm attracts a certain type of worker it cannot make positive profit as well. These two statements together with the fact that firms would rather withdraw from the market than offer loss making contract complete the proof.

Suppose two firms attract the same type of workers in equilibrium. Let $\mathbf{T}_i \subset \mathbf{T}^o$ be a set of offered contracts that would be accepted by the workers of type i given $\mathbf{T}^o$ and ρ_k. Note that all those contracts have to yield the same utility for the worker of type i. Suppose that the aggregate profit made on those contracts is positive, $\Pi > 0$, and let n be the number of firms that offer a contract in $\mathbf{T}_i$. Then one of the firms makes at most $\frac{\Pi}{n}$. This firm would be better of deviating to a different contract. For example, assuming that the contract originally offered by the considered firm was $T_i = (\alpha_i, \beta_i, \gamma_i)$, then this firm would improve by switching to $T_i' = (\alpha_i' + \varepsilon, \beta_i', \gamma_i')$, $\varepsilon > 0$. This contract would attract all the workers who were previously attracted to any contract that belonged to the set $\mathbf{T}_i$, because $CE_i(T_i') > CE_i(T_i)$. Moreover, since ε can be made arbitrarily small, this contract would yield higher profit, $\pi(T_i') = \Pi - \varepsilon > \frac{\Pi}{n}$. It means that in equilibrium, it must be that $\Pi \leq 0$. The contract that makes losses would rather be withdrawn from the market, so we must have $\Pi = 0$. If more than one firm attracts the same type of workers, say i, then the contracts $\mathbf{T}_i$ must make zero profits.

Now suppose that only one firm attracts a certain type of workers and recall that there are at least three firms that could potentially enter the market. Suppose that only one firm attracts both types of workers with a contract $T = (\alpha, \beta, \gamma)$ and makes a positive profit. It means that no other contract was accepted. Since there are more than two firms that could potentially enter the market offering employment contracts, there are at least two firms that do not employ any workers. Each of these firms would strictly prefer to change their offer to a contract slightly better from the point of view of (at least one type of) the employee, for example $T' = (\alpha + \epsilon, \beta, \gamma)$, and in this way attract this type(s) of worker, operate and make a positive profit.

Now, the only possibility left is a profitable contract offered by one firm in the separating equilibrium. Suppose that only one firm attracts workers of type i and it offers a contract T_i that makes a positive profit. It means that all the other firms whose contracts are accepted offer the contract that attracts the other type of workforce. Since there are at least three potential employers, the profits on the other contract must be equal to zero. This in turn implies that T_i cannot make a positive profit, because each of the firms that aim at the other workforce would be better off switching to workforce attracted by T_i and offering this type of worker a contract slightly better than T_i. ■

For the purpose of further analysis, it is useful to make the following observation about the zero profit surfaces. Let zero profit surfaces be defined such that α is the dependent variable and β and γ are independent variables.

Remark 12 *Zero profit surfaces of firms employing any combination of workers cross only once at* $(0, \beta, 1 - \beta)$ *in* (α, β, γ)*-space. The surfaces are downward sloping and steeper for firms whose workforce is better skilled on average.*

Proof. Recall that zero profit surfaces are described by the following function $\alpha = \frac{1}{2}(1 - \beta - \gamma)((1 + h)(\theta_i + \theta_j) + 2\beta + 2h^2\gamma)$. Since it is always true that $((1 + h)(\theta_i + \theta_j) + 2\beta + 2h^2\gamma) > 0$ we get that that $\alpha = 0 \Leftrightarrow \beta + \gamma = 1$. Therefore, zero profit surfaces cross only once at $(0, \beta, 1 - \beta)$.

Then, $\frac{d\alpha}{d\beta} < 0$ and $\frac{d\alpha}{d\gamma} < 0$ so the surfaces are downward sloping

Let $\theta_i + \theta_j \equiv \theta$ we get that $\frac{d\alpha}{d\beta d\theta} = -\frac{1}{2} < 0$ and $\frac{d\alpha}{d\gamma d\theta} = -\frac{1}{2} < 0$, so the zero profit surfaces are steeper for firms that employ better skilled workforce. ■

Recall that the contracts studied here are such that all the components of the incentive scheme, and among them the fixed wage component, are positive. This implies that highly skilled workers are always more desirable than less skilled workers. A company offering a contract such that $\alpha > 0$ will earn more the more productive workers it attracts. In other words, at any contract such that $\alpha > 0$ the firm prefers to employ highly skilled workers. Each contract that results in a non negative profit if it attracts only the least skilled workers, will also be profitable with any combination of workers. There are contracts that are profitable if they attract only highly skilled workers, but would yield a loss if they attracted less skilled workforce.[2]

Knowing that competition will force employers to pay workers their expected output and substituting equation (3.15) in equation (3.13) we can

[2]We disregard the situation when less skilled workers are more desired, because it is less realistic. Nevertheless, we acknowledge that one can imagine that when workers are extremely productive and wages are paid through the performance bonuses it may turn out that highly skilled workforce is too costly to employ and as a result less skilled workers are more desired. If $\alpha < 0$, then any contract that results in a non negative profit if it attracts only the most skilled workers, will bring a positive profit if it attracts less skilled workers. The inclusion of such a case would not bring a lot of insight to the analysis, because the properties of the solution would still be the same as when $\alpha > 0$, with an exception that the low ability (so more desirable) worker would be bearing the costs of separation.

rewrite the certainty equivalent of the worker of type i as:

$$
\begin{aligned}
CE_i(T_k|\rho_k) \quad = \quad & \frac{1}{2}(1-\beta-\gamma)(E_{\rho_k}(\theta_i+\theta_j)\,(1+h)+2\beta+2h^2\gamma)+ \\
& +\beta(\theta_i+\beta+h(E_{\rho_k}\theta_j+h\gamma))+\gamma(E_{\rho_k}\theta_j+\beta+h(E_{\rho_k}\theta_i+h\gamma))- \\
& -\frac{\beta^2+h^2\gamma^2}{2}-\frac{r}{2}(\beta^2+\gamma^2)\sigma^2 \qquad (3.16)
\end{aligned}
$$

Only the contracts that are the best from the point of view of the employees can survive as equilibrium contracts. Therefore, the set of candidate equilibrium contracts $\mathbf{T}^*$ is such that $\forall T_k^* \in \mathbf{T}^*$ and for at least one type of the worker it is true that:

$$T_k^* \in \arg\max_{T_k \in \mathbf{T}^o} CE_i(T_k|\rho_k) \qquad (3.17)$$

such that

$$CE_i(T_k^*) \geq 0 \qquad (3.18)$$

where the certainty equivalent is described by the equation (3.16) and the constraint (3.18), called the individual rationality constraint, says that the worker must receive at least the equivalent of his outside option to guarantee his participation.

There are two kinds of equilibria that could emerge in this game - separating and pooling. First, we will try to identify the separating equilibria.

3.4.3 Separating equilibrium

The competitive equilibrium is called separating if there does not exist an offered contract that is chosen with positive probability by both types of workers. Suppose that the separating equilibrium exists. The employers can design type specific contracts and employees, depending on their type self select to different firms. Let $\mathbf{T}_H^s$ be the set of contracts that employers believe will attract only high ability workers and $\mathbf{T}_L^s$ be the set of contracts that employers believe will attract only low ability workers. In equilibrium employers' beliefs must be confirmed and in agreement with the workers' beliefs. Therefore, in equilibrium a worker choosing contract $T_H^s \equiv (\alpha_H, \beta_H, \gamma_H) \in \mathbf{T}_H^s (T_L^s \equiv (\alpha_L, \beta_L, \gamma_L) \in \mathbf{T}_L^s)$ has to believe with probability one that he is going to work with high (low) ability worker and this belief needs to be confirmed by the actual employment decisions of the workers. This observation allows us to rewrite the expression for the zero profit condition for a company hiring high ability workers:

$$(ZP_H) \quad \alpha_H = (1 - \beta_H - \gamma_H)(\theta_H\,(1+h) + \beta_H + h^2\gamma_H) \tag{3.19}$$

and for company hiring low ability workers:

$$(ZP_L) \quad \alpha_L = (1 - \beta_L - \gamma_L)(\theta_L\,(1+h) + \beta_L + h^2\gamma_L) \tag{3.20}$$

and the certainty equivalent of a worker who chooses a contract that is designed for him

$$\begin{aligned} CE_H(T_H) &= \alpha_H + (\beta_H + \gamma_H)\,(\theta_H\,(1+h) + \beta_H + h^2\gamma_H) - \\ &\quad - \frac{\beta_H^2 + h^2\gamma_H^2}{2} - \frac{r}{2}(\beta_H^2 + \gamma_H^2)\sigma^2 \qquad (3.21) \\ CE_L(T_L) &= \alpha_L + (\beta_L + \gamma_L)\,(\theta_L\,(1+h) + \beta_L + h^2\gamma_L) - \\ &\quad - \frac{\beta_L^2 + h^2\gamma_L^2}{2} - \frac{r}{2}(\beta_L^2 + \gamma_L^2)\sigma^2 \qquad (3.22) \end{aligned}$$

Substituting with the zero profit condition we can rewrite the certainty equivalents as

$$\begin{aligned} CE_H(T_H) &= \theta_H\,(1+h) + \beta_H + h^2\gamma_H - \\ &\quad - \frac{1}{2}(\beta_H^2(1 + r\sigma^2) + \gamma_H^2(h^2 + r\sigma^2)) \qquad (3.23) \\ CE_L(T_L) &= \theta_L\,(1+h) + \beta_L + h^2\gamma_L - \\ &\quad - \frac{1}{2}(\beta_L^2(1 + r\sigma^2) + \gamma_L^2(h^2 + r\sigma^2)) \qquad (3.24) \end{aligned}$$

In the separating equilibrium the announced contracts must be incentive compatible i.e. both types of workers must prefer to choose the contracts that are designed for them. Therefore, the following incentive compatibility constraints must hold:

$$\begin{aligned} CE_H(T_H) &\geq CE_H(T_L) \qquad (3.25) \\ CE_L(T_L) &\geq CE_L(T_H) \qquad (3.26) \end{aligned}$$

In the model we have assumed that the agents are fully rational. Therefore if an agent of a certain type wants to deviate to a contract that is not designed for him, it means that all of the agents of that type want to do the same. Since the agents are fully rational they realize this. Therefore low (high) ability worker who chooses a contract designed for high (low) ability workers knows that then this contract pools both types of workers and updates his believes about the skill of the teammate accordingly. We now want to check whether it is possible to find contracts that would separate the different types of worker in an incentive compatible way.

Let's now try to write down the certainty equivalent of highly skilled worker under contract T_L. High ability worker who decides not to chose the contract that is designed for him (T_H) faces the following certainty equivalent

$$\begin{aligned} CE_H(T_L) &= (1+h)\,\theta_L + \beta_L + h^2\gamma_L + \beta_L\Delta\theta + \gamma_L h\Delta\theta - \\ &\quad -\frac{\beta_L^2 + h^2\gamma_L^2}{2} - \frac{r}{2}(\beta_L^2 + \gamma_L^2)\sigma^2 \end{aligned} \tag{3.27}$$

The certainty equivalent of a deviating low ability worker is equal to

$$\begin{aligned} CE_L(T_H) &= (1+h)\,\theta_H + \beta_H + h^2\gamma_H - \beta_H\Delta\theta - \gamma_H h\Delta\theta - \\ &\quad -\frac{\beta_H^2 + h^2\gamma_H^2}{2} - \frac{r}{2}(\beta_H^2 + \gamma_H^2)\sigma^2 \end{aligned} \tag{3.28}$$

where $\Delta\theta = \theta_H - \theta_L$.

Adding both incentive compatibility constraints, we get the following necessary condition to obtain separation:

$$(\beta_H - \beta_L) + (\gamma_H - \gamma_L)\,h \geq 0 \tag{3.29}$$

The assumption on h implies that it must be the case that $\beta_H \geq \beta_L$ or / and $\gamma_H \geq \gamma_L$. Moreover, whenever $\beta_H \geq \beta_L$ and $\gamma_H \geq \gamma_L$ this condition is satisfied.

Now we want to find out whether workers could have the incentive to pretend that they are different type. In order to do that we first find contracts that would emerge if we didn't have to worry about the incentive compatibility issues. In such a case workers would be receiving the contracts that leave zero profit to the employer and maximize workers' certainty equivalent.

Proposition 13 *Suppose that incentive compatibility does not bind, then separating equilibrium contracts are* $T_L^{SB} = \left(\alpha_L^{SB}, \frac{1}{1+r\sigma^2}, \frac{h^2}{h^2+r\sigma^2}\right)$ *and* $T_H^{SB} = \left(\alpha_H^{SB}, \frac{1}{1+r\sigma^2}, \frac{h^2}{h^2+r\sigma^2}\right)$*, where* α_H^s *and* α_L^s *are defined by corresponding zero profit conditions and are such that* $\alpha_H^s > \alpha_L^s$*.* $CE_H(T_H^{SB}) = \theta_H(1+h) + \frac{h^2+r\sigma^2+h^4\left(1+r\sigma^2\right)}{2(1+r\sigma^2)(h^2+r\sigma^2)} > 0$ *and* $CE_L(T_L^{SB}) = \theta_L(1+h) + \frac{h^2+r\sigma^2+h^4\left(1+r\sigma^2\right)}{2(1+r\sigma^2)(h^2+r\sigma^2)} > 0$*.*

Proof. When incentive compatibility is not an issue, than both types of workers receive the contracts that maximize their utility i.e. are the solution to the following problems
$\max_{\beta_H,\gamma_H} \theta_H(1+h) + \beta_H + h^2\gamma_H - \frac{1}{2}(\beta_H^2(1+r\sigma^2) + \gamma_H^2(h^2+r\sigma^2))$ and
$\max_{\beta_L,\gamma_L} \theta_L(1+h) + \beta_L + h^2\gamma_L - \frac{1}{2}(\beta_L^2(1+r\sigma^2) + \gamma_L^2(h^2+r\sigma^2))$. Zero profit condition, assumption that $\alpha > 0$ and the fact that bonuses are the same for both types of the workers imply that $\alpha_H^s > \alpha_L^s$. ■

At the optimum, highly skilled workers receive the same bonuses and higher fixed wage components. Both types of worker exert the same level of effort, but since highly skilled workforce is more productive, firms employing them have higher production levels. It is straightforward to see that these contracts are not incentive compatible. Since $\alpha_H > \alpha_L$ while the bonuses are equal in both contracts, contract T_H^{SB} is preferred by both types (that is, $\forall i\ CE_i(T_H^{SB}) > CE_i(T_L^{SB})$). This contract, however, would make negative profits if it attracted less skilled workforce, so this cannot be an equilibrium situation.

We have established that second best contracts are not equilibrium contracts and firms should always take into account incentive compatibility when designing the contracts. We proved that high ability worker never wants to choose T_L^{SB}. Therefore, in the separating equilibrium less skilled worker must receive his most preferred contract among those that leave zero profit to the employing firm.

Proposition 14 *In the separating equilibrium the contract for the low ability worker must be* $T_L^{TB} = T_L^{SB} = \left(\alpha_L^{SB}, \frac{1}{1+r\sigma^2}, \frac{h^2}{h^2+r\sigma^2}\right)$.

The contract for high ability worker is the most preferred from his point of view among those that satisfy low ability worker incentive compatibility constraint and leave zero profit for the employer. Therefore, it is a solution to the following problem: the contract maximizes highly skilled worker incentive compatibility

$$\max_{\beta_H,\gamma_H} \theta_H (1+h) + \beta_H + h^2\gamma_H - \frac{\beta_H^2 + h^2\gamma_H^2}{2} - \frac{r}{2}(\beta_H^2 + \gamma_H^2)\sigma^2 \tag{3.30}$$

such that the less skilled worker does not want to chose it instead of T_L^{SB}

$$CE_L(T_L^{SB}) \geq CE_L(T_H)$$

Let $\mu > 0$ be the Lagrangian multiplier. Then the first order conditions yield:

$$\begin{aligned} \mu &= \frac{1-\beta_H(1+r\sigma^2)}{1-\Delta\theta-\beta_H(1+r\sigma^2)} \\ \mu &= \frac{h^2-\gamma_H(h^2+r\sigma^2)}{h^2-h\Delta\theta-\gamma_H(h^2+r\sigma^2)} \end{aligned} \tag{3.31}$$

and the complementary slackness condition is:

$$\begin{aligned} 0 = {} & \frac{h^2+r\sigma^2+h^4(1+r\sigma^2)}{2(1+r\sigma^2)(h^2+r\sigma^2)} + \frac{\beta_H^2+h^2\gamma_H^2}{2} + \frac{r}{2}(\beta_H^2+\gamma_H^2)\sigma^2 \\ & -(1+h)\Delta\theta - \beta_H(1-\Delta\theta) - \gamma_H\left(h^2-h\Delta\theta\right) \end{aligned} \tag{3.32}$$

Due to a large number of variables the solution to this system is a complicated object. Nevertheless it is possible to make interesting observations and describe the properties of the contract for highly skilled workforce just by looking at the first order conditions.

Proposition 15 *In the separating equilibrium high ability worker will separate from less skilled worker by accepting a contract that comes with higher performance bonuses. He will exert higher effort on both tasks. The third best* *contracts have the following properties*

$$\begin{aligned}\beta_L^{TB} &= \beta_L^{SB}\\ \gamma_L^{TB} &= \gamma_L^{SB}\\ \beta_H^{TB} &> \beta_L^{TB}\\ \gamma_H^{TB} &> \gamma_L^{TB}\end{aligned}$$

Proof. Recall that $\frac{1-\beta_H(1+r\sigma^2)}{1-\Delta\theta-\beta_H(1+r\sigma^2)} = \frac{h^2-\gamma_H(h^2+r\sigma^2)}{(h^2-h\Delta\theta-\gamma_H(h^2+r\sigma^2))}$ as follows from the first order conditions. Notice that $1-\beta_H(1+r\sigma^2) > 1-\Delta\theta-\beta_H(1+r\sigma^2)$ and $h^2-\gamma_H(h^2+r\sigma^2) > h^2-h\Delta\theta-\gamma_H(h^2+r\sigma^2)$. Given that $\mu > 0$ (the incentive compatibility constraint is binding), the equality derived from the first order conditions can hold, and so the solution will exist, only if either (CASE 1) both denominators and nominators are positive, which boils down to:

$$\begin{aligned}\beta_H^{TB} &< \frac{1-\Delta\theta}{1+r\sigma^2} < \beta_H^{SB} = \beta_L^{SB}\\ \gamma_H^{TB} &< \frac{h^2-h\Delta\theta}{h^2+r\sigma^2} < \gamma_H^{SB} = \gamma_L^{SB}\end{aligned}$$

or (CASE 2) both denominators and nominators are negative

$$\begin{aligned}\beta_H^{TB} &> \frac{1}{1+r\sigma^2} = \beta_H^{SB} = \beta_L^{SB}\\ \gamma_H^{TB} &> \frac{h^2}{h^2+r\sigma^2} = \gamma_H^{SB} = \gamma_L^{SB}\end{aligned}$$

We obtain two candidates for the separating contract for high ability worker. In the first one (CASE 1) high ability worker would work less than in second best and accept lower bonuses. In the second one (CASE 2), he would do the opposit i.e. work harder on both tasks and accept a compensation scheme that comes with higher bonuses. Using the necessary condition for separation (equation (3.29)) we can reject CASE 1 as a possible equilibrium outcome. ■

A number of concluding observations can be made now. We have shown that by means of variable pay worker's type can be infered from his market behavior. Variable pay can be then seen as a self-selection device. It conditions worker's earnings on his own and his teammate's performance, which in turn are respectively affected by his own and his teammate's skill. Highly skilled workers in our model distinguish themselves from the less skilled workforce by accepting contracts with higher performance bonuses and working harder (and closer to the-first best) on their own task and helping their colleague more. High ability workers in our model exert more effort and are more teamwork oriented and firms employing highly skilled workers achieve higher production levels. Fully rational highly skilled workers are not afraid to condition their wage on the performance of their teammate because they correctly assume that the contract T_H^{TB} will attract only highly skilled workers. Therefore, they will be, for sure, paired with a worker equally skilled as they are. It is then optimal for them to work more on both (instead of only one) tasks because in this way they can minimize the disutility associated with the total effort they exert and so minimize the cost that they need to bear in order to separate themselves from less productive workers.

3.4.4 Pooling equilibrium

In the pooling equilibrium no information about the employee type is revealed after they select the contracts, because all of them make the same choice. As a result all firms offer the same contract that is accepted by both types of the employees. In this section we are going to prove that pooling of the types is not possible in the equilibrium.

As established earlier (in Proposition 11) a contract offered in the pooling equilibrium $T^p = (\alpha^p, \beta^p, \gamma^p,)$ would have to leave zero profits to the employer. Since in the pooling equilibrium the employer expects to employ on average a worker whose productivity parameter is equal on average to $\theta_A = \frac{k}{n}\theta_H + \frac{n-k}{n}\theta_L$ the zero profit condition becomes

$$\alpha^p = (1 - \beta^p - \gamma^p)\left((1 + h)\,\theta_A + \beta^p + h^2\gamma^p\right) \tag{3.33}$$

We assumed (with $\alpha > 0$) that highly skilled workers are more desirable than low ability workers, so in equilibrium the contract that attracts both types of worker would have to be the most preffered one from the point of view of highly skilled worker. In other words, among all the contracts that break even at average worker productivity it would have to be the one that maximizes utility of highly skilled worker. Formally,

Proposition 16 *If pooling equilibrium exists it is determined by a solution to the following problem*

$$\max_{\beta,\gamma}((1+h)\,\theta_A+\beta+h^2\gamma)+\beta\left(\theta_H+h\theta_{A|H}-(1+h)\,\theta_A\right)+$$
$$+\gamma(\theta_{A|H}+h\theta_H-(1+h)\,\theta_A)-\frac{\beta^2+h^2\gamma^2}{2}-\frac{r}{2}(\beta^2+\gamma^2)\sigma^2 \qquad (3.34)$$

where $\theta_{A|H}=\frac{k-1}{n-1}\theta_H+\frac{n-k}{n-1}\theta_L$ *is expected teammate's productivity from the point of view of highly skilled worker and* $\theta_{A|L}=\frac{k}{n-1}\theta_H+\frac{n-k-1}{n-1}\theta_L$ *is expected teammate's productivity from the point of view of less skilled worker when workers believe that pooling takes place in equilibrium.*

In what follows, we will try to establish or deny the existance of pooling equilibrium. If the pooling equilibrium existed it would have to be true that there do not exist other profitable contracts that if offered would attract workers.It turns out that using the single crossing property of the indifference surfaces we are able to show that there exists a set of profitable contracts, that if announced would skim only highly skilled workers away from the pooling equilibrium. Therefore, we can conclude that a contract that pools both worker types together into one firm cannot be equilibrium outcome. Formally,

Proposition 17 *Pooling equilibrium does not exist.*

Proof. We will first establish that indifference surfaces cross only once. In order to obtain the equations describing these surfaces we first write down formulas for certainty equivalent of highly and less skilled worker.

$$\begin{aligned}
CE_H(T^p) &= \alpha^p+\beta^p\left(\theta_H+\beta^p+h\left(\theta_{A|H}+h\gamma^p\right)\right)+\\
&\quad+\gamma^p(\theta_{A|H}+\beta^p+h\,(\theta_H+h\gamma^p))-\frac{(\beta^p)^2+h^2\,(\gamma^p)^2}{2}-\\
&\quad-\frac{r}{2}((\beta^p)^2+(\gamma^p)^2)\sigma^2\\
CE_L(T^p) &= \alpha^p+\beta^p\,(\theta_L+\beta^p+h\,(\theta_H+h\gamma^p))+\\
&\quad+\gamma^p(\theta_H+\beta^p+h\,(\theta_L+h\gamma^p))-\frac{(\beta^p)^2+h^2\,(\gamma^p)^2}{2}-\\
&\quad-\frac{r}{2}((\beta^p)^2+(\gamma^p)^2)\sigma^2
\end{aligned}$$

where $\theta_A = \frac{k}{n}\theta_H + \frac{n-k}{n}\theta_L$, $\theta_{A|H} = \frac{k-1}{n-1}\theta_H + \frac{n-k}{n-1}\theta_L$ and $\theta_{A|L} = \frac{k}{n-1}\theta_H + \frac{n-k-1}{n-1}\theta_L$. We will be comparing the indifference curve of highly skilled worker who believes that the contract he chooses pools both types of worker and the indifference curve of less skilled worker who believes that he is paired with highly skilled worker. Using α^p, for simplicity, as the dependent variable the following formulas define the indifference surfaces

$$
\begin{aligned}
IC_H &: \alpha^p = -\beta^p\left(\theta_H + \beta^p + h\left(\theta_{A|H} + h\gamma^p\right)\right) - \\
&-\gamma^p(\theta_{A|H} + \beta^p + h\left(\theta_H + h\gamma^p\right)) + \\
&+\frac{(\beta^p)^2 + h^2(\gamma^p)^2}{2} + \frac{r}{2}((\beta^p)^2 + (\gamma^p)^2)\sigma^2 \\
IC_L &: \alpha^p = -\beta^p\left(\theta_L + \beta^p + h\left(\theta_H + h\gamma^p\right)\right) - \\
&-\gamma^p(\theta_H + \beta^p + h\left(\theta_L + h\gamma^p\right)) + \\
&+\frac{(\beta^p)^2 + h^2(\gamma^p)^2}{2} + \frac{r}{2}((\beta^p)^2 + (\gamma^p)^2)\sigma^2
\end{aligned}
$$

$$
\begin{aligned}
IC_H &: \beta = -\left(\theta_H + h\theta_{A|H}\right) \\
IC_L &: \beta = -\left(\theta_L + h\theta_H\right)
\end{aligned}
$$

$$IC_H : -\left(\theta_H - \theta_L\right) < -h\left(\theta_H - \theta_{A|H}\right) : IC_L$$

$$IC_H : -h(\theta_H - \theta_L)?? - \left(\theta_H - \theta_{A|H}\right) : IC_L$$

Checking the derivatives we get that the indifference surface of high ability worker is steeper in the direction of β while it is either steeper or flatter in the direction of γ. For simplicity keep gamma constant at γ^p. It is easy to see that there exists a contract $T^{p\prime} = (\alpha^{p\prime}, \beta^{p\prime}, \gamma^p)$ that if offered would attract only highly skilled workers and make a positive profit. In particular, in order to separate from less skilled workers high ability workers are for given group bonus willing to lower the fixed wage component α while increasing own performance bonus β. This allows us to conclude that T^p cannot be an equilibrium contract. ■

3.4.5 Equilibrium

The preceding sections characterize pure-strategy subgame perfect equilibria of the competitive screening game. We have established that pooling equilibria will not emerge, but have not commented on the existence of separating equilibria. In this section we comment on the equilibrium inexistence problem. Rothschild and Stiglitz (1976) first observed that in the single-crossing case where risk aversion is observable, pure-strategy equilibrium need not exist. Their analysis applies with some modification to our case. Nonexistence arises in the model because, in some circumstances, firms may deviate from the candidate separating equilibria by entering the market and offering a contract that attracts a pool of highly and poorly skilled workers and which is profitable. As we have already established, in equilibrium pooling cannot take place, so for some parameter values the equilibrium will not exist. Whenever it exists, it is separating.

3.5 Conclusion

Summing up, we find out that in the competitive equilibrium better skilled workers work harder on their task and are attracted to firms that offer higher own performance bonuses. They also work harder on their teammate's task and their contract has higher teammate's performance bonus, too. The result is driven by the fact that fully rational workers are able to foresee that the separation will take place in equilibrium. They understand that in separating equilibrium they will be working with a worker equally skilled as they are. The production levels are higher in the firms that employ high ability workers and both the incentive and sorting effect of performance pay contributes to it. Moreover, our model can explain the emergence of different corporate cultures as we show that in the separating equilibrium high ability and low ability workers choose to work in distinct companies. Our prediction is that firms that employ high ability workers are more teamwork oriented and its organizational design involves more cooperation among its employees. We stress the interesting role that sorting and information play in the labor market and describe the impact that they have on the emerging incentive schemes.

The natural question to ask is whether the predictions of this model are supported in real labor markets. One of the problems that we see is the assumption that the employees are able to perfectly assess the type of their teammate. As long as it is easy to believe that people do calculate which of the offered contracts is better for them and chose the best one, it is less obvious that they will do their calculations based on the correct beliefs regarding the skill of the teammate. In fact the papers of Camerer and Lovallo (1999) and Dohmen and Falk (2001) find out that people exhibit what Camerer and Lovallo call "reference group neglect." In both of these experimental studies self-selected subjects seem not to acknowledge that the separation took place. In particular in both of the papers, self selected agents do not realize that under the option they chose they will be competing with a reference group of subjects similar to them. If workers do not realize that the separation occurs in a market their beliefs about teammate's type will be changed. Those beliefs play an important role in our model because they influence workers' employment acceptance decisions. Therefore, relaxing the assumption of full rationality of the employees and letting them have different beliefs about the workforce that will be attracted to any given contract could change the implications of our model. Nevertheless, even if indeed participants in the labor market do not behave in fully rational manner, our model is indispensable as a benchmark that would help to identify and describe the kind and magnitude of departures from rationality observed in the real labor markets.

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