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I. Introduction

This thesis contains three separate papers that deal with various aspects of organization theory and personnel economics. The first paper, which is joint work with Frank Rosar from University of Bonn, considers the impact of delegation of authority on the motivation of agents. The second paper is joint work with Emmanuelle Auriol from Toulouse School of Economics. It analyzes the impact of negative intrinsic motivation on the optimal labor contracts in profit- and mission-oriented organizations. And finally the third paper asks the question how workers should be assigned to jobs if they possess multidimensional skills that are of varying importance in different jobs.

In the following, a short overview over each paper is given, before the papers are presented in more detail in Chapter II to IV.

I.1. Authority and Motivation

In the first paper, we consider situations where two parties, a principal and an agent, have to find an agreement on the choice of a project, and analyze how decision rights should be optimally allocated between the two parties.

The importance of this question has, among others, been pointed out in a seminal paper by Aghion and Tirole (1997) who analyze how delegation of authority influences both parties' incentives to acquire information on the possible projects and their payoffs. By contrast, we assume that all project payoffs are common knowledge, but the extent to which the players are willing to accept compromises concerning the project choice is their private information. We thus consider a complementary problem to the one described in Aghion and Tirole (1997).

In our setup, authority consists of two components: the *authority to initiate* or choose a project, and the *authority to approve* or implement a project. That is, who gets to pick a project, and who has the final decision right on whether the project is going to be realized or not. The principal allocates both tasks in the beginning of the game to either himself or the agent. We assume that the principal and the agent, a priori, favor different projects, but in order to complete the project successfully, they will have to find a compromise for which both are willing to provide effort.

In the first part of the paper, we analyze a situation where the principal keeps the authority to approve, but may delegate the authority to initiate a project to the agent. We show that delegating the authority over the project choice can have a *motivating effect* on the agent as he is able to choose a project for which he is also willing to provide effort. However, delegation of authority may also have a *discouraging effect* on the agent, in particular if he is unsure about whether the principal is going to accept his project choice. Even if the project is mutually beneficial with positive probability, the agent may not be willing to provide effort when he is afraid that his effort investment will be lost.

In the second part of the paper, we go one step further and try to disentangle the different authority components by also endogenizing the allocation of the authority to approve a project. We find that under certain circumstances, the principal will give *all* authority to the agent, i.e., both the authority to initiate and to approve a project. He thus can avoid the discouraging effect of delegation that arises when the agent can initiate a project but when he is not sure whether it will be implemented. However, the more likely the principal is to approve the agent's choice, the more the latter will try to push his own preferred project, thus lowering the principal's utility. A principal who is more willing to compromise hence risks that the agent takes advantage of this circumstance. As a consequence, a principal who is more flexible with respect to the project choice will actually cede *less* authority to the agent.

I.2. The Good, the Bad, and the Ordinary

In this paper, we analyze how different sources of intrinsic motivation of workers may affect labor management and the production outcomes both in for-profit and nonprofit organizations.

Most theoretical models on intrinsic motivation suppose that it arises if workers derive a benefit from doing good or if they are interested in a certain mission, such as helping the poor or protecting the environment. However, workers may be motivated by many other aspects of a job which are not necessarily beneficial for the employer or society. For instance, a pedophile might be interested in working with children, especially if he faces a low risk of being exposed; a spy will prefer jobs where he can get his hands on sensitive information; and a terrorist might want to work in an airport to have a privileged access to planes.

To account for such different sources of motivation, we assume that there are three types of workers, who care for different things: regular workers only care about monetary incentives, good workers care about money and the mission of the organization, and bad workers care about money and whether they can do things they like, but which are harmful to the organization or society. We then consider two sectors of the economy, one profit-oriented and one mission-oriented. As in Besley and Ghatak (2005), on which our model is based, we assume that in the nonprofit sector, organizations are structured around some mission, for example providing public services, or catering to the needs of disadvantaged groups of society.[1] These organizations may attract workers who care about this specific mission and derive an intrinsic benefit from their work. They can hence offer lower extrinsic incentives and still attract motivated workers. We further generalize the approach by Besley and Ghatak (2005) by introducing "bad" workers and adding monitoring as an additional choice variable of the employer in order to deal with the

[1]We use the terms mission-oriented and nonprofit organization equivalently since we believe them to be largely congruent in reality. However, there are cases where organizations do not have the legal status of a nonprofit, but still follow a mission. For a further discussion of this, see Besley and Ghatak (2005).

different incentive issues raised by the presence of different kinds of workers: while monitoring reinforces the effort incentives of good and regular workers, it makes “bad” actions or anti-social behavior less attractive as it increases the chances of getting caught and being punished.

Given this setup, we first consider the case with only good and regular workers and find the classic result that the mission-oriented sector offers lower wages and makes less use of monitoring than the profit-oriented sector. We then introduce bad workers who derive utility from behaving in an anti-social way. It turns out that profit-oriented organizations are a priori less vulnerable to such behavior. Bad workers may behave like regular workers in the profit-oriented sector and thus be totally undistinguishable from “normal” people. By contrast, if they join the mission-oriented sector, then only in order to follow their destructive instincts. The more organizations in this sector rely on the intrinsic motivation of good workers and the less they make use of monetary incentives and control, the more likely they are to become the target of bad workers. We then analyze how contracts have to change in both sectors in order to deter bad workers from their destructive behavior. However, deterrence is costly as it implies higher monitoring, and it even may become entirely ineffective for workers with very high levels of bad motivation. We therefore also consider ex ante measures of candidate selection, which may help to reduce the occurrence of anti-social behavior.

I.3. Job Assignment with Multivariate Skills

The third paper asks the question under which circumstances the performance in one job can be a useful selection criterion for another job when workers' skills are distributed along several dimensions and jobs require different skills to a varying extent.

Using a simple model with two activities and two skills that are of different importance for each of the activities, I derive optimal assignment rules for old and new workers. The paper shows that there may be a tradeoff between short-term and long-term output maximization when new workers are hired for two periods: in the short run, output is maximized by assigning new workers to the task where the expected output of an unscreened worker is maximal. But especially if this task plays a much more important role in the overall production of the firm, the employer may prefer to first hire workers for the other task, which is thus used as a screening stage for maximizing output in the long run. That is, the employer will prefer to forego some first period output in order to make more informed choices in the long run.

However, the firm may not always be in a situation where it can assign any number of workers to any task. At least in the short run, it is likely to face slot constraints in the sense that it has a fixed number of jobs concerned with either of the two tasks. If this is the case, reassignment rules will change with the consequence that workers may end up working in a job where they are likely to be less productive. That is, a variant of the Peter Principle may hold which states that workers get promoted up to their level of incompetence. In this model, workers may get reassigned to a different job even though they are likely to be less "competent" in this job. Yet, the employer will prefer this to hiring a new worker on whom he has no information. The Peter Principle would, thus, be a by-product of a labor market where it is difficult to assess workers' characteristics.

II. Authority and Motivation

II.1. Introduction

There are many situations where a principal and an agent have to realize a project together that requires both parties' effort even though they have opposing interests as to which project to choose.

Consider, for example, the decision problem faced by a manufacturer and a supplier: While the former is interested in buying high quality goods, the latter can increase his profits by lowering his costs at the detriment of quality. In order to do business with each other, they will have to find an agreement that suits both and induces both firms to provide effort. The same would also be true for co–authors with opposing interests regarding the writing style or focus of their paper.

With scenarios such as these in mind, we analyze the effect of the allocation of decision rights on both players' motivation to conduct the chosen project. We assume that both players are symmetric except for the fact that one player has a somewhat stronger position which allows him to decide who has the authority to select a project and– in the second part of the paper– also how the work on the project should be organized. In the first example above, the stronger player could be the manufacturing firm who would thus take the role of the principal, whereas the supplier would be in the weaker position of the agent. Likewise, in the second example, the coauthors might be a professor (the principal) who writes a paper with his student (the agent). Given that the principal and the agent in each of these examples favor a different project, we ask how the principal should allocate decision rights. Should he let the agent choose a project? This may induce the agent to work harder, but it also increases the chances that the chosen project is not the one favored by the principal. And to what extent should the principal try to keep the final control over the project implementation?

To answer these questions, we propose a model which is related to the seminal paper by Aghion and Tirole (1997) who have pointed out the importance of the allocation of decision rights on motivation. A priori, the agent and the principal in our model favor different projects. While they are aware of this basic conflict of interest, they do not know how flexible the other player is concerning the project choice. That is, their respective *willingness to compromise* is their private information. Yet, in order to complete the project successfully, both players have to agree on the project choice and be willing to contribute their effort.

We then analyze the effect of the allocation of authority on both players' motivation to work on the chosen project. In order to do so, we differentiate between two components of authority: the *authority to initiate* or choose a project, and the *authority to approve* or implement a project. That is, who gets to pick a project, and who has the final decision right on whether the project is going to be realized or not. The principal allocates both tasks in the beginning of the game to either himself or the agent.

In the first part of the paper, we analyze a situation where the principal keeps the authority to approve, but may delegate the authority to initiate a project to the agent. We show that delegating the authority over the project choice can have a *motivating effect* on the agent as he is able to choose a project for which he is also willing to provide effort. However, delegation of authority may also have a *discouraging effect* on the agent, in particular if he is unsure about whether the principal is going to accept his project choice. Even if the project is mutually beneficial with positive probability, the agent may not be willing to provide effort when he is afraid that his effort investment will be lost.

In the second part of the paper, we go one step further and try to disentangle the different authority components by also endogenizing the allocation of the authority to approve a project. We find that under certain circumstances, the principal will give *all* authority to the agent, i.e., both the authority to initiate and to approve a project. He thus can avoid the discouraging effect of delegation that arises when the agent can initiate a project but cannot implement it. However, the more likely the principal is to approve the agent's choice, the more the latter will try to push his own favorite project, thus lowering the principal's utility. A principal who is more willing to compromise hence risks that the agent takes advantage of this circumstance. As a consequence, a principal who is more flexible with respect to the project choice will actually cede *less* authority to the agent.

There is a large literature on the effects of delegation in various settings. For instance, one strand of the literature considers situations where the agent has information which is payoff-relevant for the principal, who therefore might want to delegate decisions to the agent in order to take advantage of his information. Examples are the papers by Holmström (1977), Alonso and Matouschek (2007), and Alonso and Matouschek (2008).[1] By contrast, in the setting we consider, neither the principal and nor the agent have information on the project which is directly payoff-relevant for the other.

In this respect, our paper differs also from the paper by Aghion and Tirole (1997), who analyze how delegation of authority influences both parties' incentives to acquire information on the possible project payoffs. That is, they analyze a problem where the effort decision affects the project choice. By contrast, in our paper the project choice affects the motivation to provide effort such that causality is basically reversed. We are thus interested in a problem which is complementary to the one considered in Aghion and Tirole (1997). We find that the reversed time structure together with some further differences[2] may lead to delegation having qualitatively different effects on motivation. In particular, while delegation has a positive effect on motivation in Aghion and Tirole (1997), there are countervailing effects in our paper. Thus, our paper helps to

[1] The same is true for papers building on the model first presented by Crawford and Sobel (1982), as for instance Dessein (2002). However, these models usually do not incorporate effort and hence provide no results concerning the motivation of workers.

[2] In particular, effort is complementary instead of substitutive and the nature of private information differs.

understand better some further aspects of the relationship between the allocation of authority and motivation.

There are some other papers on delegation that consider a similar structure as we do. In particular, the timing of actions in these papers is similar, in that effort is spent only after a project has been chosen. Whether delegation of the project choice occurs or not then has an impact on some subsequent game. Examples are the papers by Aghion, Dewatripont, and Rey (2004) and Zabojnik (2002).[3] The latter paper is closer to our analysis as it builds on a similar notion of motivation. Yet its focus is on how delegation may help save on high-powered incentives. Also in this class of models are the papers by Bester and Krähmer (2008) and Bester (2009), the latter of which allows for a conflict of interest, since a higher payoff for the principal causes higher costs for the agent.

Furthermore, by considering different components of authority we go beyond much of the existing literature which usually focuses on delegation of the project choice, but does not take into account other components of authority. Some notable exceptions are the papers by Van den Steen (2007) and Landier, Sraer, and Thesmar (2009) who also explicitly model the implementation decision.[4]

The paper is organized as follows: the next section outlines the basic model, where the principal may delegate the authority to initiate a project to the agent, but keeps the authority to approve. This basic model is analyzed in Section II.3. In Section II.4, we then look at what happens if we change the game structure such that the agent instead of the principal has the authority to approve a project. In Section II.5, the different resulting authority structures are compared and the principal's

[3]Aghion, Dewatripont, and Rey (2004) introduce the notion of transferable but not contractible control. Zabojnik (2002) shows that if workers are liquidity constrained, it may be less costly to motivate workers by letting them work on their own ideas, even if the manager is better informed.

[4]In particular the paper by Landier, Sraer, and Thesmar (2009) is related to our analysis, but unlike in our model, the results are driven by the fact that one player has better information about the state of the world than the other.

choice of authority allocation is endogenized. Section II.6 concludes.

II.2. The Model

We consider a setting where a principal P and an agent A want to realize a project together. Both parties have diverging preferences over the project choice, and the project is only realized if the agent provides positive effort and the principal approves the chosen project.[5]

Projects. There are two projects $k = 1, 2$. The principal P prefers project $k = 1$, the agent A prefers project $k = 2$. These preferences are common knowledge, however it is private information, how much player $i = A, P$ dislikes his less preferred project. Their respective project valuations v_{ik} are as follows:

Project valuation v_{ik}	$i = P$	$i = A$
Project $k = 1$	B	αb
Project $k = 2$	βB	b

The parameters $\alpha, \beta \in [0, 1]$ measure the extent to which the preferences of the two parties are aligned.[6] We interpret them as the respective player's willingness to compromise on the project choice. The higher for example α, the higher is the utility that the agent derives from his less preferred project, i.e., the more likely he is willing to compromise about this project.[7] We assume that both parameters can be either high or low, i.e. $\alpha \in \{\underline{\alpha}, \bar{\alpha}\}$ and $\beta \in \{\underline{\beta}, \bar{\beta}\}$. The probability that player $i = A, P$ has a high type is q_i. With probability $1 - q_i$, he is of a low type.

[5]In order to make our analysis easier to compare, we use largely a similar notation as in Aghion and Tirole (1997).

[6]This is similar to the model of Aghion and Tirole (1997), except that there the congruence parameters are common knowledge whereas in our model they are private information.

[7]The analogue reasoning applies to the principal's willingness to compromise β.

Effort. The agent and the principal can either provide effort or not, i.e. $e_i \in \{0,1\}$. For the project to be successful, both players $i = A, P$ have to provide effort $e_i = 1$. Their cost of effort is given by $c_i > 0$.

Utility. Both $i = A, P$ get utility $u_{ik} = v_{ik} \cdot e_A \cdot e_P - c_i \cdot e_i$ from realizing project $k = 1, 2$ where v_{ik} is player i's valuation of project k as given by the table above. That is, the players' actions e_A, e_P are strict complements.

We assume that all types of players get the highest utility from their preferred project. Only high types (i.e., who have a willingness to compromise $\bar{\alpha}$, respectively $\bar{\beta}$) derive positive utility from the other player's preferred project, whereas low types ($\underline{\alpha}$, $\underline{\beta}$) will only want to realize their own preferred project. This means, the following has to hold:

Assumption 1: We assume that $b - c_A > \bar{\alpha}b - c_A > 0 > \underline{\alpha}b - c_A$, and $B - c_P > \bar{\beta}B - c_P > 0 > \underline{\beta}B - c_P$.

As a consequence, it is only possible to find a mutually beneficial project if at least one of the two players is of a high type. The following table gives an overview over which projects give a positive payoff to both players, given the types of the agent and the principal:

Possible projects	$\underline{\alpha}$	$\bar{\alpha}$
$\underline{\beta}$	-	$k = 1$
$\bar{\beta}$	$k = 2$	$k = 1, 2$

Authority. For the time being, we only consider how the authority to initiate should be allocated, whereas the authority to approve stays with the principal. In Section II.4, we consider the opposite case where the agent always has the authority to approve. In Section II.5, we finally endogenize the allocation of both authority components.

Information. As noted above, the players' willingness to compromise α and β, respectively, is their private information. They learn this information only after stage 1 of the game, i.e., after it has been decided

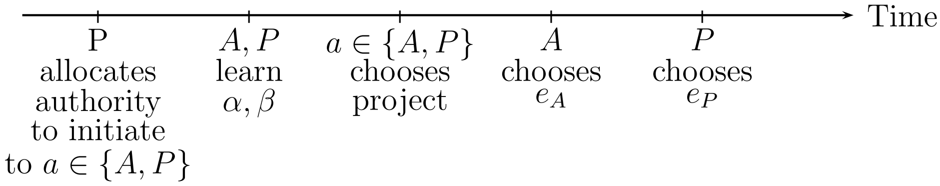


Figure II.1: Timing of events.

who is going to choose a project. The preferences over the projects as described in the above tables, the players' project valuation and utility functions, as well as the respective probabilities that the players are of a high type are common knowledge.

Timing. The timing of the game, as also represented in Fig. II.1, is as follows:

(1) *Allocation of authority to initiate:* The principal assigns authority for the project choice to $a \in \{A, P\}$.

(-) The agent and the principal learn their own willingness to compromise α and β, respectively.

(2) *Project choice:* Player a chooses project $k \in \{1, 2\}$.

(3) *Agent's effort decision:* The agent chooses his effort level $e_A \in \{0, 1\}$.

(4) *Principal's effort decision (Implementation stage):* The principal chooses his effort level $e_P \in \{0, 1\}$.

Note that the last two steps are reversed in Section II.4: then the agent gets to decide last and hence has the power to approve or veto the chosen project. In Section II.5, the choice between these two game structures is endogenized.

Solution concept. We adopt the notion of perfect Bayesian equilibrium.

II.3. The Principal has the Authority to Approve

In this section we first analyze the optimal allocation of authority over the project choice when the principal keeps the authority to approve the project, i.e., when he keeps the last word in the matter.

We solve the game by backwards induction. Let us start with the case where the agent A has the authority to choose a project.

II.3.1. The Agent Initiates a Project

At the last stage of the game, the principal can observe the project and effort choice of the agent. If the latter has provided effort, the principal will choose effort $e_P = 1$ if his favorite project $k = 1$ is chosen, or if $k = 2$ *and* his willingness to compromise is high, i.e., if P is of type $\bar{\beta}$.

Anticipating this behavior, the expected utility of the agent if he chooses $k = 1$, i.e., his less preferred project, is

$$E[u_A|k = 1] = e_A(\alpha b - c_A)\ . \tag{II.1}$$

That is, he can be sure that the principal is going to approve the choice and provide effort. By contrast, if the agent chooses his own preferred project $k = 2$, the principal will only approve with probability q_P, i.e., if his type is $\bar{\beta}$. The agent's expected utility therefore is

$$E[u_A|k = 2] = e_A(q_P b - c_A)\ . \tag{II.2}$$

Optimal project choice. Comparing these two options, we find that the agent optimally chooses project $k = 1$ if $\alpha > q_P$ and $k = 2$ otherwise.

Optimal effort choice. The agent provides effort if he gets positive expected utility from the optimal project. In case $\alpha > q_P$, the agent provides effort if $\alpha > c_A/b$. In case $\alpha < q_P$, he provides effort if $q_P > c_A/b$. Otherwise the agent's optimal effort choice is $e_A = 0$.

We thus obtain the following cases:

Case A1: $q_P \leq \underline{\alpha}$

If $q_P \leq \underline{\alpha}$ then (II.1) is greater than (II.2) and hence all types of agents optimally choose the principal's preferred project $k = 1$. However, only agents of type $\bar{\alpha}$ can get a positive utility from this choice and are willing to provide effort. Payoffs for the different types of principals and agents hence can be summarized as follows:

v_P, v_A	$\underline{\alpha}$	$\bar{\alpha}$
$\underline{\beta}$	0,0	$B - c_P$, $\bar{\alpha}b - c_A$
$\bar{\beta}$	0,0	$B - c_P$, $\bar{\alpha}b - c_A$

From an ex ante point of view, i.e., before the players learn their respective types, the expected payoff of the principal therefore is

$$E[u_P] = q_A(B - c_P) \ .$$

The expected payoff of the agent is ex ante

$$E[u_A] = q_A(\bar{\alpha}b - c_A) \ .$$

Case A2: $\underline{\alpha} < q_P \leq c_A/b$

In this case, low type agents ($\alpha = \underline{\alpha}$) prefer project $k = 2$. However, the probability that the principal is going to approve this choice is too low to make it worthwhile for the agent to provide effort. High types of agents ($\alpha = \bar{\alpha}$) prefer $k = 1$ and provide effort. As a consequence, the payoff matrix and the ex ante expected payoffs in this case are identical to the previous one.

Case A3: $c_A/b < q_P \leq \bar{\alpha}$

As in the previous case, low type agents prefer project $k = 2$, but now the probability of getting through with this choice is actually high enough, so that also the effort level is positive. If the agent is of a high type, his optimal behavior is as in the previous case, i.e., he chooses $k = 1$ and $e_A = 1$. Hence payoffs are as follows:

v_P, v_A	$\underline{\alpha}$	$\bar{\alpha}$
$\underline{\beta}$	0,$-c_A$	$B - c_P$, $\bar{\alpha}b - c_A$
$\bar{\beta}$	$\bar{\beta}B - c_P$,$b - c_A$	$B - c_P$, $\bar{\alpha}b - c_A$

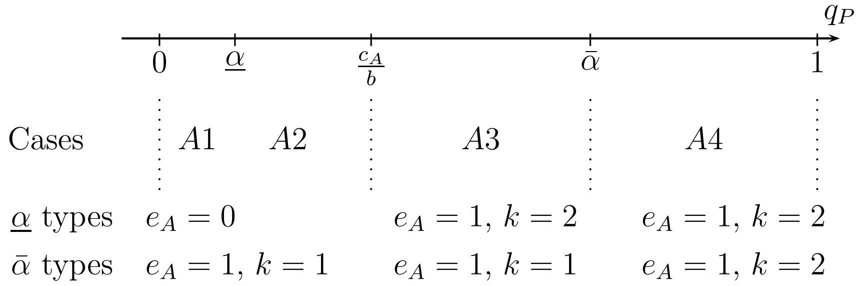


Figure II.2: Agents' effort and project choice under AP-authority, given q_P.

This leads to the following ex ante expected payoffs:

$$
\begin{aligned}
E[u_P] &= q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P) \ , \\
E[u_A] &= q_A(\bar{\alpha}b - c_A) + (1 - q_A)q_P(b - c_A) + (1 - q_A)(1 - q_P)(-c_A) \ .
\end{aligned}
$$

Case A4: $\bar{\alpha} < q_P$

In this case, the probability that the principal is of a high type and that he will therefore eventually approve even of his less preferred project $k = 2$ is so large that the agent will choose $k = 2$ and provide effort, no matter what his own type is. The payoffs can then be summarized as:

v_P, v_A	$\underline{\alpha}$	$\bar{\alpha}$
$\underline{\beta}$	$0, -c_A$	$0,\ -c_A$
$\bar{\beta}$	$\bar{\beta}B - c_P, b - c_A$	$\bar{\beta}B - c_P,\ b - c_A$

The ex ante expected payoffs of the two players are:

$$
\begin{aligned}
E[u_P] &= q_P(\bar{\beta}B - c_P) \ , \\
E[u_A] &= q_P b - c_A \ .
\end{aligned}
$$

Summing up these cases, we get the following results, as shown in Figure II.2: For low values of q_P ($q_P < c_A/b$, cases A1 and A2), i.e., if the probability that the principal is willing to compromise on the project choice is low, then only high type agents ($\alpha = \bar{\alpha}$) provide effort. To make sure that a project is realized, they will choose the principal's preferred project, $k = 1$. Low type agents ($\alpha = \underline{\alpha}$) who are inflexible on the project choice, are too afraid that their effort will be in vain even though for $q_P > 0$ there is a positive probability that even project $k = 2$ will go through. They hence prefer to do nothing and get zero payoff rather than to incur the cost of effort and possibly make a loss. That is, delegation of authority has a *discouraging effect* here.

In the intermediate range of values of q_P ($c_A/b \leq q_P < \bar{\alpha}$, case A3), this discouraging effect of delegation disappears. Now, even low type agents find it worthwhile to provide effort.[8] High type agents continue to choose the principal's preferred project. Therefore delegation has a *motivating effect* in this range of values and the principal actually gets his first-best outcome: agents always provide effort, and whenever it is possible (i.e., whenever $\alpha = \bar{\alpha}$) the principal's preferred project is chosen.

Finally, for high values of q_P ($\bar{\alpha} \leq q_P$, case A4), the probability that P is of a high type and that A hence can push through his preferred project is so high, that all types of agents choose their preferred project $k = 2$. That is, they take advantage of the principal's flexibility and hence we speak of an *exploitation effect*.

II.3.2. The Principal Initiates a Project

Let us now consider what happens if the principal picks the project himself, i.e., if he has both the authority to initiate and to approve a project.

As before, at the last stage of the game, the principal knows which project has been chosen and whether the agent has provided effort. The principal will choose effort $e_P = 1$ if his favorite project $k = 1$ is chosen or if $k = 2$ *and* his willingness to compromise is high, i.e., if P is of type $\bar{\beta}$.

If P chooses A's preferred project $k = 2$ he can be sure that A will

[8]Of course, due to Assumption 1, they still choose project $k = 2$ as this is the only project from which they get a positive payoff.

provide effort, leaving P with payoff

$$E[u_P|k=2] = \begin{cases} \bar{\beta}B - c_P & \text{if } \beta = \bar{\beta} \\ 0 & \text{if } \beta = \underline{\beta} \end{cases} ,$$

whereas P's expected payoff if he chooses $k = 1$ is

$$E[u_P|k=1] = q_A(B - c_P) ,$$

i.e., his payoff from project $k = 1$ times the probability that A is a high type and hence willing to accept this project.

Optimal project choice. From this follows that the principal optimally chooses his preferred project $k = 1$ if he is of low type $\underline{\beta}$, because his expected payoff otherwise is zero. If he is of a high type, he also chooses $k = 1$ as long as $q_A > (\bar{\beta}B - c_P)/(B - c_P)$, if this choice yields a higher expected payoff. Otherwise the principal should choose the agent's preferred project $k = 2$.

Hence, under P-authority we get two cases:

Case P1: $q_A > \frac{\bar{\beta}B - c_P}{B - c_P}$

In this case, the probability that the agent will provide effort even for his less preferred project, i.e., that he is of type $\bar{\alpha}$, is so high that the principal will always go for his own favorite project $k = 1$ which leads to the following payoffs:

v_P, v_A	$\underline{\alpha}$	$\bar{\alpha}$
$\underline{\beta}$	0,0	$B - c_P$, $\bar{\alpha}b - c_A$
$\bar{\beta}$	0,0	$B - c_P$, $\bar{\alpha}b - c_A$

From an ex ante point of view, the principal and the agent respectively get an expected payoff

$$\begin{aligned} E[u_P] &= q_A(B - c_P) , \\ E[u_A] &= q_A(\bar{\alpha}b - c_A) . \end{aligned}$$

Case P2: $q_A \leq \frac{\bar{\beta}B - c_P}{B - c_P}$

If, however, the probability that the agent is willing to compromise on the project choice is low, then only low types of principals will pick their favorite project $k = 1$. High types will prefer to play it safe and pick the agent's favorite project $k = 2$ to make sure that the agent provides effort and a project is actually realized in the end. Payoffs then are given by:

v_P, v_A	$\underline{\alpha}$	$\bar{\alpha}$
$\underline{\beta}$	0,0	$B - c_P$, $\bar{\alpha}b - c_A$
$\bar{\beta}$	$\bar{\beta}B - c_P$, $b - c_A$	$\bar{\beta}B - c_P$, $b - c_A$

The ex ante expected payoffs therefore are

$$\begin{aligned} E[u_P] &= q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P) \ , \\ E[u_A] &= q_P(b - c_A) + (1 - q_P)q_A(\bar{\alpha}b - c_A) \ . \end{aligned}$$

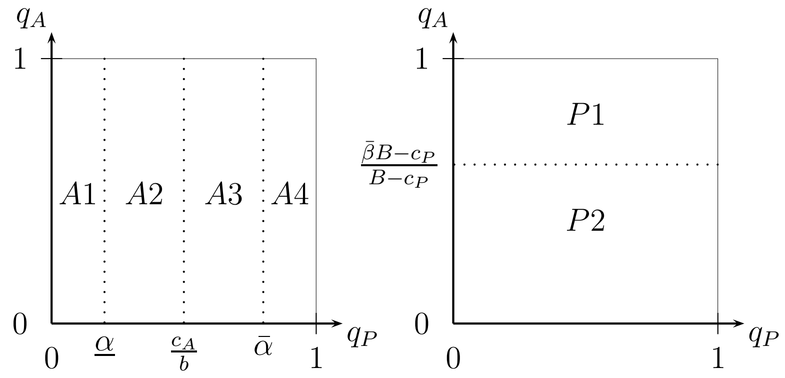
So, again summing up the different cases, we get the following results: When q_A is higher than some critical level

$$\tilde{q}_A = (\bar{\beta}B - c_P)/(B - c_P) \ , \tag{II.3}$$

i.e., if the probability that the agent is of a high type is high enough (case P1), then the principal will always choose his own preferred project. Although this gives him a higher payoff if the agent indeed has a high type, the principal also runs the risk that no project will be realized if the agent is of a low type in which case both players get zero payoffs.

On the other hand, when q_A (case P2) is smaller than the critical level $\tilde{q}_A$, then high types of principals prefer to pick the agent's favorite project in order to make sure that some project is realized.

So overall, by choosing the project himself, a high typed principal faces a risk of *coordination failure*: in the first case by choosing $k = 1$ although there is a positive chance that this choice will not be accepted by A, and in the second case by choosing $k = 2$ although there is a positive chance that even P's preferred project $k = 1$ would go through.



(a) under A-authority (b) under P-authority

Figure II.3: Different cases

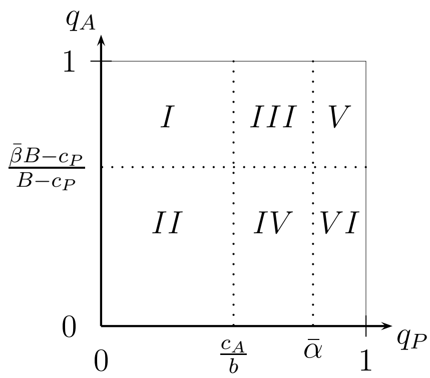


Figure II.4: Areas.

II.3.3. Comparison

When does the principal prefer to keep the authority to initiate a project and when does he delegate this task to the agent? To answer this question, we have to compare the expected payoffs of the principal, given both players' probability to be willing to compromise on the project choice.

In the previous section we identified several cases which are shown graphically in Fig. II.3. When comparing the two forms of governance we therefore can identify six areas, as displayed in Fig. II.4.[9] Table II.1 and II.2 summarize the expected ex ante payoffs of the two players for

[9]Recall that the ex ante expected payoffs in cases A1 and A2 are the same, so we can treat this as just one case.

Area	Authority to initiate	$E[u_P]$
I	A	$q_A(B - c_P)$
	P	$q_A(B - c_P)$
II	A	$q_A(B - c_P)$
	P	$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P)$
III	A	$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P)$
	P	$q_A(B - c_P)$
IV	A	$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P)$
	P	$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P)$
V	A	$q_P(\bar{\beta}B - c_P)$
	P	$q_A(B - c_P)$
VI	A	$q_P(\bar{\beta}B - c_P)$
	P	$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P)$

Table II.1: P's expected utility under A- and P-authority to initiate a project in areas I-VI.

each of these areas as calculated above.

When looking at Table II.1, it is easy to see that the principal is indifferent between the two authority structures in area I. In area II, as well as in areas V and VI, he prefers P-Authority, although for different reasons, whereas he prefers A-authority in areas III and IV. For the detailed calculations see Appendix A.

What's the intuition behind this? As we have seen in Section II.3.1, delegation of the authority to initiate a project has a *motivating effect* on the agent. By leaving the project choice to the agent, the principal can be sure that the former always provides effort and whenever possible (i.e., if $\alpha = \bar{\alpha}$) chooses the principal's pet project $k = 1$. This minimizes the risk of coordination failure between the two players and actually provides the principal with his best possible outcome: whenever a compromise is possible, it will be achieved in his favor.

However, this effect only holds for an intermediate range of values q_P

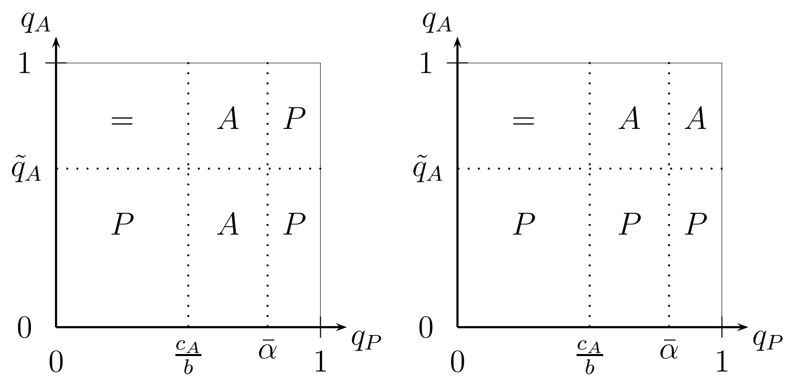
Area	Authority to initiate	$E[u_A]$
I	A	$q_A(\bar{\alpha}b - c_A)$
	P	$q_A(\bar{\alpha}b - c_A)$
II	A	$q_A(\bar{\alpha}b - c_A)$
	P	$q_P(b - c_A) + (1 - q_P)q_A(\bar{\alpha}b - c_A)$
III	A	$q_A(\bar{\alpha}b - c_A) + (1 - q_A)q_P(b - c_A)$ $+(1 - q_A)(1 - q_P)(-c_A)$
	P	$q_A(\bar{\alpha}b - c_A)$
IV	A	$q_A(\bar{\alpha}b - c_A) + (1 - q_A)q_P(b - c_A)$ $+(1 - q_A)(1 - q_P)(-c_A)$
	P	$q_P(b - c_A) + (1 - q_P)q_A(\bar{\alpha}b - c_A)$
V	A	$q_P b - c_A$
	P	$q_A(\bar{\alpha}b - c_A)$
VI	A	$q_P b - c_A$
	P	$q_P(b - c_A) + (1 - q_P)q_A(\bar{\alpha}b - c_A)$

Table II.2: A's expected utility under A- and P-authority to initiate a project in areas I-VI.

(namely for $c_A/b \leq q_P < \bar{\alpha}$), whereas for extreme values, the negative effects of delegation dominate: On the one hand, if the principal's expected willingness to compromise q_P is too low ($q_P < c_A/b$), then too little effort is provided as agents cannot be sure that their project choice is going to be implemented by the principal in the end (*discouraging effect* of delegation). But if the principal chooses the project himself, then the agent can be sure about implementation. He then knows that his effort will not be spent in vain.

On the other hand, if the principal's expected willingness to compromise q_P is too high ($q_P \geq \bar{\alpha}$), then the agent never chooses the principal's preferred project. The latter therefore prefers to pick a project himself.

Similarly, from table II.2, we can see that the agent is also indifferent between the two authority structures in area I. He prefers A-authority



(a) Principal (b) Agent

Figure II.5: Preferred authority structure by areas.

in areas III and V, whereas he would prefer P-authority in areas II, IV and VI.[10] Except for areas IV and V the agent therefore prefers the same authority structure as the principal.

What is the intuition behind the agent's preferences over authority structures? If $q_A < \tilde{q}_A$, the agent has a low willingness to compromise. In this case, if the principal picks the project, he is going to choose $k = 2$ to increase the chances that the agent agrees and provides effort. Hence, under P-authority the agent is likely to get his preferred project and he can be sure that this project is implemented, whereas this is not the case under A-authority. If $q_A > \tilde{q}_A$, then the agent has a high willingness to compromise. Knowing this, the principal is more likely to pick his own preferred project. So the agent gets a better project if he decides himself, although he faces the risk of non-implementation. Yet, the higher q_P the more likely is the principal to agree. Hence, A-authority is overall better for the agent in this area.

The results are summarized in Figure II.5. The letters indicate the player who chooses the project.

[10] As before, see Appendix A for detailed calculations.

II.3.4. Comparative Statics

How does the scope of delegation change with the parameters of our model?

Suppose $\bar{\alpha}$ is close to one, i.e., a high type agent is almost indifferent between the two projects or, in other words, the preferences of the principal and the high type agent are nearly congruent. The range of values of q_P for which the agent would take advantage of the principal under A-authority (i.e., the area to the right of $\bar{\alpha}$ in Figure II.5) then almost disappears. Being almost indifferent between the two projects, the agent rather tries to make sure to get the principal's approval and hence chooses P's preferred project $k = 1$. Exploitative behavior no longer plays a role, but the motivating effect of delegation dominates, and hence A-authority is optimal within a broader range from the principal's point of view (cf. Figure II.5(a)). If, on the other hand, the congruence of preferences between the principal and the high type agent is low, i.e., if $\bar{\alpha}$ close to c_A/b,[11] then there is almost no room for delegation, because its negative effects from the principal's point of view - the discouraging effect on one side, and the risk of exploitative behavior by the agent on the other - become too important.

When $\bar{\beta}$ is close to one, i.e., a high type principal is almost indifferent between the two projects, then the critical value $\tilde{q}_A = (\bar{\beta}B - c_P)/(B - c_P)$ goes to one. This has no impact on the principal's preferences over authority structures. It does however influence the agent's view of things: If the principal is almost indifferent between the two projects, he is likely to pick the agent's preferred project just to assure its realization. Since the agent thus obtains his first best outcome whenever compromise is possible at all, he actually is happy to leave the authority to initiate to the principal (cf. Figure II.5(b)).

Another parameter that influences the scope for delegation is the size of the agent's effort cost relative to his project valuation. If c_A is close to b, then the area where the discouraging effect of delegation dominates, i.e. the area left of c_A/b, becomes larger. By contrast, if c_A is close to

[11] Due to Assumption 1, it cannot be smaller.

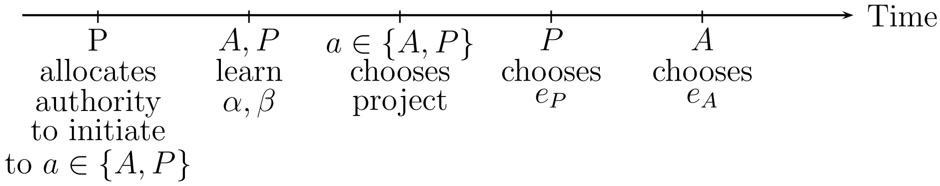


Figure II.6: Timing of the reversed game.

zero, then the discouraging effect of delegation vanishes. In that case, the agent incurs no cost of effort and hence has nothing to lose in case that the principal does not approve of the chosen project.

II.4. Reversing the Game Structure: The Agent has the Authority to Approve

So far, we have considered only under which circumstances the principal wants to delegate the project choice to the agent, i.e., when he wants to give him the authority to initiate a project. Yet, there is a second component of authority in our model, namely the authority to approve and implement a project. In the previous section, the principal always kept this part of authority. However, there might be circumstances under which the principal would also delegate this second authority component to the agent, or alternatively where he would want to keep the control over the project choice, but leave implementation to the agent.

Formally, this scenario can be described by reversing the timing of the game in the following way, as also shown in Figure II.6:

(1) *Allocation of authority:* The principal assigns authority for the project choice to $a \in \{A, P\}$.

(2) *Project choice:* Player a chooses project $k \in \{1, 2\}$.

(3) *Principal's effort choice:* The principal chooses his effort level $e_P \in \{0, 1\}$.

(4) *Agent's effort choice:* The agent chooses his effort level $e_A \in \{0, 1\}$.

That is, the principal leaves the final decision over the project, i.e. the authority to approve, to the agent by letting him have the final say in the matter. Now, given this reversed timing, when does the principal prefer to pick the project himself, and when does he also allocate the authority to initiate to the agent?

Since the utility functions of the two players are symmetric, we can solve the reversed game by using the solution of the previous game and just changing the indices.[12] Proceeding as in the previous section in order to compare the players' expected utility levels, we get the results as depicted in Figure II.7.

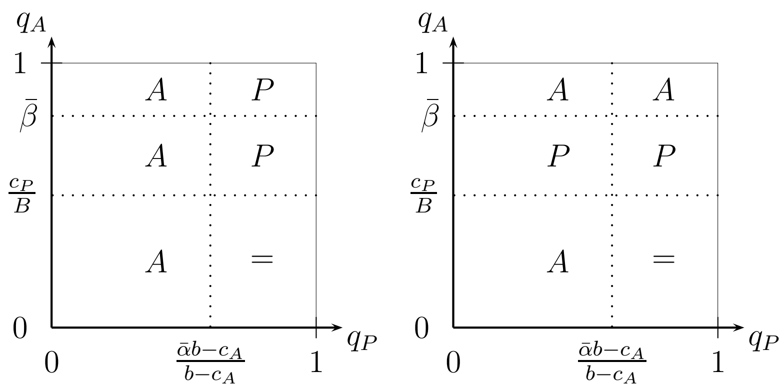
Given that the agent has the authority to implement the project, i.e., that he moves last, how will the principal allocate the authority to initiate a project? As it turns out, the principal prefers to give all authority to the agent when q_P is below some critical value

$$\tilde{q}_P = (\bar{\alpha}b - c_A)/(b - c_A) \ . \tag{II.4}$$

He thus can exploit the *motivating effect* of delegation, without having to deal with its *discouraging effect*: agents will always choose a project for which they are willing to provide effort. Also, when possible, they will rather choose the principal's preferred project, given that his expected willingness to compromise q_P is relatively low. However, since the agent has to choose effort only after the principal, the agent is no longer afraid that his effort may be spent in vain. In the worst case, the principal will not agree with the agent's choice and choose $e_P = 0$, thus leaving both players with zero payoff. But in contrast to before, the agent never incurs a loss.

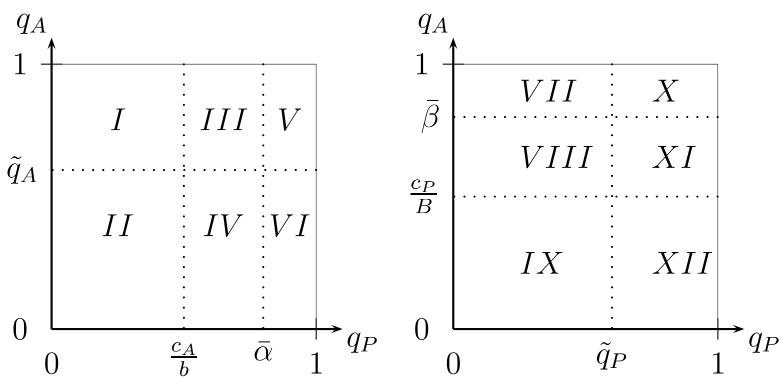
If $q_P \geq \tilde{q}_P$, on the other hand, the principal prefers to pick a project himself, because otherwise he would never get his preferred project. That is, by keeping the authority to initiate a project, the principal can avoid the *exploitation effect*.

[12]For more detailed results on this see Appendix A.



(a) Principal (b) Agent

Figure II.7: Preferred authority structure by areas when A draws last



(a) Principal implements (b) Agent implements

Figure II.8: Different cases when either A or P has authority to implement

II.5. Endogenizing the Allocation of Authority

Given the results from the two previous sections, when does the principal prefer which game? To answer this question we have to compare the principal's payoff in each game.

To get a clearer picture, Figure II.8 summarizes the different cases, I-VI being the cases from Section II.3.3 and VII to XII from Section II.4.

Table II.3 summarizes the principal's preferred authority structure and his payoff given this authority structure in each of these cases. The first letter indicates who has the authority to initiate a project, the second letter who implements the project.

Area	Authority	$E[u_P]$
I	PP	$q_A(B - c_P)$
II	PP	$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P)$
III	AP	$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P)$
IV	AP	$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P)$
V	PP	$q_A(B - c_P)$
VI	PP	$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P)$
VII	AA	$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P)$
$VIII$	AA	$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P)$
IX	AA	$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P)$
X	PA	$q_AB - c_P$
XI	PA	$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P)$
		$+(1 - q_P)(1 - q_A)(-c_P)$
XII	PA	$q_P(\bar{\beta}B - c_P)$

Table II.3: P's expected utility for his preferred authority structure for cases I-XII.

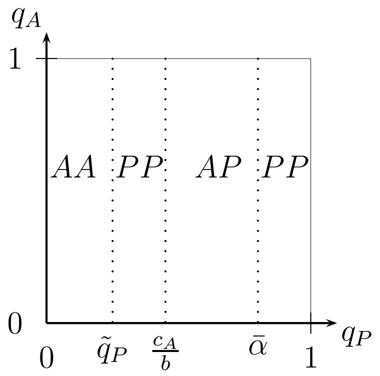
Which of these cases we have to compare depends on the position of $\tilde{q}_P$ relative to c_A/b. For all calculations concerning this comparison, see Appendix A.

Situation 1: $\tilde{q}_P < c_A/b$

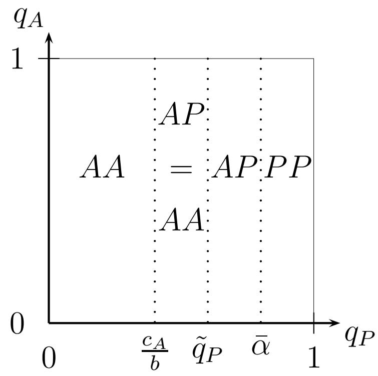
For $q_P < \tilde{q}_P$ the principal prefers to leave both the authority to initiate and the authority to implement to the agent. Between $\tilde{q}_P$ and c_A/b, as well as for $q_P > \bar{\alpha}$, he rather keeps all authority to himself, whereas he delegates merely the project choice to the agent when $c_A/b < q_P < \bar{\alpha}$.

Situation 2: $c_A/b < \tilde{q}_P < \bar{\alpha}$

In this case, the principal leaves all authority to the agent if $q_P < c_A/b$. For $c_A/b < q_P < \bar{\alpha}$ he prefers the agent to pick a project, but he rather keeps the authority to implement to himself, at least when $\tilde{q}_P < q_P < \bar{\alpha}$. For $c_A/b < q_P < \tilde{q}_P$ he is indifferent about who implements the project.



(a) Situation 1: $\tilde{q}_P < c_A/b$



(b) Situation 2: $c_A/b < \tilde{q}_P < \bar{\alpha}$

Figure II.9: Principal's preferred authority structure.

Finally, as in the previous case, the principal prefers to keep all authority to himself for $q_P > \bar{\alpha}$

Note that the case $\bar{\alpha} < \tilde{q}_P$ can never occur, since $\tilde{q}_P = (\bar{\alpha}b - c_A)/(b - c_A) < \bar{\alpha}$.

The results are summarized in Figure II.9. The letters describe the principal's preferred authority structure for each case, the first letter indicating who has the authority to initiate a project, and the second letter noting who has the authority to approve it.

In both situations 1 and 2, we find that for low values of q_P AA-authority performs best from the principal's point of view. Since under this regime the agent decides not only on the project choice, but also on implementation, the discouraging effect of delegation which we found before now completely disappears.

So, we can roughly summarize our results as follows: The higher q_P, i.e., the higher the probability that the principal is of a high type, the more likely he is to keep the final control over the project. For a very high q_P he gives no authority at all to the agent.

This is somewhat counterintuitive: the principal gives more authority to the agent when he is actually less likely to be willing to compromise. The more likely the principal is to agree with the agent's choice, the more he keeps the overall control.

The first effect is due to the fact that the agent needs the principal to get the project implemented even if the agent has the entire control.[13] So, for a very low q_P, the agent will always choose the principal's preferred project and provide effort if possible. By consequence, the principal gets his first best outcome: whenever a compromise between the two players is possible it is going to be in his favor and his preferred project is going to be realized.

However, as q_P increases, so does the probability that the agent can push through his own preferred project. To avoid this, the principal has to keep authority at least over the implementation decision, or finally even over the entire decision process and thus also the project choice.

II.6. Conclusion

Our analysis has shown that, in contrast to most of the existing literature on the topic, delegation may have a negative effect on the motivation of agents whenever the agent cannot be sufficiently sure about the implementation of a project. In that case, both parties are better off if the principal chooses a project. On the other hand, delegation has a motivating effect in the sense that if possible, the agent will choose the principal's preferred project and provide effort. When this effect dominates, delegation thus improves coordination from the principal's point of view.

Furthermore we find an exploitation effect if the agent is "too sure" about implementation. While this third effect can be avoided if the principal keeps the authority to initiate the project, the discouraging effect of delegation entirely disappears if the principal gives the agent both the authority to initiate and to implement the project.

[13]This is again what we have called the positive or motivating effect of delegation of authority before.

III. The Good, the Bad, and the Ordinary: Anti-Social Behavior in Profit and Nonprofit Organizations

III.1. Introduction

In this paper, we analyze how different sources of intrinsic motivation of workers may affect labor management and the production outcomes both in for-profit and nonprofit organizations.

Most theoretical models on intrinsic motivation suppose that it arises if workers derive a benefit from doing good - what is often referred to as "warm glow" utility - or when workers are interested in a certain goal or mission, like for example helping the poor or protecting the environment. An organization that is dedicated to such a mission may find it easier and cheaper to attract workers pursuing similar goals. Intrinsic motivation is hence treated by economists as something generally beneficial to organizations. However, other aspects of a job may also instil intrinsic motivation in certain types of workers. And these other aspects are not necessarily beneficial for the employer. Take the following example: helping refugees is the kind of mission-oriented work that is likely to attract workers interested in this mission (what we will refer to as "good" motivated workers). But such a job also involves working in a remote location with little control from the outside. Circumstances such as these may also attract workers with quite different intentions (what we will call "bad" workers), as has been illustrated by the United Nations sex-for-food scandal, which was exposed by "Save the Children", a UK-based nonprofit organization: it showed that in 2006 aid workers were systematically abusing minors in a refugee camp in Liberia, selling food for sex with girls as young as 8.[1]

Unfortunately, more or less extreme examples for destructive or anti-social behavior such as this abound: For instance, the Catholic Church is quite obviously an organization that relies on the high intrinsic motivation of its workers, but, as illustrated by the recent scandals of abuse by Catholic priests in the US, has been recurrently targeted by bad workers.[2] Similarly a pyromaniac may best be able to satisfy his urge for fire, while minimizing his risk of being discovered, by working for the firefighters, with the added advantage of being perceived as a hero.[3] A sadist might try to work in prisons or detention centers, preferably protected by national security secrecy or by their geographical remoteness, to feed his need to humiliate and harm others.[4] A pedophile, who derives some intrinsic benefit from working in a job where he is in close contact with children, will target vulnerable children, such as refugees or orphans, simply because they are less likely to expose him. Other examples of anti-social behavior in non-profits are presented in Gibelman and Gelman (2004) who summarize some recent scandals involving US

[1] See the report by Save the Children UK (2006). Similar cases have since been reported from Southern Sudan, Burundi, Ivory Coast, East Timor, Congo, Cambodia, Bosnia and Haiti (see "The U.N. sex-for-food scandal", Washington Times, Tuesday, May 9, 2006 and the report by Save the Children UK (2008)).

[2] The John Jay report (see Terry (2008)) indicated that some 11,000 allegations of sexual abuse of children had been made against 4,392 priests in the USA. This number constituted approximately 4% of the 110,000 priests who had served during the 52-year period covered by the study (1950-2002). The report found that "*the problem was indeed widespread and affected more than 95 percent of the dioceses*".

[3] Stambaugh and Styron (2003) give an overview over the problem of arson among firefighters and provide evidence, mostly from the United States, showing that the problem is very serious. Similar cases have been documented elsewhere, see for example `http://www.lexpress.fr/actualite/societe/pompier-pyromane-2-ans-de-prison_459032.html`, or `http://www.swiss-firefighters.ch/News-file-article-sid-3427.html`.

[4] As examples, see the Stanford experiment on prison (see `http://www.prisonexp.org/`) and the torture Abu Ghraib scandal (see for instance `http://www.time.com/time/magazine/article/0,9171,1025139,00.html`).

and International non-government organizations (NGOs).[5] Finally, anti-social behaviors are not the monopoly of non-profit organizations. They are also found in for-profits. For instance, a terrorist might want to work in an airport to have a privileged access to planes. Or an industrial spy would be interested in jobs in firms where he is likely to get access to a lot of sensitive information, while his risk of being discovered is low.

We therefore face a situation where there are different sources of intrinsic motivation which may affect the production outcome both in the mission- and the profit-oriented sector. To capture this problem, we assume that there are three types of workers, who care for different things: regular workers only care about monetary incentives, good workers care about money and the mission of the organization, and bad workers care about money and whether they can do things they like, but which are harmful to the organization or society. We then consider two sectors of the economy, one profit-oriented and one mission-oriented. As in Besley and Ghatak (2005), on which our model is based, we assume that in the nonprofit sector, organizations are structured around some mission, for example providing public services, or catering to the needs of disadvantaged groups of society.[6] These organizations may attract workers who care about this specific mission and derive an intrinsic benefit from their work. They can hence offer lower extrinsic incentives and still attract motivated workers. We further generalize the approach by Besley and Ghatak (2005) by introducing "bad" workers and adding monitoring as an additional choice variable of the employer in order to deal with the different incentive issues raised by the presence of different kinds of workers: while monitoring reinforces the effort incentives of good and regular

[5] "Bad" actions by NGO employees mentioned in the paper by Gibelman and Gelman (2004) include questionable fund raising practices, mismanagement, embezzlement, theft, money laundering, "personal lifestyle enhancement" and kickbacks, corruption, as well as sexual misconduct.

[6] We use the terms mission-oriented and nonprofit organization equivalently since we believe them to be largely congruent in reality. However, there are cases where organizations do not have the legal status of a nonprofit, but still follow a mission. For a further discussion of this, see Besley and Ghatak (2005).

workers, it makes "bad" actions or anti-social behavior less attractive as it increases the chances of getting caught and being punished.

Given this setup, we first consider the case with only good and regular workers and find the classic result that the mission-oriented sector offers lower wages and makes less use of monitoring than the profit-oriented sector. We then introduce bad workers who derive utility from behaving in an anti-social way. It turns out that profit-oriented organizations are a priori less vulnerable to such behavior. Bad workers may behave like regular workers in the profit-oriented sector and thus be totally undistinguishable from "normal" people. By contrast, if they join the mission-oriented sector, then only in order to follow their destructive instincts. The more organizations in this sector rely on the intrinsic motivation of good workers and the less they make use of monetary incentives and control, the more likely they are to become the target of bad workers. We then analyze how contracts have to change in both sectors in order to deter bad workers from their destructive behavior. However, deterrence is costly as it implies higher monitoring, and it even may become entirely ineffective for workers with very high levels of bad motivation. We therefore also consider ex ante measures of candidate selection, which may help to reduce the occurrence of anti-social behavior.

Psychologists have long recognized and studied anti-social behavior. One strand of the literature, as well as most traditional psychiatry, focuses on so-called internal determinants. Anti-social behaviors, perceived as a pathology, are explained by individual predispositions such as genetics, personality traits, or pathological risk factors rooted in childhood. Another strand of the literature focuses on external determinants. It aims to explain how "ordinary" people can be induced to behave in evil ways by situational variables (see Zimbardo (2004)).[7] Our paper is consistent with both views. While it takes the level of bad motivation as exogenous, it depends on the incentives given by an organization whether bad

[7]For instance, in a famous experiment on obedience to authority, Milgram (1974) has shown that two thirds of the subjects were willing to inflict lethal electrical shocks to total strangers.

workers will indeed act in an anti-social way or whether they will behave just like regular workers.

By introducing bad workers, we contribute to the literature on intrinsic motivation and its effects on agents' behavior which has received increasing attention in recent years.[8] In our analysis, intrinsic motivation can be linked to a certain mission pursued by a particular organization. Our model is hence related to models on public service motivation, as for example in Francois (2000), Francois (2002), Prendergast (2007) and, in particular, Delfgaauw and Dur (2008), to the extent that workers may show some form of intrinsic motivation when working in a certain sector or for a particular mission.[9]

Furthermore, our model is closely related to the paper by Besley and Ghatak (2005) who show that matching the mission preferences of principals and agents can enhance organizational efficiency and reduces the need for high-powered incentives. There are hence many sectors where wages are not paid conditional on performance, as for instance the civil service sector or many nonprofit organizations.[10] Nonprofits sometimes are even legally forbidden to pay incentive wages; see, for instance, the discussion in Glaeser (2002). Depending on the sector, this may have institutional reasons, as for example in the judicial sector, where economic incentives are minimized in order to guarantee high quality independent judgement (Posner, 1993). In other cases, especially in the case of development aid, performance may just be too difficult to assess due to high costs of monitoring in the field. This may lead to shirking and absenteeism as has been analyzed for example by Chaudhury, Hammer, Kre-

[8]See, for example, Bénabou and Tirole (2003), Frey (1997), Murdock (2002) and Akerlof and Kranton (2005). The effects of employees' intrinsic motivation on firm performance are discussed by Kreps (1997).

[9]Note, however, that from a technical point of view some of these models are quite different from ours. In Francois (2000), for instance, all workers care for overall output and have no particular preference for the public sector. Differences between the two sectors only come into play through differences in property rights.

[10]See also Borzaga and Tortia (2006) and Ballou and Weisbrod (2003) for empirical studies on the incentives in for-profit and different forms of nonprofit organizations.

mer, Muralidharan, and Rogers (2006) and Banerjee and Duflo (2006). However workers may not only just work less. They may also behave in a way that damages the organization for which they work or which is outright criminal. To prevent such destructive behaviors, nonprofits therefore may want to engage in a more sophisticated selection process of candidates. The difficulties of such a process have, for instance, been discussed in Goldman (1982) and Greenberg and Haley (1986) for the selection of judges.

The following section outlines the basic model with only good and regular workers. We then introduce bad workers in Section III.3 and show how the optimal contracts have to change. Section III.4 discusses the ex ante selection of job candidates, and Section III.5 concludes.

III.2. Basic Setup

There are two sectors $i = F, N$, where F stands for for-profit or profit-oriented and N for nonprofit or mission-oriented. Furthermore, there are three types of agents $j = g, r, b$, where g stands for good, r for regular and b for bad workers, with shares $x_g + x_r + x_b = 1$ in the population. As a benchmark case, we first concentrate on good and regular workers only. In contrast to regular agents, good agents derive an intrinsic benefit $\theta_g > 0$ from working in the nonprofit sector N. In sector F, neither type of agent r or g derives a positive intrinsic benefit.

Each agent produces a basic output q and, depending on his effort e, an additional output Δq with probability e. His effort cost is $c(e) = a \cdot e^2/2$. In order to induce agent j to work harder, the principal in sector i can offer him a contract consisting of a basic wage w_{ij} plus a bonus payment $t_{ij} \geq 0$ if a high output is observed. However, the principal only observes the agent's output with probability m_i, where m_i is the monitoring level in sector i. The cost of monitoring is $M(m_i)$. We assume that $m_i \in \{0, [\underline{m}, 1]\}$, i.e., the principal can choose not to monitor or else he has to choose at least a minimum level of monitoring $\underline{m} > 0$. As will become clear later on, in most cases the principal will want to set the monitoring level as low as possible. This result is similar to Becker (1968).

For the sake of clarity we therefore introduce a minimum monitoring level $\underline{m}$. The idea is that there is some fixed cost to monitoring. For example, the principal may have to hire at least one employee for the task.

We assume that there is a limited liability constraint such that the agent has to receive at least a monetary payoff of $\underline{w} \geq 0$. Furthermore, the agent's outside utility is assumed to be $\bar{u}_j \geq 0$. Given these constraints, the principals in both sectors try to maximize their profits over w_{ij}, t_{ij} and m_i as follows:

$$\pi_{ij} = q + (\Delta q - m_i t_{ij})e_{ij} - w_{ij} - M(m_i) \;, \tag{III.1}$$

subject to the following constraints

$$(LL) \qquad w_{ij} \geq \underline{w} \;, \tag{III.2}$$

$$(PC) \qquad u_{ij} = w_{ij} + (m_i t_{ij} + \theta_{ij})e_{ij} - ae_{ij}^2/2 \geq \bar{u}_j \;, \tag{III.3}$$

$$(IC) \qquad e_{ij} = \arg\max_{e \in [0,1]} \left\{ w_{ij} + (m_i t_{ij} + \theta_{ij})e_{ij} - ae_{ij}^2/2 \right\} . \tag{III.4}$$

It follows immediately from the incentive constraint (III.4) that the agent will choose his optimal effort level as $e_{ij} = (m_i t_{ij} + \theta_{ij})/a$. We assume that a is sufficiently large to make sure that we get an interior solution $e_{ij} \leq 1$:

Assumption 2: $a \geq \Delta q + \max\{\theta_g, \theta_b\}$.

Under Assumption 2, we can rewrite the maximization problem as

$$\max_{w_{ij}, t_{ij}, m_i} \pi_{ij} = q + (\Delta q - m_i t_{ij}) \frac{m_i t_{ij} + \theta_{ij}}{a} - w_{ij} - M(m_i) \;,$$

subject to

$$(LL) \qquad w_{ij} \geq \underline{w} \;,$$

$$(PC) \qquad u_{ij} = (m_i t_{ij} + \theta_{ij})^2/(2a) + w_{ij} \geq \bar{u}_j \;.$$

We aim to study cases where in the absence of intrinsic motivation, inducing effort has some value to the principal. This requires that the cost of monitoring is not too high compared to the benefit: $\frac{1}{4a}\Delta q^2 \geq$

$M(\underline{m})$. Moreover, we concentrate on outcomes with non-negative payoffs for the principal which is assured by $q - \underline{w} - M(\underline{m}) > 0$. The following assumption assures that the solutions derived in the paper are hence optimal:

Assumption 3: $\Delta q^2 \geq 4aM(\underline{m})$ and $q > \underline{w} + M(\underline{m})$.

Let us define $\underline{v}_{ij}$ as the reservation payoff level such that for $\bar{u}_j \geq \underline{v}_{ij}$ the participation constraint of agent j becomes binding and $\tilde{v}_{ij}$ as the level of outside utility where the agent's limited liability constraint ceases to be binding. Furthermore, let $\bar{v}_{ij}$ be defined as the level of reservation payoff of agent j such that principal i makes zero profit.[11] That is,

$$\begin{aligned}
\underline{v}_{ij} &\equiv \frac{1}{2a}\Big(max\{0, (\Delta q - \theta_{ij})/2\} + \theta_{ij}\Big)^2 + \underline{w}\ , \\
\tilde{v}_{ij} &\equiv \frac{1}{2a}(\Delta q + \theta_{ij})^2 + \underline{w}\ , \\
\bar{v}_{ij} &\equiv \frac{1}{2a}(\Delta q + \theta_{ij})^2 + q - M(\underline{m})\ .
\end{aligned}$$

It is straightforward to check that under Assumption 2: $\underline{v}_{ij} \leq \tilde{v}_{ij} \leq \bar{v}_{ij}$.

Then the following proposition characterizes the optimal contract:

Proposition 1: : Suppose Assumptions 1 and 2 hold. An optimal contract $(m_i^*, t_{ij}^*, w_{ij}^*)$ between a principal in sector i and an agent of type j given a reservation payoff $\bar{u}_j \in [0, \bar{v}_{ij}]$ exists and has the following features:

(a) The optimal fixed wage is

$$w_{ij}^* = \begin{cases} \underline{w} & \text{if } \bar{u}_j \in [0, \tilde{v}_{ij}] \\ \bar{u}_j - \frac{1}{2a}(\Delta q + \theta_{ij})^2 & \text{if } \bar{u}_j \in [\tilde{v}_{ij}, \bar{v}_{ij}] \end{cases},$$

(b) The monitoring level is set at the minimum level whenever extrinsic incentives are necessary, i.e., $m_i^* = \underline{m}$ when $t_{ij} > 0$, and is zero otherwise.

[11]For more details on this, see the proof of Proposition 1 in Appendix B.

(c) The optimal bonus payment is

$$t_{ij}^* = \begin{cases} \max\{0, (\Delta q - \theta_{ij})/(2\underline{m})\} & \text{if } \bar{u}_j \in [0, \underline{v}_{ij}] \\ (\sqrt{2a(\bar{u}_j - \underline{w})} - \theta_{ij})/\underline{m} & \text{if } \bar{u}_j \in [\underline{v}_{ij}, \tilde{v}_{ij}] \\ \Delta q/\underline{m} & \text{if } \bar{u}_j \in [\tilde{v}_{ij}, \bar{v}_{ij}] \end{cases}.$$

All proofs can be found in Appendix B.

We can thus discern three cases:

- *Case I:* The limited liability constraint is binding, but not the participation constraint of the agent. This corresponds to a case where $\underline{w}$ is relatively high compared to $\bar{u}_j$. In other words, this holds for low values of the reservation utility: $\bar{u}_j \in [0, \underline{v}_{ij}]$. The optimal contract in this case is described by $w_{ij}^* = \underline{w}$, $t_{ij}^* = \max\{0, (\Delta q - \theta_{ij})/(2\underline{m})\}$, and $m_i^* = \underline{m}$ if $t_{ij}^* > 0$ and zero otherwise.

- *Case II:* Both the limited liability and the participation constraint are binding . This holds for intermediary values of the reservation utility: $\bar{u}_j \in [\underline{v}_{ij}, \tilde{v}_{ij}]$. The optimal contract in this case is described by $w_{ij}^* = \underline{w}$, $m_i^* t_{ij}^* = \sqrt{2a(\bar{u}_j - \underline{w})} - \theta_{ij}$, and $m_{ij}^* = \underline{m}$ if $m_i^* t_{ij}^* > 0$ and 0 otherwise.

- *Case III:* The participation constraint is binding, but not the limited liability constraint. This corresponds to a case where $\bar{u}_j$ is relatively high, i.e., for $\bar{u}_j \in [\tilde{v}_{ij}, \bar{v}_{ij}]$. The optimal contract in this case is described by $w_{ij}^* = \bar{u}_j - (\Delta q + \theta_{ij})^2/(2a)$, $m_i^* = \underline{m}$ and $t_{ij}^* = \Delta q/\underline{m}$.

Which case is relevant for the principal depends on the agent's outside option $\bar{u}_j$ and his level of intrinsic motivation θ_{ij}. Figure III.1 gives an overview.

The first two cases are the cases described in Besley and Ghatak (2005). The reason why the third case is not relevant in Besley and Ghatak's (2005) model is that they do not have a basic payoff q which accrues to the principal even if the agent makes no special effort. As a consequence, whenever the incentive scheme is not profitable because the agent's outside option is too high, then no contract can be made. Here,

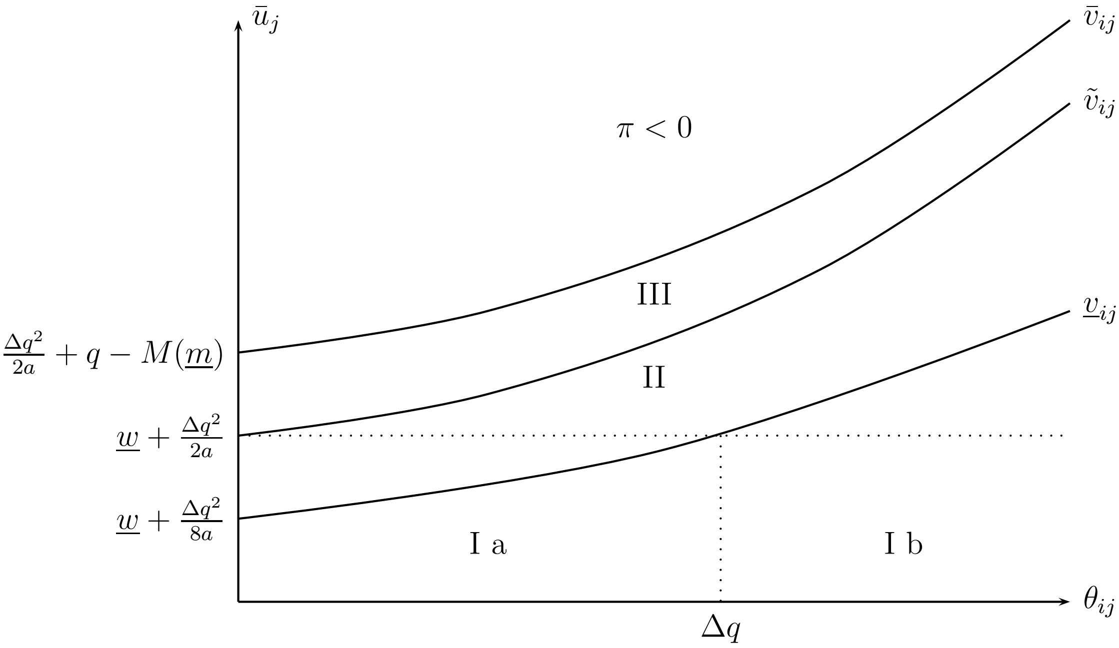


Figure III.1: Optimal contract depending on $\bar{u}$ and θ_{ij}.

by contrast, the principal can fulfill the agent's participation condition even for higher outside options (i.e., $\bar{u}_j > \underline{w} + \Delta q^2/2a$, that is the area above the horizontal dotted line in Figure III.1) because the resulting costs are still covered by the basic production payoff q.

In the following, we will discuss in more detail how Proposition 1 translates into an optimal contract in each of the two sectors N and F.

III.2.1. For-Profit Sector

Let us first consider the implications of Proposition 1 for the profit-oriented sector. The principal in the profit-oriented sector cannot rely on worker's intrinsic motivation (i.e., $\theta_{Fj} = 0$) and hence always has to provide sufficient extrinsic incentives. In particular, he always has to invest in monitoring. As a corollary from Proposition 1 we then get the following:

COROLLARY 1 : : Depending on the size of the agent's reservation utility, we can discern the following cases:

- **Case I:** For $\bar{u} \in [0, \underline{v}_F]$, the optimal contract in F is given by

$$w_F^* = \underline{w} \ , \ m_F^* = \underline{m} \ , \ t_F^* = \Delta q/(2\underline{m}) \ ;$$

- **Case II:** For $\bar{u} \in [\underline{v}_F, \tilde{v}_F]$, the optimal contract in F is given by

$$w_F^* = \underline{w} \ , \ m_F^* = \underline{m} \ , \ t_F^* = \sqrt{2a(\bar{u} - \underline{w})}/\underline{m} \ ;$$

- **Case III:** For $\bar{u} \in [\tilde{v}_F, \bar{v}_F]$, the optimal contract in F is given by

$$w_F^* = \bar{u} - \Delta q^2/(2a) \ , \ m_F^* = \underline{m} \ , \ t_F^* = \Delta q/\underline{m} \ ;$$

where

$$\begin{aligned} \underline{v}_F &= \Delta q^2/(8a) + \underline{w} \ , \\ \tilde{v}_F &= \Delta q^2/(2a) + \underline{w} \ , \\ \bar{v}_F &= \Delta q^2/(2a) + q - M(\underline{m}) \ . \end{aligned}$$

As a consequence, the utility of a worker, no matter whether good or regular, in sector F in case I hence is $u_F = \underline{w} + \Delta q^2/(8a)$. In cases II and III it is equal to $\bar{u}$.

The principal's payoff is

$$\pi_F = q - M(\underline{m}) + \begin{cases} \frac{1}{4a}\Delta q^2 - \underline{w} & \text{in case I} \\ \frac{1}{a}(\Delta q - \sqrt{(2a(\bar{u} - \underline{w}))})\sqrt{(2a(\bar{u} - \underline{w})} - \underline{w} & \text{in case II} \\ \frac{1}{2a}\Delta q^2 - \bar{u} & \text{in case III} \end{cases} .$$

III.2.2. Non-Profit Sector

In contrast to the profit-oriented sector, the mission-oriented sector N can save on wage costs by exploiting the intrinsic motivation of "good" workers. By offering a lower basic wage and/or lower effort incentives, N can still attract good workers (i.e., with $\theta_{gN} \geq 0$) whereas regular workers will prefer their outside option or work in F.

Suppose the level of intrinsic motivation of good workers is $\theta_{Ng} \equiv \theta_g$. Then we get the following corollary from Proposition 1 for the non-profit sector:

Corollary 2 : : Depending on the size of the agent's outside option, the optimal contract between a "good" agent and the principal in sector N is characterized as follows:

- **Case I:** For $\bar{u} \in [0, \underline{v}_N]$, we get two subcases:

  (a) If θ_g is low, i.e., if $\theta_g < \Delta q$ (case Ia in Fig. III.1), then the optimal contract is given by

$$w_N^* = \underline{w}\ ,\ m_N^* = \underline{m}\ ,\ t_N^* = (\Delta q - \theta_g)/(2\underline{m})$$

  (b) If θ_g is high, i.e., if $\theta_g > \Delta q$ (case Ib in Fig. III.1), then

$$w_N^* = \underline{w}\ ,\ m_N^* = 0\ ,\ t_N^* = 0$$

- **Case II:** If $\bar{u} \in [\underline{v}_N, \tilde{v}_N]$, then the optimal contract is given by

$$w_N^* = \underline{w}\ ,\ t_N^* = \tfrac{1}{\underline{m}}(\sqrt{2a(\bar{u} - \underline{w})} - \theta_g),$$
$$m_N^* = \underline{m}\ ,\ \text{if } t_N^* > 0 \text{ and } m_N^* = 0 \text{ otherwise}\ .$$

- **Case III:** If $\bar{u} \in [\tilde{v}_N, \bar{v}_N]$, then the optimal contract is given by

$$w_N^* = \bar{u} - (\Delta q + \theta_g)^2/(2a)\ ,\ m_N^* = \underline{m}\ ,\ t_N^* = \Delta q/\underline{m}\ .$$

where

$$\begin{aligned}
\underline{v}_N &= \frac{1}{2a}\Big(max\{0, (\Delta q - \theta_g)/2\} + \theta_g\Big)^2 + \underline{w}\ , \\
\tilde{v}_N &= \frac{1}{2a}(\Delta q + \theta_g)^2 + \underline{w}\ , \\
\bar{v}_N &= \frac{1}{2a}(\Delta q + \theta_g)^2 + q - M(\underline{m})\ .
\end{aligned}$$

The utility of a motivated agent in cases II and III corresponds to his reservation utility $\bar{u}$, whereas in case I he gets

$$u_{Ng} = \underline{w} + \frac{1}{2a}\begin{cases} \theta_g^2 & \text{if } \Delta q < \theta_g \\ (\Delta q + \theta_g)^2/4 & \text{if } \Delta q \geq \theta_g \end{cases}\ ,$$

which is higher or equal to what he would get in sector F. "Good" agents with low reservation utility hence prefer the contract proposed in

Corollary 2 to the contract offered in sector F. Low reservation utility typically corresponds to junior workers with no or little experience and thus relatively low outside opportunity. We thus expect young idealistic people to join the nonprofit sector. Empirically they should be over-represented compared to other workers.

Regular agents, on the other hand, do not derive any intrinsic satisfaction from working in the mission-oriented sector, but only care about monetary incentives. It turns out that for any given level of reservation utility we have: $w_N^* + m_N^* t_N^* \leq w_F^* + m_F^* t_F^*$. As a consequence, the utility of a regular worker under the above contract is always smaller than the utility level he can reach under the contract proposed in sector F.

As a result, regular workers will choose to work in sector F and "good" motivated workers will prefer to work in sector N.

The principal's profit in case I hence is

$$\pi_N = q - \underline{w} + \frac{1}{a}\begin{cases} \Delta q \theta_g & \text{if } \Delta q < \theta_g \\ \left(\frac{\Delta q + \theta_g}{2}\right)^2 - M(\underline{m}) & \text{if } \Delta q \geq \theta_g \end{cases} .$$

In case II, it is

$$\pi_N = q + \frac{1}{a}(\Delta q + \theta_g - \sqrt{(2a(\bar{u} - \underline{w}))}\sqrt{(2a(\bar{u} - \underline{w})} - \underline{w} - M(\underline{m}) ,$$

and in case III

$$\pi_N = q - \left[\bar{u} - \frac{1}{2a}(\Delta q + \theta_g)^2\right] - M(\underline{m}) .$$

By exploiting the intrinsic motivation of "good" workers, the principal in N can hence save on wage and monitoring costs relative to sector F by offering lower incentives and making less use of monitoring.[12] Indeed, comparing π_N with π_F in each case, it is straightforward to see that

[12]A nonprofit does not make any profits by definition. So while we sometimes refer to π_N and π_F as profit, it rather measures the relation between personnel costs and production. If the nonprofit has to spend less on its workers, this eases its budget constraint and makes more funds available for other things. This becomes particularly relevant if we take into account that many nonprofits are financed by donations and may have to run their operations on a rather tight budget.

$\pi_N > \pi_F$ if $\theta_g > 0$. Moreover, in contrast to sector F, principals in sector N may not need to monitor their workers at all: If $\theta_g > \Delta q$, workers are motivated enough to provide effort even if there is no extrinsic incentive and no monitoring.

III.3. Bad Motivation

So far we have considered the case where intrinsic motivation is necessarily good for the firm. However, this may not always be true. Workers may pursue their own private benefit to the detriment of the organization they work for. We model this by allowing workers to choose a "destructive effort" $d \in [0,1]$ rather than the "normal" effort e considered so far. There are some workers who get a private benefit θ_b from choosing such a negative effort, and by doing so they may cause a damage D to the firm they are working for. We denote the probability that a job candidate in sector $i = F, N$ is a "bad" type as β_i.

Consider the following utility function for bad workers in sector $i = F, N$:

$$u_{ib} = w_i + \begin{cases} m_i t_i e - ae^2/2 & \text{if } e \geq 0 \\ (\theta_b - m_i K)d - ad^2/2 & \text{if } d \geq 0 \end{cases},$$

where K is an exogenous punishment that can be imposed on a worker if a negative effort is observed. The idea behind this is that a negative effort corresponds not just to shirking but is an outright act of sabotage which can be treated as a criminal offense and hence can be punished by a fine or a prison term. However, as this is beyond the influence of the firm, we treat the punishment as exogenous.

Note that the worker chooses either one of the two options, i.e., he either decides to satisfy his destructive impulse and get intrinsic satisfaction from doing so ($d \geq 0$). Or he behaves like a regular worker, chooses $e \geq 0$ and aims at getting monetary rewards.

As can be seen from this utility function, bad guys may be willing to make a "good" effort if given the right incentives.

Taking into account the worker's optimal effort choice, which under Assumption 1 is still lower than 1 (i.e., there is an interior solution), we can rewrite his expected utility as

$$u_{ib} = w_i + \begin{cases} (m_i t_i)^2/(2a) & \text{if } e \geq 0 \\ (\theta_b - m_i K)^2/(2a) & \text{if } d \geq 0 \end{cases} .$$

Bad types therefore prefer to exert a positive effort rather than to follow their destructive impulse and sabotage if

$$m_i t_i \geq \theta_b - m_i K \; . \tag{III.5}$$

In the following, we first analyze how a bad worker's choice between sector N and F is determined before we look at the implications of this choice for the optimal contracts in each sector.

III.3.1. Automatic Deterrence of Bad Workers

In this section, we analyze the behavior of bad workers for a given set of contracts, namely the optimal contracts derived in the previous section. This also allows us to determine under what circumstances organizations in sectors N and F have to adapt their incentive schemes to the presence of bad workers and when there is "automatic" deterrence of anti-social behavior, i.e., without any change in the optimal contracts.

Suppose, for the moment, that the contracts in both sectors stay as calculated in Section 2, i.e., that they are not adapted to the presence of "bad" workers. How will bad workers behave under these circumstances? When will they opt for sector N, when for sector F?

To answer these questions, we need to compare a bad worker's payoff from choosing effort e or d in both sectors given the optimal contracts derived in Section III.2. This comparison shows that for a given reservation utility $\bar{u}$ the incentive for choosing a positive effort e are always higher in F than in N, i.e., $u_{Fb}(e) > u_{Nb}(e)$. At the same time, the monitoring level in N is always smaller or equal than that in sector F, thus making it less likely to get caught with bad actions in the nonprofit sector and therefore $u_{Nb}(d) \geq u_{Fb}(d)$. From this follows:

COROLLARY 3 : : Under the optimal contracts as proposed in Proposition 1, "bad" workers never join the mission-oriented sector to do good, i.e., in order to provide a positive effort e.

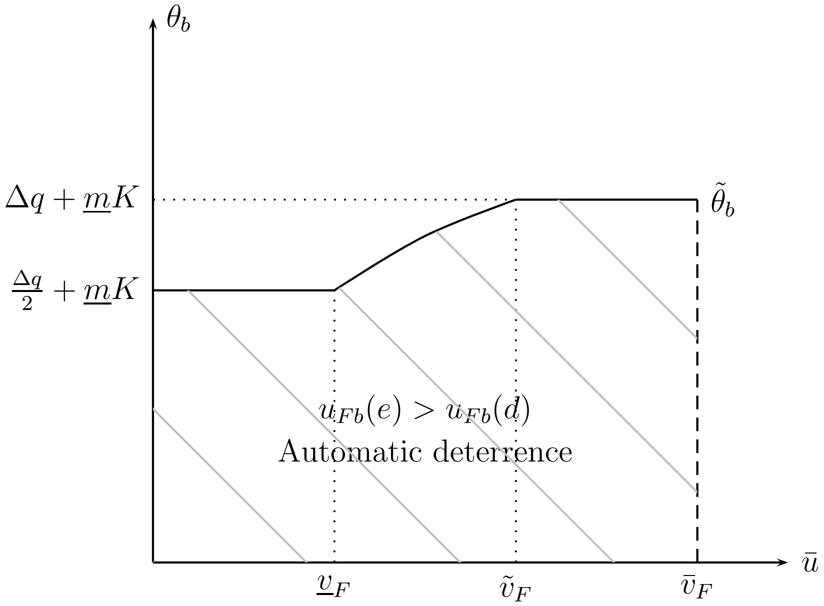


Figure III.2: Automatic Deterrence in Sector F.

That is, bad workers will only join N to follow their destructive impulse, while minimizing the risk of being detected and punished.

Next, let us look in more detail at what happens in each sector. It is clear from (III.5) that for low levels of negative motivation θ_b, bad workers are better off if they choose a positive rather than a destructive effort. In sector F, such "automatic" deterrence of bad workers, i.e., deterrence without any change of the optimal contract as derived in Corollary 1, takes place if θ_b is smaller than

$$\tilde{\theta}_b = \begin{cases} \Delta q/2 + \underline{m}K & \text{if } \bar{u} \in [0, \underline{v}_F] \\ \sqrt{2a(\bar{u} - \underline{w})} + \underline{m}K & \text{if } \bar{u} \in [\underline{v}_F, \tilde{v}_F] \\ \Delta q + \underline{m}K & \text{if } \bar{u} \in [\tilde{v}_F, \bar{v}_F] \end{cases}, \tag{III.6}$$

where $\underline{v}_F, \tilde{v}_F, \bar{v}_F$ are defined as in Corollary 1. If the above holds true, then a bad worker's payoff from choosing a "normal" effort e is anyway higher than his payoff from choosing a destructive effort d in F. As shown in Figure III.2, bad workers with $\theta_b < \tilde{\theta}_b$ are therefore "automatically" deterred from anti-social behavior.

Next, let us consider what happens in the nonprofit sector N. Bad workers will be discouraged from joining this sector as long as $u_{Nb}(d) \leq$

$u_{Fb}(e)$.[13] Automatic deterrence, i.e. deterrence of bad workers without any change in the optimal contract (m_N^*, t_N^*, w_N^*), therefore can be achieved for

$$w_N^* + \frac{1}{2a}(\theta_b - m_N^* K)^2 \leq w_F + \frac{1}{2a}(m_F t_F)^2 \ , \qquad \text{(III.7)}$$

i.e., for all θ_b smaller than

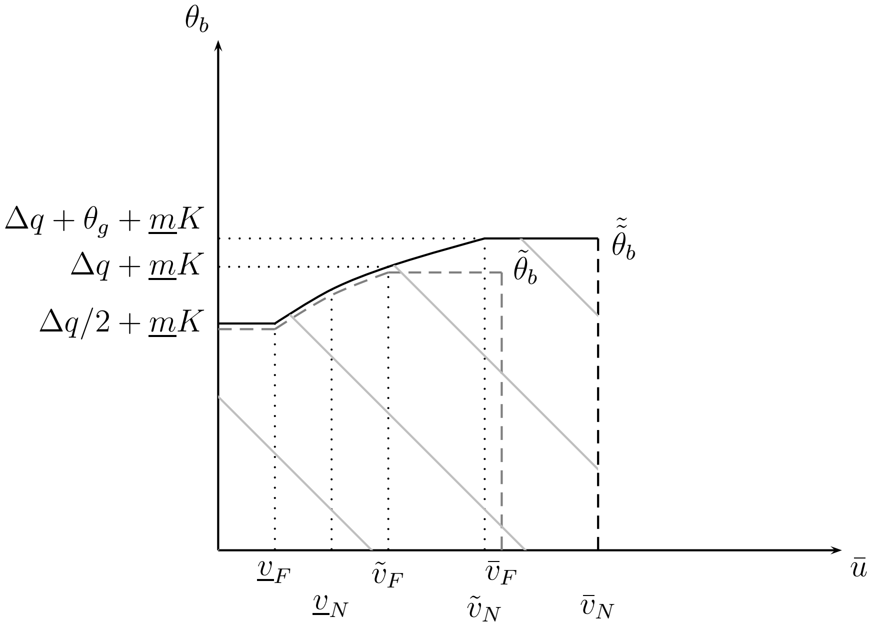
$$\tilde{\tilde{\theta}}_b \equiv \sqrt{2a(w_F - w_N^*) + (m_F t_F)^2} + m_N^* K \ . \qquad \text{(III.8)}$$

In order to determine the exact level of $\tilde{\tilde{\theta}}_b$, we then have to insert the optimal contracts in N and F into equation (III.8). For the sake of shortness, we will skip this exercise here. The interested reader may however find the detailed calculations in Appendix B. The results are also shown in Figure III.3 which depicts the level of automatic deterrence in the nonprofit sector, $\tilde{\tilde{\theta}}_b$, as a black curve. For $(\bar{u}, \theta_b)$-combinations below this curve, bad workers prefer to work either in sector F or enjoy their outside utility $\bar{u}$. Furthermore, the level of automatic deterrence in sector F, $\tilde{\theta}_b$, is also featured in Figure III.3 and is depicted as a dashed gray line. This allows us to see immediately that, depending on the exact values of θ_g, θ_b and $\bar{u}$, sector N is either better or worse protected from destructive behavior than sector F:

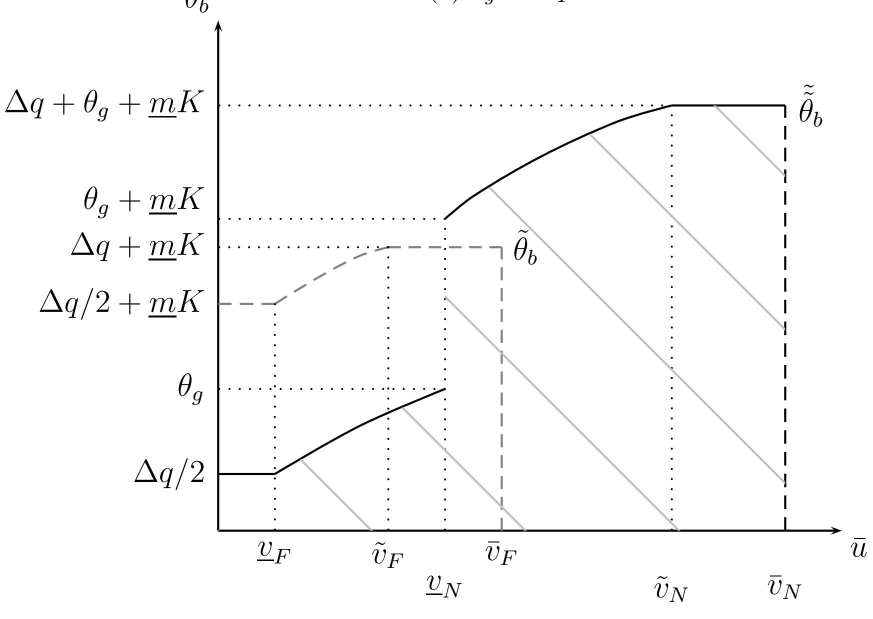
- For $\bar{u} > \bar{v}_F$, i.e., for very high levels of reservation utility, F can no longer offer contracts that would satisfy the worker's participation constraint and at the same time yield a positive payoff to the firm. Therefore, nonprofit organizations are the only possible employer for agents with such a high reservation utility. But even working in N is relatively unattractive due to rather low basic wages. Bad workers will therefore prefer to enjoy their outside utility $\bar{u}$ and only the most motivated will find it worthwhile to work at all. As a result, the level of deterrence in sector N for $\bar{u} > \bar{v}_F$ is rather high, as can be seen both from III.3(a) and III.3(b).

- A more relevant scenario is one where $\bar{u} \leq \bar{v}_F$, i.e. the outside utility of the agents is such that both types of organizations may

[13] That this is the relevant comparison follows from Corollary 3.



(a) $\theta_g < \Delta q$



(b) $\theta_g > \Delta q$

Figure III.3: Automatic Deterrence in N. For $(\bar{u}, \theta_b)$-combinations in the shaded area, bad workers are automatically deterred from bad actions in sector N.

attract workers. Let us first consider what happens if $\theta_g < \Delta q$ as shown in Figure III.3(a). For such low levels of intrinsic motivation of good workers, the level of automatic deterrence is the same in sector N and F because the monitoring level is the same in both sectors. Only for $\tilde{v}_F < \bar{u} \leq \bar{v}_F$, automatic deterrence is slightly higher in N since the basic wage in N is lower than in F and hence makes working in N less attractive.

- The most interesting case arises for low levels of reservation utility $\bar{u}$ and high intrinsic motivation of good workers ($\theta_g > \Delta q$) as shown in Figure III.3(b). In that case, the nonprofit firm relies entirely on the intrinsic motivation of good workers and hence provides no extrinsic incentives, i.e., $m_N = 0$ (Case Ib). The nonprofit firm then becomes particularly attractive for "bad" types. They can get

  $$u_{Nb}(d) = \underline{w} + \theta_b^2/(2a) \ ,$$

  from choosing a negative effort in sector N, whereas they would get utility

  $$u_{Fb}(e) = \underline{w} + \Delta q^2/(8a) \ ,$$

  from choosing a positive effort in sector F. Therefore, all bad workers with $\theta_b > \Delta q/2$ will opt for sector N and provide a destructive effort. Bad workers with a lower θ_b will choose sector F and behave like regular workers.

The analysis in this section thus has provided us with several insights: First, we have seen that bad workers only join sector N in order to behave in a destructive way, whereas they may behave like regular workers in sector F. And second, we have seen that while the low basic wages in N may act as a deterrent for high levels of reservation utility, the nonprofit sector becomes very vulnerable to anti-social behavior if it relies heavily on the intrinsic motivation of its workers and hence does not monitor enough.

In the following, we analyze how the optimal contracts in both sectors have to change in order to account for the presence of bad motivated workers if there is no "automatic" deterrence.

III.3.2. “Bad” Workers in the Profit-Oriented Sector

As we have seen in the previous section, it is not necessary to adjust the optimal contracts described in Proposition 1 as long as the intrinsic motivation of bad workers θ_b is sufficiently low. This is the case if θ_b is below $\tilde{\theta}_b$ as defined in (III.6). So, next we consider what happens if θ_b is higher than $\tilde{\theta}_b$ and how the optimal contracts then should be adjusted.

To do so, we assume that organizations in the profit-oriented sector do not take into account the policy of the mission-oriented sector, whereas the latter takes policies in the former sector as given. This is equivalent to assuming that sector N is small compared to sector F, i.e., the share of good workers in the population, x_g, is small relative to the share of regular workers, x_r.

Full Deterrence

If the principal wants to deter bad workers all together from being destructive, his maximization problem becomes[14]

$$\max_{w_F, t_F, m_F} \pi_F = q + (\Delta q - m_F t_F) m_F t_F \frac{1}{a} - w_F - M(m_F) ,$$

subject to

$$\begin{aligned} (LL) \qquad & w_F \geq \underline{w} , \\ (PC) \qquad & (m_F t_F)^2/(2a) + w_F \geq \bar{u}_j , \\ (DET) \qquad & m_F t_F \geq \theta_b - m_F K , \end{aligned}$$

where the last constraint is new. This deterrence constraint ensures that bad workers prefer to make a positive rather than a destructive effort. For $\theta_b > \tilde{\theta}_b$ the deterrence constraint becomes binding and we can hence rewrite the principal's maximization problem as

$$\max_{w_F, m_F} \pi_F = q + (\Delta q - \theta_b + m_F K)(\theta_b - m_F K) \frac{1}{a} - w_F - M(m_F) ,$$

subject to

$$(LL) \qquad w_F \geq \underline{w} , \tag{III.9}$$

$$(PC) \qquad (\theta_b - m_F K)^2/(2a) + w_F \geq \bar{u}_j . \tag{III.10}$$

[14]The agent's incentive constraint is already taken into account here.

As before, the solution of this maximization problem gives rise to three different cases, depending on the reservation utility of the workers. We define $\underline{v}_{Fb}$ as the outside utility for which the modified participation constraint as given in (III.10) becomes binding. Furthermore, let us define $\tilde{v}_{Fb}$ as the level of outside utility at which the limited liability constraint ceases to be binding and $\bar{v}_{Fb}$ as the highest level of outside utility at which the for-profit firm still makes a nonnegative profit. Additionally, we have to define an upper bound for the level of negative intrinsic motivation $\bar{\theta}_b$: for $\theta_b > \bar{\theta}_b$, the monitoring level is equal to one and cannot increase further.

The optimal contract with full deterrence in sector F then is described by the following proposition:

PROPOSITION 2: : For $\tilde{\theta}_b < \theta_b < \bar{\theta}_b$, the optimal contract with full deterrence $(m_F^{det}, t_F^{det}, w_F^{det})$ in sector F given a reservation payoff $\bar{u} \in [0, \bar{v}_{Fb}]$ has the following features:

(a) The optimal fixed wage is

$$w_F^{det} = \begin{cases} \underline{w} & \text{if } \bar{u} \in [0, \tilde{v}_{Fb}] \\ \bar{u} - \frac{1}{2a}(\theta_b - m_F^{det} K)^2 & \text{if } \bar{u} \in [\tilde{v}_{Fb}, \bar{v}_{Fb}] \end{cases} ,$$

(b) The optimal monitoring level m_F^{det} is such that the following conditions hold:

$$\begin{aligned} 2m_F^{det} K + M'(m_F^{det})a/K &= 2\theta_b - \Delta q \quad \text{if } \bar{u} \in [0, \underline{v}_{Fb}] \, , \\ m_F^{det} &= \frac{1}{K}(\theta_b - \sqrt{2a(\bar{u} - \underline{w})}) \quad \text{if } \bar{u} \in [\underline{v}_{Fb}, \tilde{v}_{Fb}] \, , \\ m_F^{det} K + M'(m_F^{det})a/K &= \theta_b - \Delta q \quad \text{if } \bar{u} \in [\tilde{v}_{Fb}, \bar{v}_{Fb}] \, . \end{aligned}$$

(c) The optimal bonus payment is

$$t_F^{det} = \frac{\theta_b}{m_F^{det}} - K \, .$$

Note that although we still may get three cases, depending on the outside utility of the agents, the borders between these three cases have shifted relative to those in Corollary 1. In particular, $\underline{v}_{Fb} > \underline{v}_F$, and

$\tilde{v}_{Fb} > \tilde{v}_F$, but $\bar{v}_{Fb} < \bar{v}_F$. For a more detailed discussion, see the proof of Proposition 2 in Appendix B.

Furthermore, Proposition 2 implies that, in order to fully deter bad workers from bad actions, the principal in sector F has to raise his monitoring level relative to the benchmark case without destructive motivation, no matter what the outside utility of the agent, i.e. $m_F^{det} > m_F^*$. Besides, he has to raise the expected bonus payment for good effort, i.e., $m_F^{det} t_F^{det} \geq m_F^* t_F^*$. As a consequence, besides deterring bad workers from bad actions, this contract will also induce regular workers to choose a higher effort level.

No Full Deterrence

Alternatively, the principal may accept the possibility that destructive behavior may occur. Let β_F be the share of bad workers in sector F in this case.[15] Taking into account the agent's optimal effort choice, the principal's maximization problem then corresponds to

$$\begin{aligned}\max_{w_F, t_F, m_F} \pi_F &= (1-\beta_F)(\Delta q - m_F t_F)\frac{m_F t_F}{a} - \beta_F D(\theta_b - m_F K)\frac{1}{a} \\ &\quad + q - w_F - M(m_F)\ ,\end{aligned}$$

subject to the worker's limited liability and participation constraint as stated in (III.2) and (III.3).

The optimal contract then takes the following form:

Proposition 3: : For $\theta_b > \tilde{\theta}_b$, the optimal contract $(m_F^{nd}, t_F^{nd}, w_F^{nd})$ in sector F given a reservation payoff $\bar{u} \in [0, \bar{v}_F]$ has the following features:

(a) The optimal fixed wage is

$$w_F^{nd} = \begin{cases} \underline{w} & \text{if } \bar{u} \in [0, \tilde{v}_F] \\ \bar{u} - \frac{1}{2a}\Delta q^2 & \text{if } \bar{u} \in [\tilde{v}_F, \bar{v}_F] \end{cases},$$

(b) The monitoring level m_F^{nd} is such that $M'(m_F^{nd}) = \beta_F DK/a$.

[15]Note that β_F is actually endogenous. It is defined as the share of bad workers in sector F. If, for example, all regular and all bad workers opt for sector F, then the share of bad workers in this sector is $\beta_F = x_b/(x_r + x_b)$.

(c) The optimal bonus payment is $t_F^{nd} = (m_F^* t_F^*)/m_F^{nd}$, where $m_F^* t_F^*$ as defined in 1.

Note that the incentives to provide effort e are still the same as without bad workers, i.e., $m_F^* t_F^* = m_F^{nd} t_F^{nd}$ in each of the three cases. However, the transfer level t_F^{nd} is lower than without bad workers, whereas the monitoring level m_F^{nd} has increased. While the principal may not be able to prevent bad behavior, the expected reward for such behavior thus is lower and hence the level of destructive effort chosen by the workers is lower. Therefore, the expected damage from bad behavior goes down.

Whether the principal in sector F prefers full deterrence or whether he opts for no full deterrence depends on his respective expected profit. Under the former regime, his expected profit is

$$\pi_F^{det} = q + (\Delta q - m_F^{det} t_F^{det}) \frac{m_F^{det} t_F^{det}}{a} - w_F^{det} - M(m_F^{det}) \ ,$$

whereas in the latter case his profit becomes

$$\begin{aligned} \pi_F^{nd} &= (1 - \beta_F)(\Delta q - m_F^{nd} t_F^{nd}) \frac{m_F^{nd} t_F^{nd}}{a} - \beta_F D(\theta_b - m_F^{nd} K) \frac{1}{a} \\ &\quad + q - w_F^{nd} - M(m_F^{nd}) \ . \end{aligned}$$

As can be seen easily from the second function, the expected profit without full deterrence is strictly decreasing in the share of bad workers in sector F, β_F, in the damage these workers may cause D and in their intrinsic motivation θ_b. This means that the larger the share of bad workers in sector F and the higher the expected damage, the more likely it is that $\pi_F^{det} > \pi_F^{nd}$, i.e., that the principal in sector F will prefer to fully deter bad workers. If, for instance, the number of regular workers in the population x_r is very high, this implies that the relative share of bad workers in sector F, β_F, is low and full deterrence hence is less attractive. Furthermore, the monitoring technology plays a role. If the marginal cost of an increased level of monitoring is high, then full deterrence may be too costly.

III.3.3. "Bad" Workers in the Mission-Oriented Sector

For low levels of "bad" motivation θ_b, the non-profit sector is protected from destructive behavior by the higher effort incentives offered in the profit-oriented sector, i.e., bad workers' utility from choosing a normal effort e in sector F is higher than their utility from choosing a destructive effort d in sector N. This is true as long as

$$w_F + \frac{1}{2a}(m_F t_F)^2 \geq w_N + \frac{1}{2a}(\theta_b - m_N K)^2 \; .$$

The principal in the mission-oriented sector therefore does not need to adapt his optimal wage policies (w_N^*, m_N^*, t_N^*) as defined in Corollary 2 as long as

$$\theta_b \leq \tilde{\tilde{\theta}}_b \equiv \sqrt{2a(w_F - w_N^*) + (m_F t_F)^2} + m_N^* K \; ,$$

given a contract (w_F, m_F, t_F) in sector F.

If the level of motivation of bad workers is higher, i.e., if $\theta_b > \tilde{\tilde{\theta}}_b$, then the principal in sector N will have to increase his monitoring level to deter bad workers from choosing a destructive effort. However, the principal cannot increase his monitoring level beyond $m_N = 1$. To account for this fact and make sure that $m_N \leq 1$, the following assumption is sufficient:

Assumption 4: $\theta_b \leq K + \Delta q/2$.

The effort incentives for good workers, however, need not be affected by this change in the intensity of monitoring: in order to induce good workers to provide effort, nothing more than the optimal incentives as described in Corollary 2 are needed.

Therefore the following proposition holds:

Proposition 4: : For $\tilde{\tilde{\theta}}_b < \theta_b \leq K + \Delta q/2$, and given a contract (m_F, t_F, w_F) in sector F and a reservation payoff $\bar{u} \in [0, \bar{v}_F]$, the principal in sector N can achieve full deterrence of "bad" workers by offering a contract $(m_N^{det}, t_N^{det}, w_N^{det})$ with the following features:

(a) The fixed wage is $w_N^{det} = w_N^*$ where w_N^* as defined in Corollary 2.

(b) The monitoring level is

$$m_N^{det} = (\theta_b - \sqrt{2a(w_F - w_N) + (m_F t_F)^2})/K.$$

(c) The bonus payment is $t_N^{det} = m_N^* t_N^* / m_N^{det}$, with $m_N^* t_N^*$ as defined in Corollary 2.

Suppose there is full deterrence in sector F. For $\bar{u} \in [0, \tilde{v}_F]$, i.e., if the basic wage is the same in both sectors, N can achieve full deterrence of bad workers by choosing the same monitoring level in N as in F. If $\bar{u} > \tilde{v}_F$, then the basic wage in F is higher than in N, hence making work in N less attractive for bad workers. This gives some additional protection to sector N and hence allows principals in this sector to achieve full deterrence of bad workers with a monitoring level slightly lower than the one used in sector F, albeit still higher than the optimal monitoring level without bad workers.

With bad workers, the mission-oriented sector hence looses much of its wage cost advantage compared to the for-profit sector. The loss is particularly high when $\theta_g > \Delta q$: in this case (case Ib in the above), the presence of bad workers means that firms have to go from no monitoring at all to whatever monitoring there is in the for-profit sector. That is, by raising the level of monitoring, destructive behavior in N becomes sufficiently unattractive and bad workers prefer to behave like regular workers in sector F. However, there is no need for sector N to adapt its incentives otherwise, i.e., the optimal basic wage stays the same as before, and overall incentives will still be equal to $m_N^* t_N^*$. Even with full deterrence of bad workers, the profit in sector N therefore is still higher than in sector F.

The expected profit in N under full deterrence in both sectors is

$$\pi_N^{det} = q + (\Delta q - m_N^* t_N^*)\frac{m_N^* t_N^*}{a} - w_N^* - M(m_N^{det}) \; . \tag{III.11}$$

Under which circumstances will there be no full deterrence in sector N? If the principal in N chooses no full deterrence, his maximization problem is

$$\begin{aligned} \max_{w_N, t_N, m_N} \pi_N^{nd} \;\; &= \;\; (1-\beta_N)(\Delta q - m_N t_N)\frac{m_N t_N}{a} - \beta_N D(\theta_b - m_N K)\frac{1}{a} \\ &\quad\; + q - w_N - M(m_N) \; , \end{aligned}$$

subject to the limited liability and participation constraints of the workers as given by (III.2) and (III.3). Similar as in sector F, his optimal monitoring level then is $m_N^{nd} = \beta_N DK/a$, while the basic wage and the expected bonus payment stay the same as without bad workers, i.e., $w_N^{nd} = w_N^*$ and $t_N^{nd} = (m_N^* t_N^*)/m_N^{nd}$.

The expected profit in N without full deterrence therefore is

$$\begin{aligned}\pi_N^{nd} &= (1-\beta_N)(\Delta q - m_N^* t_N^*)\frac{m_N^* t_N^*}{a} - \frac{\beta_N D\theta_b}{a} + \Big(\frac{\beta_N DK}{a}\Big)^2 \\ &\quad + q - w_N^* - M\Big(\frac{\beta_N DK}{a}\Big) . \qquad \text{(III.12)}\end{aligned}$$

Comparing (III.12) and (III.11), we find that no full deterrence is the better strategy in sector N if

$$\frac{\beta_N}{a}\Big[(\Delta q - m_N^* t_N^*)m_N^* t_N^* + D\theta_b\Big] - (m_N^{nd})^2 < M(m_N^{det}) - M(m_N^{nd}) .$$

i.e., if the share of bad workers in sector N, β_N, is lower and if additional monitoring is very costly.

Proposition 5: : If there is full deterrence in F, then full deterrence in N is optimal.

The reasons for this statement are straightforward: We know that F will only prefer full deterrence if the expected damage from bad workers is large enough, i.e., in particular if β_F, the share of bad workers in F without full deterrence, is high.

Note that β_F is equal to the number of bad workers over all workers in sector F, i.e., it is equal to $x_b/(x_b+x_r)$ if all bad workers (share x_b in the overall population) and all regular (share x_r in the overall population) workers work in F. Similarly, $\beta_N = x_b/(x_g+x_b)$ if all bad workers choose to work in N, which also attracts all good workers (share x_g in the overall population).[16]

Since we assumed that $x_r > x_g$, $x_b/(x_b+x_r) < x_b/(x_b+x_g)$. Hence if full deterrence is optimal in F, then it must also be optimal in N since the otherwise expected damage in N is even higher than in F. Also, as we have seen above, the costs of full deterrence in N are lower than those in F.

If there is no full deterrence in F, whether N opts for full deterrence or not depends on the share of bad workers in the overall population,

[16]If all bad workers prefer sector N over F, then $\beta_N = 0$.

x_b, and the cost of increased monitoring. When the expected damage from bad workers is sufficiently low or if a high level of monitoring is too costly, there will be no full deterrence in N. However, N is more affected by the presence of bad workers since $x_g < x_r$ and hence may opt for full deterrence even if there is no full deterrence in F.

III.4. Ex Ante Control

The last section has shown that depending on the level of negative motivation of bad workers, θ_b, firms may be able to deal with the problem by adapting their incentive schemes and in particular their monitoring levels. However, this increase of ex post monitoring may be very costly, and for high levels of negative motivation it becomes even entirely ineffective. Firms therefore may want to invest in ex ante measures to reduce the probability of hiring a bad worker in the first place.

Some form of applicant screening, which may serve to filter out more trustworthy or motivated workers, is quite common in most firms. The higher the expected damage of hiring a bad worker, the more an organization or firm will be inclined to invest in a more sophisticated selection process of applicants. This is commonly observed especially in sectors where candidates, once hired, are difficult to fire, as for example civil servants,[17] or where the stakes are high, e.g., in intelligence services. The selection process in these cases can be quite lengthy and generally involves all kinds of tests and background checks. For instance, the CIA states on its web site:[18] "Depending on an applicant's specific circumstances, the [application] process may take as little as two months or more than a year. [...] Applicants must undergo a thorough background investigation examining their life history, character, trustworthiness, reliability and soundness of judgment [...], [their] freedom from conflicting allegiances, potential to be coerced and willingness and ability to abide by regulations governing the use, handling and the protection of sensitive

[17] Goldman (1982) and Greenberg and Haley (1986) discuss this issue for the case of judges in the United States.

[18] See https://www.cia.gov/careers/faq/index.html#a3

information. The Agency uses the polygraph to check the veracity of this information. The hiring process also entails a thorough medical examination of one's mental and physical fitness to perform essential job functions." The FBI states that "The clearance process can take anywhere from several months to a year or more",[19] and lists as part of the background check "a polygraph examination; a test for illegal drugs; credit and records checks; and extensive interviews with former and current colleagues, neighbors, friends, professors, etc."

Similarly, many nonprofit organizations require a lot of previous experience and conduct extensive interviews before hiring someone, especially in cases where monitoring in the field is difficult (e.g., Médecins sans Frontières).

A better candidate selection process can thus serve as a (partial) substitute for worker monitoring.[20] However, checking each applicant is costly, and therefore has to be seen in relation to the potential damage of hiring a bad worker.

In this context, legal requirements may play an important role in order to help employers screen out bad workers. In Germany, for instance, employers can ask applicants for their official police record ("Führungszeugnis"), which, however, only documents offenses that are punishable beyond a certain degree of penalty in order to give offenders a second chance. Unfortunately, until recently, many potentially relevant cases of molestation, child pornography, exhibitionism etc. did thus not appear in the records. This came under discussion with the occurrence of several cases of child molestation where the employer was unaware of his employee's history, although the employee had been convicted for similar behavior before. To prevent cases like this in the future, the government introduced an "extended police record" ("erweitertes Führungszeugnis"), which can be requested for anyone seeking employment in a job that may

[19]See `http://www.fbijobs.gov/61.asp#3`

[20]See Huang (2007) and Huang and Cappelli (2006) for a discussion on the possible tradeoff between worker monitoring and ex ante applicant screening.

bring him or her in contact with children or youths.[21]

In other cases, establishing a clearer profile of bad workers may help. This has, for example, been done in the US to prevent fire fighter arson. Studies by the South Carolina Forestry Commission and the FBI[22] have found that arsonists are typically white males between 17 and 26 years of age, with a difficult family background, lacking social and interpersonal skills, often of average intelligence but with poor academic performance. Also, arson seems to be more likely with volunteer fire fighters than with professionals who, in the U.S. as well as in many European countries make up for at least 75% of all fire fighters. The South Carolina Forestry Commission hence has designed an "Arson Screening and Prediction System" which is supposed to help field level administrators to evaluate candidates. It attributes a numeric score to the answers to a questionnaire covering areas such as the candidate's family background, his social skills, capacity for self control, intelligence, self-esteem and academic performance, stress and attitudes towards the fire service.

Yet another measure to prevent destructive behavior may be to promote peer monitoring, which is especially attractive if ex ante candidate screening is less than perfect and monitoring of workers is difficult.[23] In the case of fire fighter arson, for example, promoting peer monitoring consists of awareness programs that are supposed to alert fire departments to the problem and keep their eyes open. In other cases, peer monitoring can be induced through simple institutional features, such as letting employees work pairwise, as it is common for police officers, hiring

[21]See press release of the German Ministry of Justice from 14 May 2009, `http://www.bmj.bund.de/enid/Nationales_Strafrecht/Erweitertes_Fuehrungszeugnis_1js.html` .

[22]See Stambaugh and Styron (2003) for a summary of both studies.

[23]There are relatively few theoretical papers on peer monitoring, exceptions being Barron and Gjerde (1997) and Kandel and Lazear (1992), who both analyze the interaction between peer pressure and the provision of incentives in teams.

couples,[24] or providing joint housing for aid workers.[25] While this may give rise to collusion among evil-doers, such a scheme is likely to work reasonably well if there are enough “good” motivated workers who care about the mission of the organization they work for.

III.5. Conclusion

We have shown how the existence of “destructive” workers who derive satisfaction from actions that are detrimental to their employer or others may affect the optimal wage contracts offered. In particular, we discussed how this may affect nonprofit organizations that rely at least to some extent on the intrinsic motivation of their workers but may be unable to filter out workers with a “negative” motivation.

First of all, we showed that without bad workers, the mission-oriented sector N can save on wage and monitoring costs compared to the profit-oriented sector F. If the intrinsic motivation of good workers is high enough, it may even forego bonus payments and monitoring altogether. However, the lack of monitoring and extrinsic incentives makes N particularly vulnerable to destructive behavior by bad workers: we showed that if bad workers join sector N then only to follow their destructive instincts and not because they want to provide a positive effort.

In order to reduce the negative impact of bad workers, both the profit- and the mission-oriented sector have to increase their monitoring levels. We showed that to achieve full deterrence of bad workers, the profit-oriented sector may even have to increase effort incentives beyond the optimal level as described in Section III.2, i.e., not only monitoring has

[24]There is anecdotal evidence that, for example, the French service for teaching abroad prefers to hire couples, not only for monitoring reasons, but mainly because they have been found to withstand stress caused by a new environment better.

[25]This is for example the approach of Ärzte für die Dritte Welt (Doctors for Developing Countries), a German NGO that runs several permanent projects in Africa, Asia and Central America with the help of doctors doing short term volunteer work. Again, this rather has practical reasons and is not necessarily intended as a measure to promote peer monitoring, but still it may act in such a way.

to be increased, but also the expected return for effort $m_F t_F$ is higher. By contrast, the mission-oriented sector can achieve full deterrence by choosing the same monitoring level as in sector F, but otherwise keeping extrinsic incentives at the same level as before. That is, to the same extent that the monitoring level m_N increases, the bonus payment t_N decreases such that the overall effort incentives are still at their optimal level $m_N^* t_N^*$. The mission-oriented sector therefore still may enjoy a certain cost advantage, since it is cheaper to get already motivated workers to provide effort.

However, increased monitoring of workers may be difficult and expensive under many circumstances, thus requiring firms to make a better ex ante candidate selection.

In order to focus on the incentive problems raised by the presence of "bad" workers, we have not taken into account other differences between profit- and mission-oriented organizations. Yet it may be worthwhile to take a look at those differences, in particular the way organizations are financed: While profit-oriented organizations usually have to survive on the proceeds from their business, many mission-oriented organizations are run as non-government organizations or associations that essentially depend on donations. For them, the scandal caused by bad workers may hence also have considerable negative consequences for their funding, thus making deterrence of bad workers all the more important.

Another aspect that needs to be discussed is the effect of control on the intrinsic motivation of good workers. There is a recent literature on the crowding out of intrinsic motivation by extrinsic incentives or control.[26] Taking into account such effects would mean that the more the mission-oriented sector N increases monitoring in order to prevent damage from bad workers, the lower would be the intrinsic motivation of good workers. N would therefore also have to increase his monetary effort incentives t_N in order to induce good workers to work hard enough, thus losing its cost advantage. Eventually, good intrinsic motivation would disappear all together and organizations in sector N would operate under

[26] See Seabright (2009), Frey and Jegen (2001), Frey and Oberholzer-Gee (1997).

the same conditions as firms in the profit-oriented sector F and also offer the same contracts.

IV. Job Assignment with Multivariate Skills

IV.1. Introduction

Under which circumstances can performance in one job act as an indicator for performance in another job? Why would an employer want an employee to work first in job 1 before letting him do job 2? Two explanations seem plausible: (i) worker selection: By observing a worker's performance in job 1, the employer learns more about the worker's ability; and (ii) training: Working in job 1 provides the worker with training and skills that are useful in job 2.

In the following, I concentrate on the first option. To do so, I abstract from any considerations concerning wage costs or workers' incentives to exert effort. Instead, I focus on the employer's task assignment problem when workers differ in their skills and tasks require different combinations of skills. Workers in the model are characterized by a skill combination (x, z) where x and z are two different skills that are independently distributed across the worker population. However, a worker's skill profile is not directly observable, but only his overall performance in a given task. The employer therefore faces the problem of how to allocate workers to tasks that put different weights on both skills.

Although there is a lot of literature on job assignment, as nicely summarized in Sattinger (1993), this problem has not been considered in this form. Most papers on the topic assume that workers' ability varies along a single dimension ("general ability") but do not take into account that workers may possess many skills that matter for their performance. Some others note that workers may have a comparative advantage in one task, but then often reduce the analysis to a problem with only two types.

Allowing for several skill-dimensions, the first part of the paper analyzes the task assignment of current and new workers if the employer faces no constraints concerning the number of workers he can assign to each task. I derive rules for optimal assignment and show that there may be a tradeoff between maximizing short-term and long-term output when new workers are hired for two periods: in the short run, output is maximized by assigning new workers to the task where the expected output of an unscreened worker is maximal. But especially if this task plays a much more important role in the overall production of the firm, the employer may prefer to first hire workers for the other task, which is thus used as a screening stage for maximizing output in the long run. That is, the employer will prefer to forego some first period output in order to make more informed choices in the long run.

However, firms often need a fixed number of workers in each task, i.e., there is a given number of jobs in each activity. Given such slot constraints, the second part of the paper determines under what circumstances workers are reallocated between jobs.

The analysis provides theoretical evidence for a variant of the Peter Principle, after Peter and Hull (1969), which states that workers are promoted up to their level of incompetence. In the present model, something similar may arise over a certain range of output realizations: workers producing output in this range will get reallocated although, at least in expected terms, they will be less productive at their new job. Nevertheless, the reallocation of these workers is efficient: when the employer has to fill an open position, he prefers to reallocate a mediocre worker on whom he has at least some information rather than hiring an unknown worker.

Other papers on the Peter Principle are Fairburn and Malcomson (2001), Faria (2000) and Lazear (2004), which is closest to the present paper. Lazear (2004) explains the Peter Principle as follows: if only the best get promoted out of a job, then, after promotion, those left behind are perceived as less capable. By contrast, I show that workers may get reallocated in the first place although they are expected to be less competent after reallocation. Rather than being a statistical artefact, the Peter Principle hence arises as a by-product of incomplete information about job candidates.

The following section describes the optimal task assignment of workers when there are two tasks that require two skills, and there are no slot constraints. This latter assumption is relaxed in Section IV.3, which analyzes under which circumstances workers are reallocated between jobs if there is a fixed number of workers needed in each job. Additionally, Section IV.4 proposes extensions of the model such as the generalization to J jobs and I skills, and Section IV.5 discusses assignment patterns such as job rotation. Section IV.6 concludes.

IV.2. Optimal Task Assignment

Suppose there are two kinds of activities or tasks in a firm. A worker engaged in either of these two activities produces an output y_j, $j = 1, 2$, according to the following production functions

$$\begin{aligned} y_1 &= a \cdot x + b \cdot z \\ y_2 &= c \cdot x + d \cdot z \ , \end{aligned}$$

where x and z are two different skills needed in both activities, although to different extents. For example, x can be thought of as technical and z as marketing skills. Let us assume that $a > c$ and $d > b$, i.e., skill x is more important for activity 1 and skill z for activity 2.

The skills are independently distributed in the population with $x \sim N(\mu_x, \sigma_x)$ and $z \sim N(\mu_z, \sigma_z)$. The employer can observe the output produced by a worker, but not the worker's specific skill level (x, z). Furthermore, the employer can hire workers for 2 periods of time at most and may reassign them after the first period. That is, upon hiring a worker he faces a sequence of decisions as shown in Figure IV.1.

Given this simple setup, how do workers get assigned to tasks? The next section considers the employer's ad interim decision problem, i.e., it analyzes under which conditions the employer will want to reallocate workers once he has observed their performance in one of the two activities.[1] Given this analysis, Section IV.2.2 then turns to the allocation of

[1]This corresponds to the employer's decision problem at $t = 1$ in Figure IV.1.

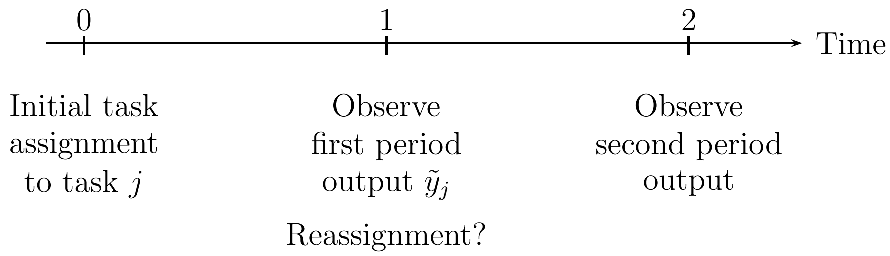


Figure IV.1: Time line.

new workers,[2] before the possibility for lay-offs is introduced in Section IV.2.3.

IV.2.1. Internal Reallocation of Workers

Let us first consider how an employer would reallocate a given set of workers whose performance in either of the two activities he has observed for one period.

I will say that it is individually efficient to reallocate an employee if

$$E(y_2|\hat{y}_1) > \hat{y}_1 \ , \tag{IV.1}$$

i.e., if the expected performance of a worker in task 2 is higher than his observed current performance in task 1, $\hat{y}_1$.

The conditional expectation of y_2 given $\hat{y}_1$ is

$$E(y_2|\hat{y}_1) = E(y_2) + \frac{ac\sigma_x^2 + bd\sigma_z^2}{a^2\sigma_x^2 + b^2\sigma_z^2} \cdot (\hat{y}_1 - E(y_1)) \ . \tag{IV.2}$$

For more information on the calculation of the conditional expected output, see Appendix C. The coefficient $k_1 \equiv (ac\sigma_x^2 + bd\sigma_z^2)/(a^2\sigma_x^2 + b^2\sigma_z^2)$ of the term $(\hat{y}_1 - E(y_1))$ in (IV.2) is equal to the ratio between the covariance of output in tasks 1 and 2 and the variance of output in task 1. That is

$$k_1 = \frac{Cov(y_1, y_2)}{Var(y_1)} \ .$$

[2]That is, Section IV.2.2 analyzes the optimal allocation of workers at $t = 0$, as shown in Figure IV.1.

In order to make reassignment efficient, i.e., in order to fulfill (IV.1), the current output $\hat{y}_1$ therefore has to fulfill the following inequality:

$$(k_1 - 1)\hat{y}_1 \geq k_1 E(y_1) - E(y_2) \; .$$

As a consequence, there exists a critical value $\tilde{y}_1$ of the form

$$\tilde{y}_1 = [k_1 E(y_1) - E(y_2)] \frac{1}{k_1 - 1} \; , \qquad \text{(IV.3)}$$

such that, if $k_1 > 1$, then reallocation is individually efficient if the observed output $\hat{y}_1$ is *higher* than $\tilde{y}_1$. Otherwise, for $k_1 < 1$, reallocation is individually efficient if $\hat{y}_1$ is *smaller* than $\tilde{y}_1$.

That is, if $k_1 > 1$, i.e., if the covariance of output in the two tasks is higher than the variance of output in task 1, the best performing workers in task 1 are likely to be even better in task 2. If $k_1 < 1$, then the worst performers in task 1 are likely to be better in task 2.

By a similar reasoning, a reallocation from task 2 to task 1 is individually efficient if the worker's task 2 output is higher (lower) than a critical output level

$$\tilde{y}_2 = [k_2 E(y_2) - E(y_1)] \frac{1}{k_2 - 1} \; , \qquad \text{(IV.4)}$$

for k_2 larger (smaller) than 1, where k_2 is defined as

$$k_2 = \frac{Cov(y_1, y_2)}{Var(y_2)} = \frac{ac\sigma_x^2 + bd\sigma_z^2}{c^2\sigma_x^2 + d^2\sigma_z^2} \; .$$

By definition, one has

$$k_1 \cdot k_2 = \frac{(Cov(y_1, y_2))^2}{Var(y_1) \cdot Var(y_2)} = \varrho^2_{y_1 y_2} \; .$$

Since the correlation coefficient $\varrho_{y_1 y_2}$ can be at most equal to one, it follows directly that the variables k_1 and k_2 cannot both at the same time be larger than 1.

Therefore the following proposition holds:

PROPOSITION 6: For $k_1 > 1$, there exists a critical task 1 output level $\tilde{y}_1$ as defined in (IV.3) such that for $y_1 > \tilde{y}_1$ it is individually efficient to reallocate a worker from task 1 to task 2. At the same time, there exists a critical task 2 output level $\tilde{y}_2$ as defined in (IV.4) such that for $y_2 < \tilde{y}_2$ it is individually efficient to reallocate workers from task 2 to task 1.

As a corollary to this proposition, we get that if $k_2 > 1$, then it is individually efficient to reallocate workers with an observed output $\hat{y}_1 < \tilde{y}_1$ to task 2 and workers with $\hat{y}_2 > \tilde{y}_2$ to task 1.

Furthermore the case may arise that $k_1 < 1$ and $k_2 < 1$, and hence only the worst performers get reallocated, i.e., workers with $\hat{y}_1 < \tilde{y}_1$ and with $\hat{y}_2 < \tilde{y}_2$. This result also holds when the covariance between tasks 1 and 2 is negative. However, both these cases are not particularly interesting. Therefore I focus on cases where either k_1 or k_2 is greater than one.

IV.2.2. Assignment of New Workers

So far, the reallocation of current workers has been considered. But how about new workers? To which task should they be first allocated? There are two criteria that may possibly play a role: (i) Which task provides the employer with more precise information about the employee? (ii) Where can an unscreened worker be expected to produce more?

If new workers get hired for only one period, then learning about the employee obviously does not play a role, and the employer will therefore prefer to allocate new workers to the task where the expected output of an unknown worker is higher, and thus the second motive dominates. The same is true if workers get hired for several periods but cannot be reallocated or fired.

If workers instead get hired for two periods and reallocation is possible, then there may be a tradeoff between the two motives, i.e., between learning and output maximization of unscreened workers. To see this, let us assume that $E(y_1) > E(y_2)$, i.e., an unscreened worker is expected to be more productive in task 1. The employer can hire the worker for either of the two tasks $j = 1, 2$. After one period of work, he will observe the worker's first period output $\tilde{y}_j$. According to the rules derived in the previous section, he will then either let the worker continue to work on his current task or he will reassign him. Assuming that $k_1 > 1$ and $k_2 < 1$, this means that workers first assigned to task 1 get reallocated to task 2 if $\tilde{y}_1$ greater than $\tilde{y}_1$, as defined in (IV.3), and task 2 workers get reassigned to task 1 if $\tilde{y}_2 \leq \tilde{y}_2$ which was defined in (IV.4). All other

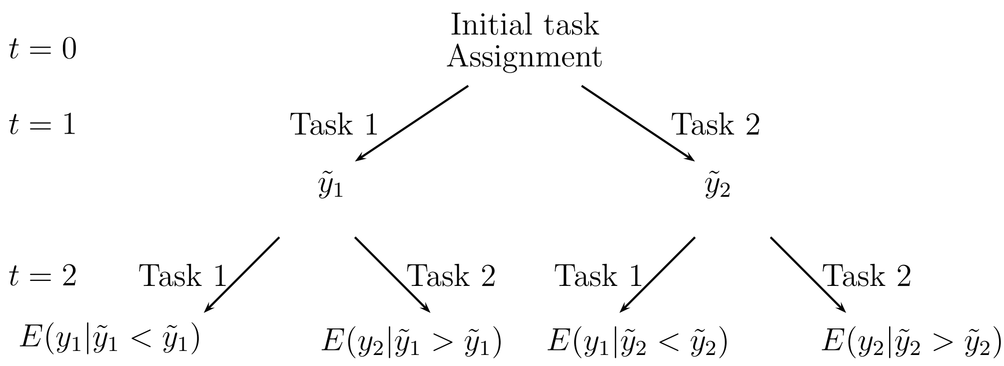


Figure IV.2: Hiring strategies for new workers ($k_1 > 1$, $k_2 < 1$).

workers continue to work on the same task. Figure IV.2 illustrates these considerations.

From an ex ante point of view, the expected output of a worker hired for two periods and first assigned to task 1 therefore is

$$E(y_1) + [E(y_1|\tilde{y}_1 < \tilde{y}_1) \cdot Prob(\tilde{y}_1 \leq \tilde{y}_1)] + [E(y_2|\tilde{y}_1 > \tilde{y}_1) \cdot Prob(\tilde{y}_1 > \tilde{y}_1)],$$

i.e., the worker's expected first period production in task 1 plus his second period output conditional on his observed performance $\tilde{y}_1$ in the first period. Note that a worker's performance at a given task does not change over time, that is his second period output in task 1 is the same as in the first period, $\tilde{y}_1$. His expected second period performance in task 2 is given by (IV.2). Taking this into account, one can rewrite the above expression as

$$E(y_1) + [y_1 \cdot Prob(y_1 \leq \tilde{y}_1)] + [E(y_2) + k_1(y_1 - E(y_1))] \cdot Prob(y_1 > \tilde{y}_1) \ .$$

Let $F(\cdot)$ be the cumulative distribution function according to which y_1 is distributed.[3] Then the expected output of a worker hired for two periods is

$$E(y_1) + [F(\tilde{y}_1)] + [E(y_2) + k_1(1 - F(\tilde{y}_1)) - k_1 E(y_1)] \ . \qquad \text{(IV.5)}$$

[3]Given the assumptions about x and z, y_1 is normally distributed with mean $a\mu_x + b\mu_z$ and variance $a^2\sigma_x^2 + b^2\sigma_z^2$.

A similar reasoning applies when workers first work on task 2. After observing their first period performance $\tilde{y}_2$, the employer will reassign them to task 1 if $\tilde{y}_2 \leq \tilde{y}_2$ and otherwise let them continue to work on task 2. From an ex ante point of view the expected output of a worker hired for two periods and first assigned to task 2 hence is

$$\begin{aligned} &E(y_2) + [E(y_1|\tilde{y}_2 < \tilde{y}_2) \cdot Prob(\tilde{y}_2 \leq \tilde{y}_2)] + [E(y_2|\tilde{y}_2 > \tilde{y}_2) \cdot Prob(\tilde{y}_2 > \tilde{y}_2)] \\ &= E(y_2) + [E(y_1) + k_2(y_2 - E(y_2))] \cdot Prob(\tilde{y}_2 \leq \tilde{y}_2) + [y_2 \cdot Prob(\tilde{y}_2 > \tilde{y}_2)] \ . \end{aligned}$$

Let $G(\cdot)$ be the cumulative distribution function of y_2.[4] Then the above expression can be rewritten as

$$E(y_2) + [E(y_1) + k_2 G(\tilde{y}_2) - k_2 E(y_2)] + [1 - G(\tilde{y}_2)] \ . \qquad \text{(IV.6)}$$

When comparing (IV.5) and (IV.6), i.e., the expected payoffs from assigning a worker first to task 1 or to task 2, respectively, the second strategy turns out to be better if

$$E(y_1) > \frac{k_2}{k_1} E(y_2) + \frac{k_1 - 1}{k_1}(1 - F(\tilde{y}_1)) + \frac{1 - k_2}{k_1} G(\tilde{y}_2) \ . \qquad \text{(IV.7)}$$

Recall that $k_1 = Cov(y_1, y_2)/Var(y_1)$ and $k_2 = Cov(y_1, y_2)/Var(y_1)$. Whether it is better first to assign a worker to task 1 or to task 2 thus depends on the exact distributions of y_1 and y_2, which in turn depend on the distribution of skills x and z.

Proposition 7: The employer will prefer to assign new workers first to task 2 if condition (IV.7) is fulfilled.

The employer thus prefers to sacrifice a certain amount of first-period production in order to have more information on workers that are assigned to the task that is likely to generate a higher output. This tradeoff is similar to the one described in Grossman, Kihlstrom, and Mirman (1977), who show that individuals or firms may find it profitable to modify their behavior in order to base their future decisions on better information. That is, they experiment in order to gain information.

[4] y_2 is normally distributed with mean $c\mu_x + d\mu_z$ and variance $c^2\sigma_x^2 + d^2\sigma_z^2$.

The same is true in the present model. It would seem natural that the employer should assign workers to the job where they can be expected to produce the highest output. However, if task 1 is sufficiently more important than task 2, or if performance in task 2 is much more informative about workers' skills, then the employer may find it worthwhile to assign workers first to task 2, thus basically buying information on workers at the cost of a lower expected output in the short run. Or in the terms of the model by Grossman, Kihlstrom, and Mirman (1977): the employer decides to "experiment" if the benefits from more informed future choices outweigh the costs incurred because he modifies his behavior relative to what would be optimal if there was no learning.

Note, however, that, while it is possible that such "experimentation" arises, it is not necessarily the case. Depending on the exact distributions of y_1 and y_2, it may very well be the case that $E(y_1) > E(y_2)$ and at the same time condition (IV.7) is not fulfilled. That is, there is not necessarily a tradeoff between maximizing the first period output of an unknown worker and learning about his skills. In that case, the employer will be better off assigning new workers to task 1 where they are expected to produce a higher output.

IV.2.3. Firing

Another option not yet considered so far is to fire workers if their performance is too low. If there are no turnover costs,[5] the employer will want to replace workers whose observed performance in task $\tilde{y}_j$ is below the expected performance of a new worker $E(y_j)$.[6]

That is, given their first period performance and assuming that $k_1 > 1$ and $k_2 < 1$, workers get assigned according to the following rules:

- A worker with observed performance $\tilde{y}_1$ in task 1 will be reallocated to task 2 if $\tilde{y}_1 > \tilde{y}_1$. He will continue to work on task 1 if $E(y_1) <$

[5]Also, wage costs are not taken into account here.

[6]Note that if $\tilde{y}_j < E(y_j)$, then also $E(y_{-j}|\tilde{y}_j) < E(y_{-j})$. That is, if a worker is a less than average performer in one task, then his expected output in the other task is also lower than that of a new worker.

$\tilde{y}_1 \leq \tilde{\tilde{y}}_1$, and he will be fired if $\tilde{y}_1 \leq E(y_1)$.

- A worker with observed performance $\tilde{y}_2$ in task 2 will continue to work on task 2 if $\tilde{y}_2 > \tilde{\tilde{y}}_2$. He will be reallocated to task 1 if $E(y_2) < \tilde{y}_2 \leq \tilde{\tilde{y}}_2$, and he will be fired if $\tilde{y}_2 \leq E(y_2)$.

Given these assignment rules and applying the same reasoning as in the previous section, the ex ante expected payoff of hiring a worker initially for task 1 hence is

$$E(y_1) + [F(\tilde{\tilde{y}}_1) - F(E(y_1))] + [E(y_2) + k_1(1 - F(\tilde{\tilde{y}}_1)) - k_1 E(y_1)] \quad \text{(IV.8)}$$

whereas the ex ante payoff of first assigning him to task 2 is

$$E(y_2) + [E(y_1) + k_2(G(\tilde{\tilde{y}}_2) - G(E(y_2))) - k_2 E(y_2)] + [1 - G(\tilde{\tilde{y}}_2)] \quad \text{(IV.9)}$$

From the comparison of these two options arises the following proposition:

Proposition 8: The employer will prefer to assign new workers first to task 2 if

$$\begin{aligned} E(y_1) > \ & \tfrac{k_2}{k_1} E(y_2) + \tfrac{k_1 - 1}{k_1}(1 - F(\tilde{\tilde{y}}_1)) + \tfrac{1 - k_2}{k_1} G(\tilde{\tilde{y}}_2) \\ & - F(E(y_1)) + k_2 G(E(y_2)) \ . \end{aligned} \quad \text{(IV.10)}$$

That is, it depends again on the entire distribution of possible outputs in both tasks whether new workers should first be assigned to task 1 or 2.

IV.3. Job Assignment in the Short Term

The previous section has established criteria for assigning both new and old workers to one of two activities in the firm. These criteria are relevant if the employer faces no constraints concerning the number of employees working on each task. However, the employer may not be able to assign any number of workers to any task. At least in the short run he is likely to face slot constraints in the sense that he needs a fixed number of employees in each activity.

Let us assume that the firm needs n workers to do task 1 and m workers for task 2. That is, there are n jobs of type 1 and m jobs of type 2. All prices are normalized to one and the firm's objective function is given by

$$\sum_{i=1}^{n} y_1^i + \sum_{i=1}^{m} y_2^i \ ,$$

i.e., the principal wants to maximize the sum of outputs. In the following, only the employer's short term perspective is considered, i.e., he wants to maximize the sum of outputs in the next period. To fill all available slots, the employer can either reallocate current workers or hire new unscreened workers for either of the two jobs. So when does the firm choose which option?

IV.3.1. External Recruiting vs. Internal Reallocation

Suppose the firm has to fill one open position in job 2. Should it fill the position in job 2 with someone who has worked in job 1 before, or should it hire an unknown worker?

If the firm promotes worker i from job 1 to job 2 and fills the opening in job 1 with an unknown worker, its expected profit in the next period is

$$E(y_1) + E(y_2^i|\hat{y}_1^i) \ ,$$

i.e., the sum of the expected output of an unknown worker in job 1 and the expected output of worker i in job 2, conditional on his *observed* performance $\hat{y}_1^i$ in his current job.

If the firm does not promote worker i and hires an unknown worker for job 2, its expected profits are

$$\hat{y}_1^i + E(y_2) \ ,$$

i.e., worker i will continue to produce the same output $\hat{y}_1^i$ as before, and the new worker has expected job 2 output $E(y_2)$.

Promoting worker i hence is the better option if

$$\begin{aligned} E(y_1) + E(y_2^i | \hat{y}_1^i) &> \hat{y}_1^i + E(y_2) \\ \Leftrightarrow E(y_1) + E(y_2) + k_1(\hat{y}_1^i - E(y_1)) &> \hat{y}_1^i + E(y_2) \\ \Leftrightarrow (k_1 - 1)\hat{y}_1^i &> (k_1 - 1)E(y_1) \; . \end{aligned}$$

As before, one has to distinguish two cases: If $k_1 > 1$, then promotion is profitable for $\hat{y}_1^i > E(y_1)$. In the opposite case, i.e., if $k_1 < 1$, promotion is only profitable if the current output is below the expected output in this job, i.e., if $\hat{y}_1^i < E(y_1)$. The analogue reasoning applies for job 2.

PROPOSITION 9: For $k_1 > 1$, rather than hiring a new worker, the employer prefers to reallocate a current worker from job 1 to job 2 if his output $\hat{y}_1 > E(y_1)$, and from job 2 to job 1 if $\hat{y}_2 < E(y_2)$.

As a corollary, we get that for $k_2 > 1$ reallocation from job 1 to 2 is profitable if $\hat{y}_1 < E(y_1)$ and from job 2 to 1 if $\hat{y}_2 > E(y_2)$.[7]

IV.3.2. The Peter Principle: Inefficient reallocation?

When we compare the results on reassignment under slot constraints from the previous section with the optimal assignment rules derived in Section IV.2, it becomes clear that the two assignment rules do not always coincide: Proposition 6 tells us that a worker currently employed in job 1 can be expected to produce a higher output in job 2 if his output is greater than $\tilde{y}_1$ as defined in (IV.3). Hence reassigning him is individually efficient if his observed output $\tilde{y}_1$ exceeds $\tilde{y}_1$. However, this criterium turns out not to be decisive when there is a fixed number of slots to fill and hiring of outside candidates is possible. Then, according to Proposition 9, workers with an above average output, i.e., with $\hat{y}_1 > E(y_1)$, are candidates for reallocation.

If we assume that $E(y_1) > E(y_2)$, then $\tilde{y}_1 > E(y_1)$ (see Figure IV.3). That is, workers producing output $\tilde{y}_1 > \tilde{y}_1 > E(y_1)$ are candidates for

[7]If both k_1 and k_2 are smaller than one, then reallocation is profitable for $\hat{y}_1 < E(y_1)$ and $\hat{y}_2 < E(y_2)$, but this case seems less relevant.

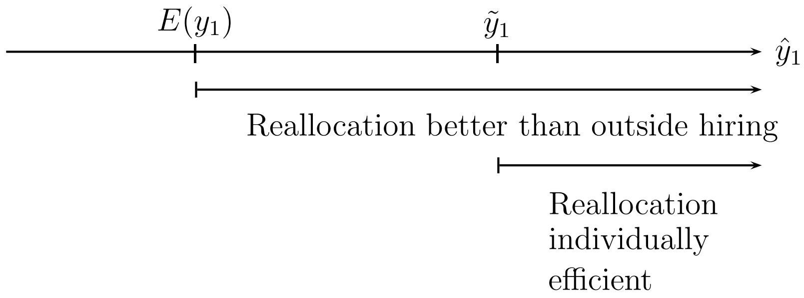


Figure IV.3: Individual efficiency and profitability of reallocation for $k_1 > 1$.

reallocation according to Proposition 9, even though they are likely to produce a higher output in their current job.

This immediately brings to mind the well-known Peter Principle,[8] which states that workers get promoted up to their level of incompetence. If this principle applies in the present model, then after reallocation, there must be some workers who are less competent or less productive at their new job than they were at their previous job. As we have seen, this may indeed be the case. Workers producing output between $E(y_1)$ and $\tilde{y}_1$ are candidates for reallocation since they produce an above-average output. However, their expected output after reallocation $E(y_2|\hat{y}_1)$ is smaller than their current observed output $\hat{y}_1$. That is, at least in expected terms, they will produce less after reallocation. In other words: given their observed performance in job 1, these workers are likely to be more productive or "more competent" at their current job. Nevertheless, they may get transferred to job 2. The model therefore predicts indeed that there are some workers who get reallocated although they can be expected to be less productive or less competent afterwards, as suggested by the Peter Principle.

There is some previous literature on the Peter Principle. For example, Fairburn and Malcomson (2001) discuss how promotions can limit the effect of influence activities of workers and show that depending on the degree of risk aversion, promotions may take place that are not justified

[8]After Peter and Hull (1969).

by reasons of job assignment (what the authors refer to as the "Peter Principle effect"). In Lazear (2004), the Peter Principle is explained as a regression to the mean. After promoting the best job 1 workers, the average performance of job 1 workers left behind is lower than it was before. That is, ability appears lower after promotion purely as a statistical matter.

The present model proposes a different explanation. It shows that workers get promoted as soon as they produce more than the average unscreened worker, even if they are likely to be less able and hence less productive after promotion. This is due to the fact that the employer faces an opportunity cost of hiring an unknown worker, and therefore always prefers to fill an open position with a worker on whom he has at least some (positive) information.

Note however, that this is an efficient assignment policy. The Peter Principle thus occurs as a by-product of a labor market where workers' skills are difficult to assess. If the employer's information on outside candidates improves, the scope for individually inefficient job assignment diminishes.

IV.4. Extensions of the Model

IV.4.1. Generalization

The basic model described above can be further generalized to encompass both more tasks and skills, as well as external shocks: suppose that there are $j = 1, .., J$ possible tasks and $i = 1, .., I$ skills. Each skill has a different weight c_{ij} in each task. Furthermore let y_j denote the output in task j. The production function for task j then can be written as

$$y_j = \sum_{i=1}^{I} c_{ij} \cdot x_i + \epsilon_j \ ,$$

where x_i denotes the endowment of a worker with skill i, and ϵ is a noise term. I assume that skills are independently distributed in the population according to $N(\mu_{x_i}, \sigma_{x_i})$. The noise term is also assumed to be independently distributed according to $N(0, \sigma_\epsilon)$.

This generalization allows for external productivity shocks, which makes it better comparable to existing models of job assignment. The analysis from the previous section also applies to this more general version of the model: given an observed output in job j, $\hat{y}_j$, the expected output of a worker in job $-j$ is

$$E(y_{-j}|\hat{y}_j) = E(y_{-j}) + \frac{Cov(y_j, y_{-j})}{Var(y_j)} \cdot [\hat{y}_j - E(y_j)] \ .$$

This expected output in job $-j$ is greater than his current output in job j if

$$\Big(\frac{Cov(y_j, y_{-j})}{Var(y_j)} - 1\Big)\hat{y}_j > \frac{Cov(y_j, y_{-j})}{Var(y_j)} \cdot E(y_j) - E(y_{-j}) \ . \qquad \text{(IV.11)}$$

That is, if the above inequality holds, then the individual worker in question will in expected terms be more productive after reallocation, i.e., it is individually efficient to reallocate him.

If the firm has to decide between reallocating a current worker or hiring a new unscreened worker, it goes for the former option if

$$\Big(\frac{Cov(y_j, y_{-j})}{Var(y_j)} - 1\Big)\hat{y}_j > \Big(\frac{Cov(y_j, y_{-j})}{Var(y_j)} - 1\Big)E(y_j) \ . \qquad \text{(IV.12)}$$

Suppose that $Cov(y_j, y_{-j}) > Var(y_j)$. In that case, a worker can be expected to be more productive in job $-j$ than in his current job j if his output is higher than $\tilde{y}_j$ which can be derived from (IV.11) as

$$\tilde{y}_j = \Big[\frac{Cov(y_j, y_{-j})}{Var(y_j)} \cdot E(y_j) - E(y_{-j})\Big]\frac{Var(y_j)}{Cov(y_j, y_{-j}) - Var(y_j)} \ .$$

Furthermore, from (IV.12) it follows, that reallocation is preferable over outside hiring if $\hat{y}_j > E(y_j)$.

Assuming that jobs $j = 1, .., J$ are ordered in such a way that the expected output of an unscreened worker is higher for a job with a lower index, $E(y_j)$ is smaller than $\tilde{y}_j$, such that workers producing output between these two values are candidates for reallocation even though they are expected to be less productive after being reassigned. That is, the Peter Principle as explained above still holds in the generalized version of the model: after reallocation, there may be some workers that are less productive at their new job than at their previous job.

IV.4.2. Long-Term Perspective

In the analysis above, the employer was assumed to maximize output in the next period. He did not care about the longer-term implications of hiring a new worker in either of the two jobs existing in the firm. This could be due either to a strong present bias or because he is unable to assess the possibilities of employing new workers for a second period.

If, however, the employer does take a long-term perspective and he decides between hiring a new worker in $t = 1$ or reallocating an old worker, the employer would also have to take into account the expected output of the new worker in $t = 2$, given the likely assignment possibilities in that period. Ultimately this would lead to a kind of overlapping-generations model similar to the one in Meyer (1994), who analyzes the optimal task assignment of young and old workers in team production.

IV.5. Job Design

In the model presented here, the employer can only learn more about a worker's type if he assigns the worker to different jobs. This raises the questions how an employer wants to structure a possible career path. Will consecutive jobs be closely related to each other? When is job rotation a useful mechanism?

Consider the following specification of the model: There are four jobs that use four different skills as follows:

$$\begin{aligned}
y_1 &= c_{11}x_1 + c_{12}x_2 \\
y_2 &= c_{22}x_2 + c_{23}x_3 \\
y_3 &= c_{33}x_3 + c_{34}x_4 \\
y_4 &= c_{41}x_1 + c_{42}x_2 + c_{43}x_3 + c_{44}x_4
\end{aligned}$$

Suppose that job 4 is a management job. In order to choose candidates for this job, the employer faces the option of letting a worker move gradually through jobs 1,2 and 3, i.e., structure his career path as a *job ladder*. Or he may want to let workers do job 1 and 3 before moving them to job 4, i.e., implement a *job rotation* between quite different jobs (1 and 3).

The latter structure allows the employer to extract the most information about the worker in just two time periods. However, switching a job 1 worker to job 3 promises the same expected job 3 output as hiring a completely new worker for the job. Also, by letting a worker work his way through job 1 to 3, the employer gets more observations and hence a better estimate of the worker's skills.

A job ladder hence provides the employer with a more thorough candidate screening, but it also takes more time. A job rotation programm, by contrast, is a speedier way to collect some information about aspiring managers, though at the cost of possibly getting a very low performance of workers in job 3.

This cost can however be mitigated if the employer has better information about workers before hiring them for a job rotation program. Supposing workers can signal their skills through education, previous work, extracurricular activities and so on, workers with good signals from various fields therefore seem to be more likely to be selected into job rotation schemes, such as, for example, high-profile trainee programs.[9]

Of course, the analysis in this paper also neglects a second aspect that may play an important role here, namely that the structuring of a career path also affects the learning process of the employee. This aspect is analyzed in Gibbons and Waldman (2004), who introduce task-specific human capital that is acquired through learning by doing.[10] Reallocating workers to similar jobs, i.e., specialization, hence makes the most efficient use of this capital. However, for a manager it may be more important to be somewhat knowledgeable in several fields than being an expert in just one, which would explain the existence of job rotation.

So which of these two explanations - learning by the employer or learning by the employee - goes the longer way in explaining why firms adopt job rotation practices? The papers by Ortega (2001) and Eriksson

[9]This would correspond to the results of the studies by Campion, Cheraskin, and Stevens (1994) and Kusunoki and Numagami (1998) which both suggest that rotation may be good for a worker's career and possibly is used to generate the promotion pool for new managers.

[10]Note that this is an important difference to the present model, where workers' skill levels are given from the outset and at best may be improved through learning by doing.

and Ortega (2006) try to shed light on exactly this question.[11] While they find evidence that both employer and employee learning may play a role, the evidence for the former seems slightly stronger. In particular the authors find that tenure in the firm has a significant negative effect on rotation, whereas tenure in the industry does not, thus suggesting that rotation is rather a means to get to know the employee than a training device. Furthermore, firms with more hierarchy levels and broader recruiting strategies, as well as growing firms, are more likely to adopt job rotation, all of which supports the employer learning hypothesis.

IV.6. Conclusion

The paper proposed a simple task assignment model with multidimensional skills and derived conditions, under which the employer can increase output by reallocating workers. However, there is a potential tradeoff between short-term output maximization and learning about the employee's skills. If one task is sufficiently important then the employer may be interested in choosing workers for this task in a more sophisticated way. For instance, he can get more information on these workers by first assigning them to another task with lower expected output, thus reducing his short-run expected output for the sake of making a more informed choice in the future.

While this first part of the paper thus looked at the optimal assignment of a given worker if the employer is free to assign him to any task he sees fit, the second part considered a setting where the employer has to fill a given job with a worker which he may choose from within or outside the firm. In such a setting, workers may get reassigned to another job even if, in expectation, they will be less productive after reassignment. This simply arises because employers prefer to reallocate workers on whom they have some information rather than hire completely new workers on the market.

[11] Ortega (2001) and Eriksson and Ortega (2006) also identify a third motive for job rotation, namely motivating employees by mitigating boredom. However, they find little evidence in support of this motive.

The paper thus provides a new explanation for the Peter Principle: workers may indeed get reallocated in such a way that, in the end, they are actually less suited for their current than for their previous job. However, this policy is efficient, since the employer otherwise has to fill his open positions with new applicants on whom he has less information than on his current workers. The Peter Principle thus arises as a by-product of insufficient knowledge about outside candidates and its relevance varies with the availability of information on workers.

Whether this effect plays a role therefore depends crucially on the transparency of the relevant labor market. The transparency of the labor market, in turn, and hence the information available on candidates depends on market structures, the degree of competition and the availability of reliable signals on workers' capabilities. While these aspects are beyond the current model, it may be interesting to explore them further.

Appendix A

A.1. Authority Structures and Utility Levels

A.1.1. Principal's Utility

Area I: follows directly from Table II.1.

Area II: The expected utility[1] under P-authority can be rewritten as

$$E[u_P^{II}] = E[u_A^{II}] + q_P[\bar{\beta}B - c_P - q_A(B - c_P)]\ .$$

The second term is greater than zero since in area II $q_A < (\bar{\beta}B - c_P)/(B - c_P)$ holds. Hence the principal gets higher expected utility under P-authority.

Area III: The expected utility under A-authority can be rewritten as

$$E[u_A^{III}] = E[u_P^{III}] + (1 - q_A)q_P(\bar{\beta}B - c_P)\ .$$

Since the second term is greater than zero, the principal gets higher expected utility under A-authority.

Area IV: Rewrite the expected utilities as follows:

$$\begin{aligned} E[u_A^{IV}] &= q_A(B - c_P) + q_P(\bar{\beta}B - c_P) - q_A q_P(\bar{\beta}B - c_P) \\ E[u_P^{IV}] &= q_A(B - c_P) + q_P(\bar{\beta}B - c_P) - q_A q_P(B - c_P)\ . \end{aligned}$$

[1]To keep notation short, in this section only, the lower index indicates who has the authority to initiate a project. While this is quite an abuse of notation since, originally, the lower index indicates whose utility we are talking about, we still use this notation here for the sake of shortness.

By Assumption 1, we know that $B - c_P > \bar{\beta}B - c_P$. Hence the expected utility under A-authority is higher.

Area V: Consider the expected utility under P-authority:

$$E[u_P^V] = q_A(B - c_P) > \bar{\beta}B - c_P \ ,$$

since $q_A > (\bar{\beta}B - c_P)/(B - c_P)$ in area V. Compare this to the expected utility under A-authority:

$$E[u_A^V] = q_P(\bar{\beta}B - c_P) \ .$$

Since $q_P \leq 1$, the expected utility under P-authority is higher or at least as high as under A-authority.

Area VI:The expected utility under P-authority can be rewritten as

$$E[u_P^{VI}] = E[u_A^{VI}] + (1 - q_P)q_A(B - c_P) \ .$$

Since the last term is greater than zero, the expected utility under P-authority is higher.

A.1.2. Agent's Utility

Area I: follows directly from Table II.2.

Area II: The expected utility under P-authority can be rewritten as

$$E[u_P^{II}] = E[u_A^{II}] + q_P[b - c_A - q_A(\bar{\alpha}b - c_A)] \ .$$

If the term in square brackets is greater than zero, the agent's expected utility is higher under P-authority, i.e. if

$$\begin{aligned} b - c_A - q_A(\bar{\alpha}b - c_A) &> 0 \\ \frac{b - c_A}{\bar{\alpha}b - c_A} &> q_A \end{aligned}$$

By Assumption 1, we know that $b - c_A > \bar{\alpha}b - c_A$, and hence that the left hand side is greater than one, whereas the right hand side cannot be greater than one since q_A is a probability. Therefore the inequality is fulfilled, and we have shown that the agent's expected utility under P-authority is higher.

Area III: The expected utility under A-authority can be rewritten as

$$\begin{aligned} E[u_A^{III}] &= E[u_P^{III}] + (1-q_A)q_P(b-c_A) + (1-q_A)(1-q_P)(-c_A) \\ &= E[u_P^{III}] + (1-q_A)[q_P b - c_A] \, . \end{aligned}$$

Since $q_P > c_A/b$ in area III, the last term in square brackets is greater than zero. Therefore the expected utility under A-authority is higher.

Area IV: Rewrite the expected utilities as follows:

$$\begin{aligned} E[u_A^{IV}] = q_P(b-c_A) + q_A(\bar{\alpha}b - c_A) - q_A q_P(b-c_A) - (1-q_A)(1-q_P)c_A \\ E[u_P^{IV}] = q_P(b-c_A) + q_A(\bar{\alpha}b - c_A) - q_A q_P(\bar{\alpha}b - c_A) \, . \end{aligned}$$

By assumption 1, we know that $b - c_A > \bar{\alpha}b - c_A$. Hence the expected utility under P-authority is higher.

Area V: Consider the expected utility under A-authority:

$$E[u_A^V] = q_P b - c_A > \bar{\alpha}b - c_A \, ,$$

since $q_P > \bar{\alpha}$ in area V. Compare this to the expected utility under P-authority:

$$E[u_P^V] = q_A(\bar{\alpha}b - c_A) \, .$$

Since $q_A \leq 1$, the expected utility under A-authority is higher or at least as high as under P-authority.

Area VI: The agent prefers P-authority if

$$\begin{aligned} q_P(b-c_A) + (1-q_P)q_A(\bar{\alpha}b - c_A) &> q_P b - c_A \\ -q_P c_A + (1-q_P)q_A(\bar{\alpha}b - c_A) &> -c_A \\ (1-q_P)c_A + (1-q_P)q_A(\bar{\alpha}b - c_A) &> 0 \\ c_A + q_A(\bar{\alpha}b - c_A) &> 0 \, . \end{aligned}$$

Since the term in brackets is positive, the inequality is fulfilled, and hence the agent prefers P-authority.

A.2. Reversing the Game Structure - Payoffs

A.2.1. Payoffs for A-authority over project choice

If the agent has both the authority to initiate and to implement a project, the players' ex ante expected payoffs are:

Case AA1: $q_P > \frac{\bar{\alpha}b-c_A}{b-c_A}$

$$\begin{aligned} E[u_A] &= q_P(b-c_A) \\ E[u_P] &= q_P(\bar{\beta}B-c_P)\ . \end{aligned}$$

Case AA2: $q_P < \frac{\bar{\alpha}b-c_A}{b-c_A}$

$$\begin{aligned} E[u_A] &= q_A(\bar{\alpha}b-c_A)+(1-q_A)q_P(b-c_A) \\ E[u_P] &= q_A(B-c_P)+(1-q_A)q_P(\bar{\beta}B-c_P) \end{aligned}$$

A.2.2. Payoffs for P-authority over project choice

If the principal has the authority to initiate a project and the agent has the authority to implement it, the players' ex ante expected payoffs are:

Case PA1: $q_A \leq \underline{\beta}$

$$\begin{aligned} E[u_A] &= q_P(b-c_A) \\ E[u_P] &= q_P(\bar{\beta}B-c_P) \end{aligned}$$

Case PA2: $\underline{\beta} < q_A \leq c_P/B$ The payoff matrix and the ex ante expected payoffs in this case are identical to the previous one.

Case PA3: $c_P/B < q_A \leq \bar{\beta}$

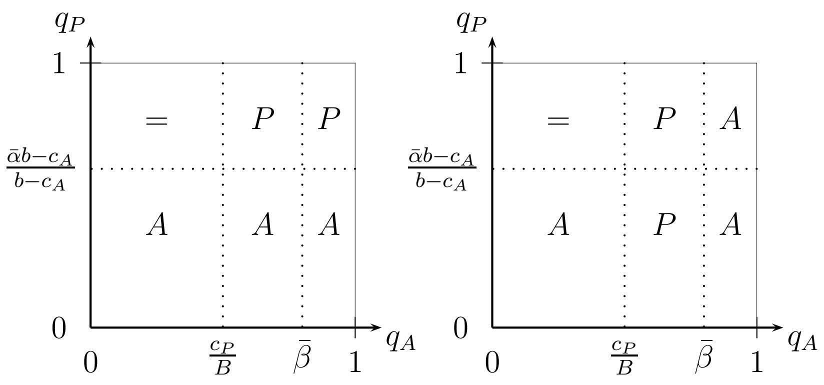
$$\begin{aligned} E[u_A] &= q_P(b-c_A)+(1-q_P)q_A(\bar{\alpha}b-c_A) \\ E[u_P] &= q_P(\bar{\beta}B-c_P)+(1-q_P)q_A(B-c_P)+(1-q_P)(1-q_A)(-c_P) \end{aligned}$$

Case PA4: $\bar{\beta} < q_A$

$$\begin{aligned} E[u_A] &= q_A(\bar{\alpha}b-c_A) \\ E[u_P] &= q_AB-c_P \end{aligned}$$

We then have to compare the respective expected utilities. The results of this comparison are shown in Figure A.1.

In order to get a picture that is comparable to Figure II.5, we have to mirror both graphs along the diagonal. We then get Figure II.7.



(a) Principal (b) Agent

Figure A.1: Preferred authority structure by areas when A draws last

A.3. Endogenizing the Game Structure - Principal's preferences

Case 1: $\tilde{q}_P < c_A/b$

Let us start with the area where $q_P < \tilde{q}_P$. Here, we have to compare PP-authority (cases I and II) with AA-authority (VII, VIII and IX). P's utility in the latter case is

$$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P) \ , \tag{A.1}$$

which is always greater than P's utility in case I as given by

$$q_A(B - c_P) \ . \tag{A.2}$$

It is also greater than P's utility in case II as given by

$$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P) \ . \tag{A.3}$$

To see this take the difference between (A.1) and (A.3) which is

$$q_A q_P[(B - c_P) - (\bar{\beta}B - c_P)] \ .$$

By assumption 1, the term in square brackets is positive, and hence (A.1) is greater than (A.3). Therefore the principal prefers AA-authority for $q_P < \tilde{q}_P$.

Next, we have a look at P's preferences for $\tilde{q}_P < q_P < c_A/b$. Here we are comparing PP-authority (cases I and II) with PA-authority (cases

X,XI and XII). It is easy to see that (A.2) is bigger than P's utility in case X as given by

$$q_A B - c_P \ , \tag{A.4}$$

i.e., PP-authority is better. In case XI, P gets

$$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P) + (1 - q_P)(1 - q_A)(-c_P) \ . \tag{A.5}$$

Taking the difference between I and XI we get

$$q_P[q_A(B - c_P) - (\bar{\beta}B - c_P)] + (1 - q_P)(1 - q_A)c_P \ ,$$

which divided by $(B - c_P)$ equals

$$q_P[q_A - \tilde{q}_A] + (1 - q_P)(1 - q_A)\frac{c_P}{B - c_P} \ .$$

Since the comparison between I and XI is only relevant for $\bar{\beta} > q_A > \tilde{q}_A$, the term in square brackets is positive, and hence also the difference between I and XI, i.e., PP-authority is better. In case XII, P gets

$$q_P(\bar{\beta}B - c_P) \ . \tag{A.6}$$

Again subtracting this from P's utility in case I and dividing by $(B - c_P)$ we get

$$q_A - q_P\tilde{q}_A \ .$$

Since the comparison between I and XII is only relevant if $c_P/B > q_A > \tilde{q}_A$ and $q_P \leq 1$, this expression is positive and hence utility in case I is bigger than in XII, i.e., PP-authority is better.

Now let us compare case II with cases X to XII. Taking the difference between II as given by (A.3) and X as given by (A.4), we get

$$q_P\Big[(\bar{\beta}B - c_P) - q_A(B - c_P)\Big] + (1 - q_A)c_P \ .$$

Dividing this by $B - c_P$ we get

$$q_P\Big[\tilde{q}_A - q_A\Big] + (1 - q_A)\frac{c_P}{B - c_P} \ .$$

Since the comparison between II and X is only relevant if $\tilde{q}_A > q_A > c_P/B$, the term in square brackets is positive and utility in II is higher than in X, i.e., PP-authority is better. The difference between case II and XI as described by (A.5) is given by

$$(1 - q_P)(1 - q_A)c_P \ ,$$

which is positive, i.e., utility in II is higher than in XI and PP-authority is preferable from the principal's point of view. Finally, it is straightforward to see that utility in II is higher than in XII (cf. (A.6)). So we have shown that for $\tilde{q}_P < q_P < c_A/b$ P prefers PP-authority.

Now, when $c_A/b < q_P < \bar{\alpha}$, we have to compare AP-authority (cases III and IV) with PA-authority (cases X, XI and XII). In cases III and IV, the principal gets

$$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P) \ . \tag{A.7}$$

It is easy to see that this is bigger that (A.4), P's utility in case X. Utility under AP-authority is also higher when comparing to case XI. Let us take the difference between the (A.7) and (A.5), which is

$$q_A q_P[(B - c_P) - (\bar{\beta}B - c_P)] + (1 - q_P)(1 - q_A)c_P \ .$$

By Assumption 1 the term in square brackets is positive and hence P's utility under AP-authority is higher. The same is true when comparing to case XII: The difference between (A.7) and (A.6) is

$$q_A[(B - c_P) - (\bar{\beta}B - c_P)] \ ,$$

which again by Assumption 1 is positive. We therefore get that P prefers AP-authority over PA-authority when $c_A/b < q_P < \bar{\alpha}$.

Finally, when $\bar{\alpha} < q_P$, we have to compare PP-authority(cases V and VI) to PA-authority (cases X to XII). P's utility in case V is

$$q_A(B - c_P) \ , \tag{A.8}$$

which is obviously greater than (A.4), P's utility in case X. Next, consider the difference between utility in case V (cf. (A.8))and case XI (cf. (A.5)):

$$q_P[(B - c_P) - (\bar{\beta}B - c_P)] + (1 - q_P)(1 - q_A)c_P \ .$$

By Assumption 1 the term in square brackets is greater than zero and therefore utility in case V is higher. Also, P's utility in case V is higher than in case XII (cf. (A.6)). To see this, consider the difference between the two

$$q_A(B - c_P) - q_P(\bar{\beta}B - c_P) = q_A - q_P\tilde{q}_A \; .$$

The comparison between V and XII is only relevant when $c_P/B > q_A > \tilde{q}_A$. Therefore the above expression is positive and utility in case V is higher.

P's utility in case VI is

$$q_P(\bar{\beta}B - c_P) + (1 - q_P)q_A(B - c_P) \; , \tag{A.9}$$

which is obviously greater than (A.5), P's utility in case XI, and (A.6), P's utility in case XII. So we only have to check whether case VI is more advantageous for P than case X (cf.(A.4)). Subtracting X from VI, we get

$$q_P[(\bar{\beta}B - c_P) - q_A(B - c_P)] + (1 - q_A)c_P \; ,$$

which after dividing by $(B - c_P)$ is equivalent to

$$q_P[\tilde{q}_A - q_A] + (1 - q_A)\frac{c_P}{B - c_P} \; .$$

Since the comparison between VI and X is only relevant if $\tilde{q}_A > q_A > \bar{\beta}$, the expression in square brackets is positive and hence utility in case VI is higher. Therefore for $\bar{\alpha} < q_P$, P overall prefers PP-authority over PA-authority.

Case 2: $c_A/b < \tilde{q}_P < \bar{\alpha}$

For $q_P < c_A/b$, we have to compare PP-authority (cases I and II) with AA-authority (cases VII, VIII and IX). As shown above, P prefers AA-authority under these circumstances.

For $c_A/b < q_P < \tilde{q}_P$, we have to compare AP-authority (cases III and IV) with AA-authority (cases VII, VIII and IX). It turns out that P's expected utility in all these cases is the same, namely

$$q_A(B - c_P) + (1 - q_A)q_P(\bar{\beta}B - c_P) \; ,$$

so that the principal is indifferent between these two authority structures.

For $\tilde{q}_P < q_P < \bar{\alpha}$, we have to compare AP-authority (cases III and IV) with PA-authority (cases X, XI and XII). As we have seen in the last subsection, the principal prefers AP-authority.

Finally, for $\bar{\alpha} < q_P$, we compare PP-authority (cases V and VI) with PA-authority (cases X, XI and XII). This comparison has also already been made above, and we have seen that the principal prefers PP-authority.

Appendix B

B.1. Proof of Proposition 1

The principal in sector i who wants to hire an agent j faces the following maximization problem:

$$\max_{w_{ij},t_{ij},m_i} \pi_{ij} = q + (\Delta q - m_i t_{ij})(m_i t_{ij} + \theta_{ij})\frac{1}{a} - w_{ij} - M(m_i) \ ,$$

subject to

$$\begin{array}{rl} (LL) & w_{ij} \geq \underline{w} \ , \\ (PC) & u_{ij} = (m_i t_{ij} + \theta_{ij})^2/(2a) + w_{ij} \geq \bar{u}_j \ . \end{array}$$

Let λ_{LL} and λ_{PC} be the respective Lagrange multipliers of the two constraints for the modified optimization problem stated above. The resulting Lagrangian is

$$\begin{aligned} \max_{w_{ij},m_i,t_{ij},\lambda_{LL},\lambda_{PC}} \quad & L = q + (\Delta q - m_i t_{ij})(m_i t_{ij} + \theta_{ij})\frac{1}{a} - w_{ij} - M(m_i) \\ & + \ \lambda_{LL}(w_{ij} - \underline{w}) + \lambda_{PC}(w_{ij} + (m_i t_{ij} + \theta_{ij})^2/(2a) - \bar{u}_j) \ , \end{aligned}$$

and the corresponding first-order conditions are

$$
\begin{aligned}
\frac{\partial L}{\partial w_{ij}} &= -1 + \lambda_{LL} + \lambda_{PC} \leq 0 \;, && \text{(B.1)}\\
\frac{\partial L}{\partial t_{ij}} &= \frac{m_i}{a}[\Delta q - 2m_i t_{ij} - \theta_{ij} + \lambda_{PC}(m_i t_{ij} + \theta_{ij})] \leq 0 \;, && \text{(B.2)}\\
\frac{\partial L}{\partial m_i} &= \frac{t_{ij}}{a}[\Delta q - 2m_i t_{ij} - \theta_{ij} + \lambda_{PC}(m_i t_{ij} + \theta_{ij})] \\
&\quad - M'(m_i) \leq 0 \;, && \text{(B.3)}\\
\frac{\partial L}{\partial \lambda_{LL}} &= w_{ij} - \underline{w} \geq 0 \;, && \text{(B.4)}\\
\frac{\partial L}{\partial \lambda_{PC}} &= w_{ij} + (m_i t_{ij} + \theta_{ij})^2/(2a) - \bar{u}_j \geq 0 \;, && \text{(B.5)}\\
0 &= \lambda_{LL}(w_{ij} - \underline{w}) \;, && \text{(B.6)}\\
0 &= \lambda_{PC}(w_{ij} + (m_i t_{ij} + \theta_{ij})^2/(2a) - \bar{u}_j) \;, && \text{(B.7)}
\end{aligned}
$$

From (B.1) follows immediately that at least one of the two constraints has to be binding, i.e., it is not possible that $\lambda_{LL} = \lambda_{PC} = 0$. Indeed, if both $\lambda_{LL} = \lambda_{PC} = 0$, (B.1) implies that the profit of the principal could be increased by reducing w_{ij} to its minimum legal level $\underline{w}$, a contradiction with $\lambda_{LL} = 0$.

Furthermore, if (B.2) is binding, then (B.3) cannot be, unless $m_i = t_{ij} = 0$. The first-order condition with respect to m is always smaller or equal to zero, (i.e., $\frac{\partial L}{\partial m_i} \leq 0$) so that the principal wants to set m as low as possible. We deduce that $m_i^* = \underline{m}$ if extrinsic incentives for effort are needed and $m_i^* = 0$ if no such incentives are needed.

We then get three cases:

Case I: (LL) binding, (PC) not binding

If the (LL) constraint is binding then $\lambda_{LL} > 0$ and $w_{ij} = \underline{w}$. If the (PC) is not binding then $\lambda_{PC} = 0$. By assumption 3, namely that $\Delta q^2 \geq 4aM(\underline{m})$, the principal always wants to induce some effort from the worker. Extrinsic incentives are necessary only if θ_{ij} is small. To be more specific, from (B.2) it follows that $m_i t_{ij} = \max\{0, (\Delta q - \theta_{ij})/2\}$ is optimal.

The principal's payoff then is

$$\pi^I_{ij} = q - \underline{w} + \begin{cases} \frac{1}{a}\Delta q\theta_{ij} & \text{if } \Delta q < \theta_{ij} \\ \frac{1}{a}\left(\frac{\Delta q+\theta_{ij}}{2}\right)^2 - M(\underline{m}) & \text{if } \Delta q \geq \theta_{ij} \end{cases} ,$$

and the agent's payoff is

$$u_{ij} = \underline{w} + \frac{1}{2a}\begin{cases} \theta^2_{ij} & \text{if } \Delta q < \theta_{ij} \\ (\Delta q + \theta_{ij})^2/4 & \text{if } \Delta q \geq \theta_{ij} \end{cases} ,$$

In the limit, if the agent's reservation utility is equal to this payoff, his reservation utility becomes binding. This is true if $\bar{u}_j = \underline{v}(\theta_{ij})$ where

$$\underline{v}(\theta_{ij}) \equiv \frac{1}{2a}\Big(max\{0, (\Delta q - \theta_{ij})/2\} + \theta_{ij}\Big)^2 + \underline{w} \ .$$

This means that Case I is only relevant when the agent's reservation utility is $\bar{u}_j \in [0, \underline{v}(\theta_{ij})]$.

Case II: (LL) binding, (PC) binding

If the (LL) constraint is binding ($\lambda_{LL} > 0$), then $w_{ij} = \underline{w}$. If the (PC) is also binding ($\lambda_{PC} > 0$), then from (B.5) follows that $m_i t_{ij} = \sqrt{2a(\bar{u}_j - \underline{w})} - \theta_{ij}$ is optimal. For this to be a solution, it is necessary that $m_i t_{ij} \geq 0$ which is equivalent to $\bar{u}_j \geq \underline{w} + \frac{\theta^2_{ij}}{2a}$. The agent's payoff is by construction

$$u_{ij} = \bar{u}_j \ .$$

The principal's payoff is

$$\pi^{II}_{ij} = q - \underline{w} + \frac{1}{a}\Big(\Delta q + \theta_{ij} - \sqrt{2a(\bar{u}_j - \underline{w})}\Big)\sqrt{2a(\bar{u}_j - \underline{w})} - M(\underline{m}) \ .$$

It is easy to check that $\pi^I_{ij} = \pi^{II}_{ij}$ if $\bar{u}_j = \underline{v}(\theta_{ij})$.

Case III: (LL) not binding, (PC) binding

If the (PC) constraint is binding ($\lambda_{PC} > 0$), then $w_{ij} = \bar{u}_j - (m_i t_{ij} + \theta_{ij})^2/(2a)$.

If the (LL) constraint is not binding ($\lambda_{LL} = 0$), then $w_{ij} > \underline{w}$. This implies in (B.1) an interior solution so that $\lambda_{PC} = 1$. We deduce that if

$m_i = \underline{m} > 0$, by (B.2), we get $m_i t_{ij} = \Delta q$. Plugging that into the participation constraint which is binding we get $w_{ij} = \bar{u}_j - (\Delta q + \theta_{ij})^2/(2a)$.

Note that for this it has to hold that $\bar{u}_j - (\Delta q + \theta_{ij})^2/(2a) > \underline{w} > 0$. That is, Case III is only relevant for agents with a reservation utility above

$$\tilde{v}(\theta_{ij}) \equiv \frac{1}{2a}(\Delta q + \theta_{ij})^2 + \underline{w} \ .$$

The principal's payoff then is

$$\pi_{ij}^{III} = q - \left[\bar{u}_j - \frac{1}{2a}(\Delta q + \theta_{ij})^2\right] - M(\underline{m}) \ ,$$

which, under the assumption that $\Delta q^2 \geq 4aM(\underline{m})$, is higher than the profit achieved without monitoring (i.e., without extrinsic incentives $\pi_{ij} = q - [\bar{u}_j - \frac{1}{2a}(\theta_{ij})^2]$). The agent's payoff is by construction

$$u_{ij} = \bar{u}_j \ .$$

The principal's payoff from case III becomes negative if the agent's outside utility exceeds

$$\bar{v}(\theta_{ij}) \equiv \frac{1}{2a}(\Delta q + \theta_{ij})^2 + q - M(\underline{m}) \ .$$

Finally comparing π_{ij}^{II} with π_{ij}^{III} it is easy to check that $\pi_{ij}^{II} = \pi_{ij}^{III}$ iff $\bar{u}_j = \tilde{v}(\theta_{ij})$. The principal prefers Case III over Case II whenever the agent's outside utility exceeds $\tilde{v}(\theta_{ij})$.

This means that Case III is relevant when the agent's reservation utility is $\bar{u}_j \in [\tilde{v}(\theta_{ij}), \bar{v}(\theta_{ij})]$, that case II is relevant when the agent's reservation utility is $\bar{u}_j \in [\underline{v}(\theta_{ij}), \tilde{v}(\theta_{ij})]$, and that Case I is relevant when the agent's reservation utility is $\bar{u}_j \in [0, \underline{v}(\theta_{ij})]$.

To finish the proof, we have to make sure that the principal's payoff from each scenario is positive. For this, $q - \underline{w} - M(\underline{m}) > 0$ is a sufficient assumption. It also ensures that $\underline{v}(\theta_{ij}) \leq \tilde{v}(\theta_{ij}) \leq \bar{v}(\theta_{ij})$. QED

B.2. Calculating the Level of Automatic Deterrence in N

In order to calculate the level of automatic deterrence in N, $\tilde{\tilde{\theta}}_b$, we have to insert the relevant contracts both in sector N and F into (III.8). This

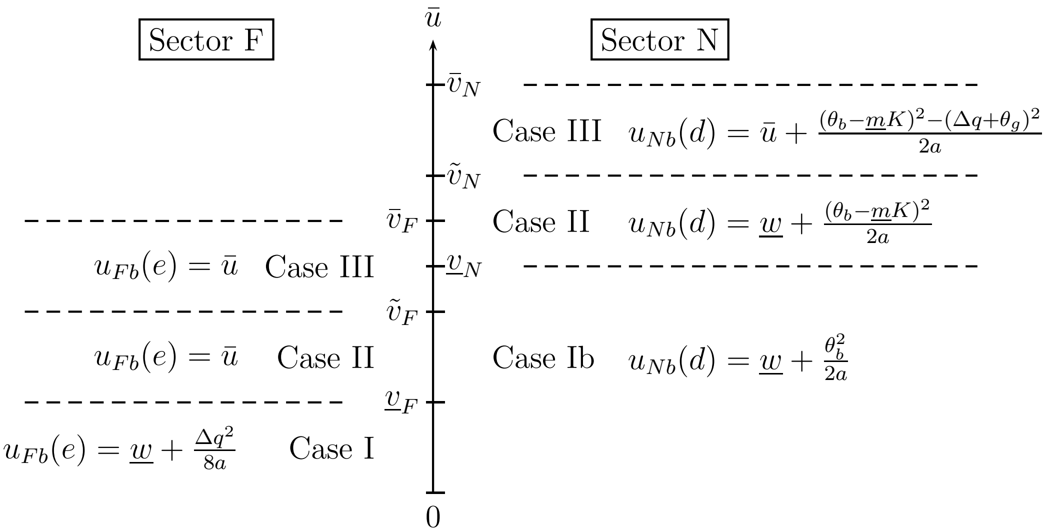


Figure B.1: Bad workers' utility from positive effort in F (i.e., $u_{Fb}(e)$) and negative effort in N (i.e., $u_{Nb}(d)$) for $\theta_g > \Delta q$.

is equivalent to comparing the utility of a bad worker from effort e in F with his utility from effort d in N.

Let us first consider the case where $\theta_g > \Delta q$. Depending on the level of reservation utility of the agents, Figure B.1 indicates which of the cases derived in Corollaries 1 and 2 is relevant in each sector and summarizes the resulting utility levels $u_{Nb}(d)$ and $u_{Fb}(e)$ that can be achieved by bad workers. We then have to compare each possible combination of utility levels in order to determine the relevant level of automatic deterrence. For instance, Case Ib in sector N overlaps with cases I, II and III in sector F. If we insert the relevant values for m_N, t_N, w_N as well as m_F, t_F, w_F into (III.7), we find that $\tilde{\tilde{\theta}}_b = \Delta q/2$ if $\bar{u} < \underline{v}_F$ and $\tilde{\tilde{\theta}}_b = \sqrt{2a(\bar{u} - \underline{w})}$ if $\underline{v}_F < \bar{u} < \underline{v}_N$.

Similar comparisons have to be made for the remainder of cases, as well as for a setting where $\theta_g < \Delta q$.

B.3. Proof of Proposition 2

The solution to the principal's maximization problem with full deterrence of bad workers is similar to the solution in the benchmark model. We can formulate the following Lagrangian:

$$
\begin{aligned}
\max_{w_F, m_F, \lambda_{LL}, \lambda_{PC}} \quad & L(w_F, m_F, \lambda_{LL}, \lambda_{PC}) \\
= \quad & q + (\Delta q - \theta_b + m_F K) \cdot \frac{\theta_b - m_F K}{a} - w_F - M(m_F) \\
+ \quad & \lambda_{LL}(w_F - \underline{w}) + \lambda_{PC}\Big(w_F + \frac{(\theta_b - m_F K)^2}{2a} - \bar{u}_j\Big) ,
\end{aligned}
$$

The corresponding first-order conditions are

$$
\begin{aligned}
\frac{\partial L}{\partial w_F} &= -1 + \lambda_{LL} + \lambda_{PC} = 0 , && \text{(B.8)} \\
\frac{\partial L}{\partial m_F} &= \frac{K}{a}[2\theta_b - 2m_F K - \Delta q] - M'(m_F) \\
&\quad +\lambda_{PC}\frac{K}{a}(\theta_b - m_F K) . && \text{(B.9)}
\end{aligned}
$$

Furthermore it has to hold that

$$
\begin{aligned}
0 &= \lambda_{LL}(w_F - \underline{w}) && \text{(B.10)} \\
0 &= \lambda_{PC}(w_F + (\theta_b - m_F K)^2/(2a) - \bar{u}_j) . && \text{(B.11)}
\end{aligned}
$$

As before, we get three cases:

Case I: (LL) binding, (PC) not binding

If the limited liability constraint is binding, $\lambda_{LL} > 0$, and given condition (B.10) it follows immediately that the optimal basic wage in case I $w^I = \underline{w}$. If the (PC) is not binding, then $\lambda_{PC} = 0$. Hence, from condition (B.9) it follows that the optimal monitoring level m_F^I has to be such that

$$2\theta_b - \Delta q = \frac{a}{K} M'(m_F) + 2m_F K .$$

Case II: (LL) and (PC) binding

If both conditions are binding, then $\lambda_{LL} > 0$ and $\lambda_{PC} > 0$. Again, by condition (B.10) we therefore have that the optimal wage in case II $w^{II} = \underline{w}$. Furthermore, condition (B.11) is fulfilled iff

$$m_F^{II} = \frac{\theta_b - \sqrt{2a(\bar{u} - \underline{w})}}{K} .$$

Case III: (LL) not binding, (PC) binding

Since the limited liability constraint is not binding, $\lambda_{LL} = 0$ and hence by (B.8) $\lambda_{PC} = 1$. Inserting this in (B.9), we get that the monitoring level in case III m_F^{III} has to be such that the following holds:

$$\theta_b - \Delta q = \frac{a}{K} M'(m_F) + m_F K \ .$$

Furthermore, since the participation constraint is binding the optimal basic wage is

$$w_F^{III} = \bar{u} - \frac{(\theta_b - m_F^{III} K)^2}{2a} \ .$$

In all three cases $k = I, II, III$ the optimal transfer level t_F^k is calculated as

$$t_F^k = \frac{\theta_b - m_F^k K}{\underline{m}} \ .$$

This is due to the fact that the deterrence constraint $m_F t_F = \theta_b - m_F K$ is binding.

Having calculated these three solutions, the question is, when each of them is relevant, i.e., we have to calculate the critical values of the agent's outside utility delimiting the above three cases $\underline{v}_{Fb}$, $\tilde{v}_{Fb}$ and $\bar{v}_{Fb}$.

Let us start with $\underline{v}_{Fb}$ which is defined as the outside utility for which the participation constraint of the agents becomes binding. That is

$$(\theta_b - m_F^I K)^2/(2a) + w_F^I = \bar{u}_j \ ,$$

has to hold, and hence $\underline{v}_{Fb}$ is defined as

$$\underline{v}_{Fb} \equiv (\theta_b - m_F^I K)^2/(2a) + \underline{w} \ .$$

Recall that $\underline{v}_F = (m_F^* t_F^*)^2/(2a) + \underline{w}$ and that $(\theta_b - m_F^I K) > m_F^* t_F^*$ since $\theta_b > \tilde{\theta}_b$. Therefore $\underline{v}_{Fb} > \underline{v}_F$.

Next, let us consider $\tilde{v}_{Fb}$, which defines the border between case II and III. Case III is only relevant if $\bar{u}_j - (\theta_b - m_F^{III} K)^2/(2a) > \underline{w} > 0$. That is, Case III is only relevant for agents with a reservation utility above

$$\tilde{v}_{Fb} \equiv \frac{1}{2a}(\theta_b - m_F^{III} K)^2 + \underline{w} \ .$$

For outside values above this one, case III holds. Note that the limited liability constraint is trivially fulfilled if $\bar{u} > \tilde{v}_{Fb}$. Again, since we consider only cases where $\theta_b > \tilde{\theta}_b$ and hence $(\theta_b - m_F^{III}K) > m_F^* t_F^*$, we get that $\tilde{v}_{Fb} > \tilde{v}_F$.

Finally, $\bar{v}_{Fb}$ is defined as the outside utility of the agent for which the principal's profit in case III becomes zero, i.e., for which $\pi_F^{III} = 0$. That is:

$$\begin{aligned} \bar{v}_{Fb} &\equiv q + \frac{1}{2a}(\theta_b - m_F^{III}K)^2 - M(m_F^{III}) \\ &+ (\Delta q - \theta_b + m_F^{III}K)(\theta_b - m_F^{III}K)\frac{1}{a} , \end{aligned}$$

where m_F^{III} is such that

$$\theta_b - \Delta q = \frac{a}{K} M'(m_F) + m_F K .$$

The derivative of $\bar{v}_{Fb}$ with respect to θ_b is given as

$$\begin{aligned} \frac{d\bar{v}_{Fb}}{d\theta_b} &= \frac{\partial \bar{v}_{Fb}}{\partial \theta_b} + \frac{\partial \bar{v}_{Fb}}{\partial m_F^{III}} \cdot \frac{\partial m_F^{III}}{\partial \theta_b} \\ &= \frac{1}{a}(\Delta q - \theta_b + m_F^{III}) \\ &- \left[\frac{K}{a}(\Delta q - \theta_b + m_F^{III}K) + M'(m_F^{III})\right] \frac{1}{K + M''(m_F^{III})} . \end{aligned}$$

This expression is smaller than zero if

$$(\Delta q - \theta_b + m_F^{III}) M''(m_F^{III}) \ \leq \ a M'(m_F^{III}) .$$

We assumed that $M'(m) > 0$ and $M''(m) > 0$. Since we consider only cases where $\theta_b > \tilde{\theta}_b$ it holds that $(\theta_b - m_F^{III}K) > m_F^* t_F^* = \Delta q$. Hence the expression in brackets is negative and the above inequality is fulfilled. We therefore know that $\bar{v}_{Fb}$ is decreasing in θ_b.

How high is $\bar{v}_{Fb}$ relative to $\bar{v}_F$? Recall that

$$\bar{v}_F \ \equiv \ q + \frac{1}{2a}\Delta q^2 - M(\underline{m}).$$

Hence $\bar{v}_{Fb} > \bar{v}_F$ if

$$\begin{aligned} &\frac{1}{2a}[(\theta_b - m_F^{III}K)^2 - \Delta q^2] - M(m_F^{III}) + M(\underline{m}) \\ &\qquad + (\Delta q - \theta_b + m_F^{III}K)(\theta_b - m_F^{III}K)\frac{1}{a} \ > \ 0 . \end{aligned}$$

As we have seen above, $\bar{v}_{Fb}$ is decreasing in θ_b, and the lowest value of θ_b for which case III is actually relevant is $\theta_b = \tilde{\theta}_b = \Delta q + \underline{m}K$. If we plug this into the above inequality, after some simplification we find that $\bar{v}_{Fb} > \bar{v}_F$ if

$$-M(m_F^{III}) + M(\underline{m}) - \frac{K^2}{2a}(m_F^{III} - \underline{m})^2 > 0 \ .$$

Since $m_F^{III} > \underline{m}$ and $M(\cdot)$ is an increasing function of m, the left-hand side of this inequality is negative, and we hence have shown by contradiction that $\bar{v}_{Fb} < \bar{v}_F$ must hold.

B.4. Proof of Proposition 3

The solution of the principal's maximization problem when there are bad workers follows the analysis in the benchmark model when there are only good and regular workers. As we have seen, the principal's maximization problem without full deterrence corresponds to

$$\begin{aligned} \max_{w_F, t_F, m_F} \pi_F = \quad & q \quad - w_F - M(m_F) + (1-\beta_F)(\Delta q - m_F t_F)\frac{m_F t_F}{a} \\ & - \quad \beta_F D(\theta_b - m_F K)\frac{1}{a} \ , \end{aligned}$$

subject to the following constraints

$$\begin{aligned} (LL) \qquad & w_F \geq \underline{w} \ , \\ (PC) \qquad & (m_F t_F)^2/(2a) + w_F \geq \bar{u}_j \ . \end{aligned}$$

Let again λ_{LL} and λ_{PC} be the respective Lagrange multipliers of the two constraints for the modified optimization problem stated above. The resulting Lagrangian is

$$\begin{aligned} \max_{w_F, m_F, t_F, \lambda_{LL}, \lambda_{PC}} \quad & L(w_F, m_F, t_F, \lambda_{LL}, \lambda_{PC}) = q - w_F - M(m_F) \\ + \quad & (1-\beta_F)(\Delta q - m_F t_F)\frac{m_F t_F}{a} - \beta_F D(\theta_b - m_F K)\frac{1}{a} \\ + \quad & \lambda_{LL}(w_F - \underline{w}) + \lambda_{PC}(w_F + (m_F t_F)^2/(2a) - \bar{u}_j) \ , \end{aligned}$$

and the corresponding first-order conditions are

$$
\begin{aligned}
\frac{\partial L}{\partial w_F} &= -1 + \lambda_{LL} + \lambda_{PC} = 0 \ , && \text{(B.12)} \\
\frac{\partial L}{\partial t_F} &= \frac{m_F}{a}[(1-\beta_F)(\Delta q - 2m_F t_F) - \lambda_{PC} m_F t_F] = 0 \ , && \text{(B.13)} \\
\frac{\partial L}{\partial m_F} &= \frac{t_F}{a}[(1-\beta_F)(\Delta q - 2m_F t_F) - \lambda_{PC} m_F t_F] \\
&\quad - M'(m_F) + \frac{\beta_F DK}{a} = 0 \ . && \text{(B.14)}
\end{aligned}
$$

Furthermore, the following has to be true:

$$
\begin{aligned}
0 &= \lambda_{LL}(w_F - \underline{w}) \ , && \text{(B.15)} \\
0 &= \lambda_{PC}(w_F + (m_F t_F)^2/(2a) - \bar{u}_j) \ . && \text{(B.16)}
\end{aligned}
$$

Equation (B.13), i.e. ,the first-order condition with respect to t_F, is fulfilled if the expression in square brackets is equal to zero. This implies that (B.14), the first-order condition with respect to m_F, simplifies to

$$-M'(m_F) + \frac{\beta_F DK}{a} = 0 \ ,$$

and hence the optimal level of monitoring without full deterrence of bad workers is m_F^{nd} is such that $M'(m_F^{nd}) = \beta_F DK/a$.

Note that no other change in extrinsic incentives is needed in order to account for the presence of bad workers. In particular, effort incentives for regular workers can stay at the same level. The further solution of the problem hence runs along the same lines as the proof of Proposition 1, except that the optimal monetary transfer level t_F^{nd} is adapted such that the overall incentives are still the same, i.e., that $m_F^* t_F^* = m_F^{nd} t_F^{nd}$.

Appendix C

Conditional Normal Distributions: General Theorem

How to calculate the conditional expectation of x and z? A nice summary is provided in Greene (2003): Let $\mathbf{x} = (x_1, x_2, \cdots, x_n)'$ be a vector of n random variables with mean vector $\boldsymbol{\mu}$ and covariance matrix $\boldsymbol{\Sigma}$. Let $\mathbf{x_1}$ be any subset of variables, and let $\mathbf{x_2}$ be the remaining variables. Likewise, partition $\boldsymbol{\mu}$ and $\boldsymbol{\Sigma}$ so that

$$\boldsymbol{\mu} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix}$$

and

$$\boldsymbol{\Sigma} = \begin{pmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{pmatrix} .$$

Then the conditional distribution of $\mathbf{x_1}$ given $\mathbf{x_2}$ is normal as well:

$$\boldsymbol{x_1}|\boldsymbol{x_2} \sim N(\mu_{1.2}, \Sigma_{11.2}) ,$$

with

$$\begin{aligned} \mu_{1.2} &= \mu_1 + \Sigma_{12}\Sigma_{22}^{-1}(x_2 - \mu_2) , \\ \Sigma_{11.2} &= \Sigma_{11} - \Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21} \end{aligned}$$

Application to the Production Function

Since all variables in the production function

$$y = ax + bz ,$$

are normally distributed, we can use this theorem.[1] It will be helpful to rewrite everything in matrix notation. The above equation can thus be rewritten as

$$\begin{pmatrix} x \\ z \\ y \end{pmatrix} = \underbrace{\begin{pmatrix} 1 & 0 \\ 0 & 1 \\ a & b \end{pmatrix}}_{\equiv A} \begin{pmatrix} x \\ z \end{pmatrix} .$$

The covariance matrix $\hat{\Sigma}$ of this vector of normally distributed variables is calculated as $A\Sigma A'$,[2] where A is the matrix of constants defined above and Σ is the covariance matrix of x and z, i.e.,

$$\Sigma = \begin{pmatrix} \sigma_x^2 & \sigma_x\sigma_z \\ \sigma_x\sigma_z & \sigma_z^2 \end{pmatrix} .$$

So the covariance matrix of vector $(x, z, y)'$ is given by

$$\hat{\Sigma} = \begin{pmatrix} \sigma_x^2 & \sigma_x\sigma_z & a\sigma_x^2 + b\sigma_x\sigma_z \\ \sigma_x\sigma_z & \sigma_z^2 & a\sigma_x\sigma_z + b\sigma_z^2 \\ a\sigma_x^2 + b\sigma_x\sigma_z & a\sigma_x\sigma_z + b\sigma_z^2 & a^2\sigma_x^2 + b^2\sigma_z^2 + 2ab\sigma_x\sigma_z \end{pmatrix} .$$

So, we have a set of normally distributed variables (x, z, y) with mean vector (μ_x, μ_z, μ_y) and covariance matrix $\hat{\Sigma}$, which we will partition into two subsets, namely in vector $(x, z)'$ and (y). The mean vector and the covariance matrix $\hat{\Sigma}$ are also partitioned accordingly, such that we can rewrite matrix $\hat{\Sigma}$ as

$$\hat{\Sigma} = \begin{pmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{pmatrix} ,$$

where

$$\Sigma_{12} \equiv \begin{pmatrix} a\sigma_x^2 + b\sigma_x\sigma_z \\ a\sigma_x\sigma_z + b\sigma_z^2 \end{pmatrix} ,$$

[1]It is assumed that x and z are normally distributed. Then their weighted sum y is also normally distributed with mean μ_y and variance σ_y^2, which corresponds to Σ_{22} as calculated below.

[2]See Greene (2003), Appendix B.11.

and

$$\Sigma_{22} \equiv \left(\begin{array}{c} a^2\sigma_x^2 + b^2\sigma_z^2 + 2ab\sigma_x\sigma_z \end{array} \right) .$$

Following the above-mentioned theorem, the expectation of x, respectively z, given the observed value of y then is

$$\begin{aligned} E\left[\left(\begin{array}{c} x \\ z \end{array} \right) |y\right] &= \left(\begin{array}{c} \mu_x \\ \mu_z \end{array} \right) + \Sigma_{12}\Sigma_{22}^{-1}(y - \mu_y)) \\ &= \left(\begin{array}{c} \mu_x \\ \mu_z \end{array} \right) + \left(\begin{array}{c} a\sigma_x^2 + b\sigma_x\sigma_z \\ a\sigma_x\sigma_z + b\sigma_z^2 \end{array} \right) \cdot \frac{y - a\mu_x - b\mu_z}{a^2\sigma_x^2 + b^2\sigma_z^2 + 2ab\sigma_x\sigma_z} \end{aligned}$$

This can, in turn, be used to calculate the worker's expected output in the second job, given his performance in the first.

With Independently Distributed Skills

If x, z are independently distributed, their covariance is zero, and the conditional expectation of x and z given y then simplifies to

$$E\left[\left(\begin{array}{c} x \\ z \end{array} \right) |y\right] = \left(\begin{array}{c} \mu_x \\ \mu_z \end{array} \right) + \left(\begin{array}{c} a\sigma_x^2 \\ b\sigma_z^2 \end{array} \right) \left(\begin{array}{c} \frac{1}{a^2\sigma_x^2 + b^2\sigma_z^2} \end{array} \right) (y - a\mu_x - b\mu_z)$$

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Erklärung

Hiermit erkläre ich, dass ich die vorliegende Dissertation selbständig angefertigt und mich keiner anderen als der in ihr angegebenen Hilfsmittel bedient habe. Insbesondere sind alle Stellen, die wï¿½rtlich oder sinngemï¿½ï¿½ aus verï¿½ffentlichten und nicht verï¿½ffentlichten Schriften entnommen sind, als solche kenntlich gemacht.

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