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THREE ESSAYS ON CONTRACT THEORY

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Contents

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Chapter 1

Introduction

In this thesis the reader will find three chapters that analyse two topics related to the Theory of Contracts. The two chapters following the introduction, "Investing in Avoiding the Hold-up Problem" and "Contracting Externalities and Multiple Equilibria in Sectors: Theory and Evidence", apply incomplete contracts theory to study the role that outside opportunities play in investment decisions. The third chapter, "Interaction among Agents with Moral Hazard and Adverse Selection" applies the complete contract approach, with a principal who faces two agents who have private information on the distribution of outcomes related to specific organisational structures and who are willing to exert the minimum degree of effort.

Economic relations, may these be between workers and employers, consumers and producers, borrowers and lenders, have been studied extensively through the Theory of Contracts. The outcomes of these relations are determined by the characteristics of the agents involved, such as their initial knowledge and skills, their talent and ability to learn and the levels of effort they are willing to exert. The outcomes are also determined by the type of good/service they are producing, e.g. whether it is a good that is tailored specifically to only one buyer or it can be made available to a wider market. The production technology also has a bearing as it may require learning and/or a given level of effort from the agents. Another factor is the wider economic environment in which the relations operate. The economic environment affects outside opportunities for the agents: whether they are able to find competition for the services they offer, or conversely to access vacancies in other companies, or to fill vacancies in their own companies with the adequate candidates. The economic environment influences how much agents are willing to invest in the economic relation they are involved in. The outside opportunities offered by the environment have an impact on the bargaining power of the agents inside the firm and the ability of the agents to hold-up their business partners and seek better deals elsewhere. We believe that the incomplete contracts theory is a valid approach to analyse relationships where agents are not able to commit to future actions and payments. This is especially the case in labour relations, where contract renegotiations occur often. Workers have the possibility of holding up their employers. Their threat of strikes is credible, and through them they induce negotiations which may change the initial contracts. Employers often change the terms of the initial contract when for example want to offer a permanent position to a temporary worker, or make adjustments to salary increases or bonuses promised at the beginning of the year.

1.1 Investing in Avoiding the Hold-up Problem

In chapter two we investigate the incentive effects of actively investing in improving outside opportunities. More specifically we investigate employers looking for alternative workers. We focus on two agents who sign an incomplete contract. One of them, the employer, invests in outside opportunities. This investment leads to two conflicting effects. On the one hand, the more the employer invests in searching new alternatives the more she avoids the hold-up problem and strengthens her bargaining power. On the other hand, she also discourages the other agent from investing in the company. The latter, seeing that he can be replaced more easily, believes that his investment becomes more irrelevant. Therefore, he feels expropriated, especially when the potential substitute can recover part of his own initial investment in the project.

There are variables exogenous to the company that can affect outside opportunities and therefore the incentives of the agents. We consider two situations. The first analyses the incentive effects of the flexibility of labour contracts. In many European countries, such as Spain, there have been progressive changes in legislation that allow several forms of temporary contracts. While this might be a useful tool to tackle unemployment, workers' productivity might be negatively affected. We want to analyse whether making workers more replaceable affects their productivity. The results show that the employee feels deprived from the outcome of his effort and has fewer incentives to invest in it. The second situation explores the effects of the availability of outsiders. The degree of availability of alternative candidates is related to the level of unemployment in an economy. We find that the lower the unemployment the less bargaining power the employer has, which motivates the worker to invest in human capital.

1.2 Contracting Externalities and Multiple Equilibria in Sectors: Theory and Evidence

In chapter 3 we study the effects of outside opportunities from another perspective. It focuses on externalities that do not affect production technologies but instead affect transactions.

We consider an economy where the production technology has constant returns to scale, but where in the decentralized equilibrium there are aggregate increasing returns to scale. The result follows from a positive contracting externality among firms. If a company is surrounded by more companies, employees may have opportunities outside their own job. Increasing outside options improve employees' incentives to invest in the presence of ex post renegotiation at the firm level, at no cost: outside opportunities are not used in the equilibrium.

In the model there are no direct or technological externalities across firms. Our theory starts from a simple observation. As the scale of an economy increases, the number of inefficient reallocations of factors increases exponentially. Inefficient reallocations serve as outside options to agents when bargaining for the terms of trade. Although these options do not directly contribute to social welfare, they change agents' incentives to engage in human capital investments. With transaction costs deriving from inefficient ex post bargaining, we find that in the decentralized equilibrium there are generally increasing returns to scale.

If transaction costs matter, outside opportunities present an option value for each of the players. Outside opportunities replicate naturally as the size of the economy expands, but employees' competition to take them remains constant (and nil), since they present a less attractive alternative than staying at their current job.

The main result of the chapter is that the level of interaction between the population of a region and its degree of development are linked to sectorial employment. When the population and/or the level of development in the industrial sectors of the region are low enough, there are multiple equilibria in the level of total sectorial employment. One of these equilibria corresponds to the absence of sectorial activity. On the other hand, if either the scale of the region (in terms of total population) and/or the level of development is large enough, there is a unique employment level equilibrium in the industrial sectors of the region. In the unique equilibrium there is positive industrial activity. This result is a consequence of the reinforcement effect between total activity and incentives to invest inside the firm. In particular, outside activity is shown to relax an incentive compatibility constraint to exert effort of the worker (not asset owner), without affecting the constraint of the manager (asset owner). This asymmetry between the effect of total activity on the two incentive compatibility constraints is due precisely to the fact that the effect works through the outside opportunities.

From the theoretical model we derive an econometrical equation of the evolution of sectorial employment in regions. The model is applied to the Spanish *provincias*. The empirical results are strongly consistent with the multiple equilibria hypothesis. The average sector in Spanish regions has three steady states, two stable and one unstable. One stable steady state is associated with the absence of activity (no sectorial employment). The other stable steady state is associated with a positive employment level, greater than the level of the unstable steady state. We call the estimated unstable steady state the critical mass of the sector. If in a region a shock sets the sectorial employment level below the critical mass, the industry follows a delocation process that ends with the collapse of sectorial employment in the region.

We find moreover that there are significant differences across Spanish regions. The more developed, densely populated regions are found to have a stable steady states with greater sectorial size, and smaller critical sizes. For other sparsely populated and less economically developed regions we find a range for the critical mass of the average sector.

1.3 Interaction among Agents with Moral Hazard and Adverse Selection

In the final chapter we ignore outside opportunities and shift the focus towards the inside of a company and how agents might exploit hidden information and hidden actions. The approach used in this case is based on complete contracts. This framework assumes that all contingencies that may affect a contractual relationship are taken into account in the contract, hence holding-up the other party in the negotiations is no longer a possibility.

The chapter studies the case of a principal who has two projects to delegate to two different agents. She faces a twofold challenge. First, moral hazard, that is, to encourage the best level of effort on each project in order to maximise profits. The second, adverse selection, is related to the organisation of both projects. The principal has to decide whether to place the agents working together or to separate them. This depends on the nature of the projects. There are certain tasks which are better performed by being with other workers doing similar tasks. In this model, when interaction is beneficial, positive synergy arises between the agents. This synergy increases the likelihood of a good outcome. On the other hand, other types of tasks are not benefited or are hindered by interaction, meaning that no positive synergy appears between the agents.

In our model, the principal does not have sufficient knowledge to decide whether the agents will perform better working together or separated. The principal is unsure whether the synergy effect will or will not outweigh the mutual insurance effect. Conversely, the agents, who are specialists in their own field, know precisely what will be the effect on the project of working with someone else, but always want to work together to insure against possible bad outcomes. The principal has to design a contract that gives incentives to the agents to self-select.

The solution to the model is such that the risk given to solve the moral hazard in the possible team organisation for the project is enough to get rid of the adverse selection. In other words, the contract that gives incentives to exert high effort also induces agents to self-select.

Chapter 2

Investing in Avoiding the Hold-Up Problem

There is an employer who actively invests in searching for outside candidates that can recover the investment made by the initial worker. The search affects the incentives of this worker – he feels more dispensable and hence is less willing to invest in the company. The employer needs to find a balance between improving her bargaining position and not giving too many negative incentives to the current worker in her company. Increasing the flexibility of labour contracts results in an employer who finds it easier to hire alternative candidates and hence in a worker who feels more dispensable and less motivated. A lower level of unemployment in the rest of the economy leads to less choice and bargaining power for the employer and a more encouraged worker.

2.1 Introduction

There are economic relations which require complementary investments by the agents. The possibility of renegotiating the initial contract after investments are made and before profits are distributed leads to a problem of incentives. The fear of being held up, that is, that negotiations are broken and no agreement is reached, makes agents underinvest and be less productive. This problem has been investigated by Grout (1984) and by the incomplete contracts theory introduced by Grossman and Hart (1986) and Hart and Moore (1990). In their models, they include outside opportunities, which are an alternative to recover, at least partially, the investment should negotiations between the parties be unsuccessful.

Outside opportunities are relevant and play an important role when agents invest and bargain. For example, we see employees exploring the possibilities of alternative employment at the same time they work for a given firm, and also employers prospecting for potential workers even when they are not actively looking to expand the size of their companies. These investments in outside opportunities are useful from two points of view. The most straight forward is that it provides alternatives if agents do not ultimately reach any agreement. The other is that the availability of outside opportunities allows strengthening the bargaining position.

In more traditional incomplete contracts settings, agents influence their outside options in a more indirect way - an employee, when working in a given company, invests in acquiring a skill which might be useful if he ever decides to move to some other company; a seller creates a product for a given buyer, but he might find alternative buyers interested in the product in case the agreement with the initial buyer is broken.

This article investigates the case of employers looking for alternative workers or sellers undertaking market research to find other potential buyers. They get involved in an *active* search and thus take specific decisions concerning their outside opportunities.

We focus on two agents who sign an incomplete contract, one of whom invests in outside opportunities. This investment has two conflicting effects. On the one hand, the more one agent invests in searching new alternatives the more she avoids the hold-up problem. On the other hand, she also provides negative incentives to the other agent. The latter, seeing that he can be replaced more easily, believes that his investment may be more irrelevant. Therefore, he feels expropriated, especially when the potential substitute can recover part of his own investment in the project.

There are variables exogenous to the company that can affect outside opportunities and therefore the incentives of the agents. We consider two situations. The first analyses the incentive effects of the flexibility of labour contracts. In many European countries there have been progressive changes in legislation that allow several forms of temporary contracts. While this might be a useful tool to tackle unemployment, workers' productivity might be negatively affected. We analyse this question by asking how making workers easier to replaceable affects their productivity. The second, explores the effects of unemployment, and hence of the availability of prospective employees, on the incentives of the worker inside the firm.

We believe that the incomplete contracts approach is valid to analyse this type of relationship. Workers have the possibility of holding up their employers. Their threat of strikes is credible, and through them they induce negotiations which may change the initial contracts. Hence, as in Grout (1984), the effect of ex-post bargaining has distorting effects on previous investments.

This chapter is organised as follows. The next section introduces the reader to the notation and to the main assumptions of the model. Section 3 derives agents' utility functions. Section 4 draws the results related to the incentives effects of investing in outside opportunities. Section 5 and 6, introduce the effects of exogenous variables such as changes in labour legislation and the effects of unemployment. Finally, in section number 7 we summarise and comment on the main conclusions of the chapter.

2.2 Description of the Model

Agent M, an owner-manager, buys a physical asset, K, and sets up a firm. With the physical asset, the manager wants to produce a good or project which requires $T > 1$ periods to be completed. The physical asset needs one worker. To fill this vacancy, M goes to the labour market. There she faces agents with identities $j, k, l, \ldots$ who are potential workers. Before joining the firm, these agents are homogeneous. She picks and contracts one of them. We denote the identity of the worker as $i_t \in \{j, k, l, \ldots\}$, with $t = 0, 1, 2, \ldots, T$. The worker is initially hired at date $t = 0$, and at the end of each period, he and the manager-employer decide whether to continue working together for the following period. If they decide to terminate the relationship, the employer would go again to the labour market and choose and contract another worker with a different identity to finish the project.

2.2.1 Technology and Surplus

Let the employer's human capital be $B \in \{0, \bar{B}\}$, with $\bar{B} > 0$. Both the employer's human capital and the physical asset K are indispensable for production.

The worker must make some investment in effort, e_t, so that surplus is positive. This investment is observable but non-verifiable and has a utility cost of $c(e_t)$ which is increasing and convex. We assume that the investment is productive for longer than one period. The effort made at period t affects surplus in period t itself and in the following period, $t+1$. We can interpret it as learning or alternatively as investment in making the technology more productive[1].

The surplus looks as follows:

$$S_t\left(e_t, e_{t-1}; i_t, i_{t-1}; \bar{B}; K\right)$$

with $S_t\left(e_t, e_{t-1}; i_t, i_{t-1}; 0; K\right) = 0$ and $S_t\left(e_t, e_{t-1}; i_t, i_{t-1}; \bar{B}; 0\right) = 0$.

Let

$$s_t\left(e_t, e_{t-1}; i_t, i_{t-1}\right) \equiv S_t\left(e_t, e_{t-1}; i_t, i_{t-1}; \bar{B}; K\right) \quad \text{with} \quad B > 0 \quad \text{and} \quad K > 0$$

s_t is increasing and concave in both efforts

The presence of the worker is indispensable in the following way:

(A1) $\forall i_t, i_{t-1} \in \{j, k, l \ldots\}$

$$\begin{aligned} s_t\left(0, e_{t-1}; i_t, i_{t-1}\right) &= 0 \quad \forall e_{t-1} \qquad \forall t \in \{1, \ldots, T\} \qquad \text{and} \\ s_t\left(e_t, 0; i_t, i_{t-1}\right) &> 0 \quad \forall e_t > 0 \quad \forall t \in \{0, ..., T\} \end{aligned}$$

The identity of the workers needs to be taken into account. We can have either $i = i_{t-1}$ or $i \neq i_{t-1}$. The following assumptions will be related to it.

[1] We could also assume that e_t has influence in all the surpluses from t up to T. In this case, the conclusions of the model would be stronger.

(A2) $\forall i_t, i_{t-1} \in \{j, k, l, \} \ldots, \forall t \in \{1, \ldots, T\}$ and for $e_0 = e_t$

$$\frac{\partial s_0\left(e_0; i_0\right)}{\partial e_0} = \frac{\partial s_t\left(e_t, e_{t-1}; i_t, i_{t-1}\right)}{\partial e_t}$$

(A2) means that present effort affects present surplus equally in all periods and independently of the employee's identity. Since there was no previous investment before, s_0 only depends on present effort.

(A2) implies that: $\frac{\partial^2 s_t}{\partial e_t \partial e_{t-1}} = 0$

(A3) $\forall i_t, i_{t-1} \in \{j, k, l, \ldots\}$ and $\forall t \in \{1, \ldots, T\}$

$$\frac{\partial s_t\left(e_t, e_{t-1}; i_t, i_{t-1}\right)}{\partial e_t} \geq \frac{\partial s_t\left(e_t, e_{t-1}; i_t, i_{t-1}\right)}{\partial e_{t-1}}$$

(A3) implies that present effort is at least as productive as past effort, in both cases, when the worker is the same as in the previous period and when he is new in the firm. If we interpret effort as learning, this inequality is very intuitive – recent learning is more productive than old learning.

(A4) $\forall i_t = i'$ and $i_{t-1} \in \{i', i''\}$ with $i' \neq i''$, where $i', i'' \in \{j, k, l, \ldots\}$ and $\forall t \in \{1, \ldots, T\}$

$$\frac{\partial s_t\left(e_t, e_{t-1}; i', i'\right)}{\partial e_{t-1}} \geq \frac{\partial s_t\left(e_t, e_{t-1}; i', i''\right)}{\partial e_{t-1}}$$

(A4) captures the fact that the insider may be more efficient in recovering his own effort. This also is intuitive, since he made the first effort and hence he has learned. He understands the technology better and benefits from the specificities of it. Additionally, we assume that second derivatives exhibit the same behaviour as first derivatives: $\frac{\partial^2 s_t(e_t, e_{t-1}; i', i')}{\partial e_{t-1}^2} \geq \frac{\partial^2 s_t(e_t, e_{t-1}; i', i'')}{\partial e_{t-1}^2}$, showing once again the higher efficiency of the insider.

2.2.2 Bargaining and outside options

By the end of the each period, before production takes place, both agents negotiate. They decide how to share the surplus and whether to continue with the contractual relation for the next period.

The same worker may continue in the following period depending on whether he and the manager reach an agreement. Since ex-ante this is never sure the manager screens the labour market for possible candidates during periods $t \in \{0, \ldots, T-1\}$. During period t she looks for candidates who might be able to work in $t+1$. We model it as an investment in the probability

$$0 \leq q_t < 1 \qquad \text{with} \qquad t \in \{0, \ldots, T-1\}$$

that he finds such a candidate, with $q_t = 0$ meaning that the manager does not make any effort in looking for alternative employees. Investing in q_t is *investing in flexibility*, that is, in having the option of replacing the present worker by another. This new candidate substitutes the worker for the same vacancy. The more the employer invests in placing advertisements, interviewing prospective candidates, etc, the greater is the probability that she encounters another suitable employee for her business. This investment has a cost of $f(q_t)$, with $f(0) = 0$ increasing and convex. In the case that she does not find an alternative employee (with probability $1 - q_t$), and she does not reach an agreement with her existing employee, i_t, her outside opportunity is zero[2].

We assume that the firm is small compared to the labour market, and hence, the search and possible hiring of an outsider has no influence in the supply and demand of labour. The probability q_t itself might depend on the conditions of the labour market. For example, in an economy with a high level of unemployment it might be easier for the employer to find a substitute for her worker. Although at the beginning q_t is considered totally exogenous, later in the chapter, in sections 5 and 6, we explore the possibility that it is affected by the conditions in the labour market.

In the case worker i quits the firm he might find another job in the following period. The outside opportunities of the worker depend on his experience, on the probability of finding another job, and on the wage he would earn in his new job. The probability of being contracted in some other

[2] We assume that there is no market for second-hand assets.

firm increases linearly with experience, then at t, his outside option is

$$p(e_{t-1})\, r$$

with $p(0) = 0$. The probability is linearly increasing in effort $p'(e_{t-1}) > 0$, and $p''(e_{t-1}) = 0$, until the value e^*_{t-1} when $p(e^*_{t-1}) = 1$. For higher values, the probability becomes constant. The parameter r denotes the wage he would receive in the alternative job, with $r < s_t$.

2.2.3 Agents

There are three types of agents inside the firm together with the outsiders[3]:

- *The manager* (M): the one who owns the physical asset.

- *The insider* (I): the worker who has been in the firm for at least one period.

- *The entrant* (E): the worker who exerts effort during the period that he is contracted. If he manages to stay in the firm, the period after he becomes an insider.

  Then, at a given period in time, the worker can be of one of two types, either I or E with $I, E \in \{j, k, l, \ldots\}$.

  For example, worker j during the period when he is contracted, say t^c, is of type E. The period after, $t^c + 1$, he becomes of type I.

- *The outsiders:* The agents outside the firms, who are homogeneous

Agents are risk neutral, have no liquidity constraints, and their discount factor is $\delta \in (0, 1)$.

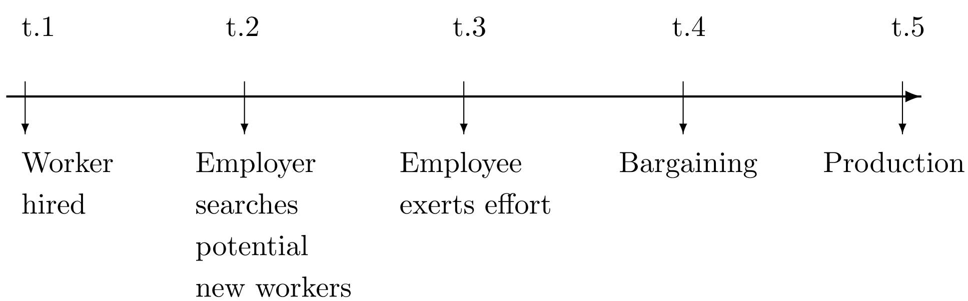
[3] We take the usual names of the insider-outsider literature. See, for example, Lindbeck & Snower (1988).

2.2.4 Timing

The model has two time granularities. The timing of the firm (or of the project) which is composed by periods, and the timing inside each period, which is composed of stages.

The timing of the firm starts at $t = 0$. From then onwards the firm needs one worker. The worker and the employer negotiate the contract at the end of each period. In the event that at date $t^f < T$ the contract is broken, in the following period, $t^f + 1$, another agent might substitute the worker for the remaining $T - t^f$ periods.

Each period t has several stages:



$t.1$: The firm employs the worker. He may face two situations. In the case we are in period $t = 0$, the employee is the first working in the firm. The second possibility is $t > 0$, in which he is substituting some other worker who left the firm at $t - 1$.

From $t = 1$ on, nothing happens in this stage if the same worker who was in the firm in $t - 1$ continues being employed by the manager.

$t.2$: The manager decides q_t, which is observed by the employee.

$t.3$: The worker chooses his effort e_t.

$t.4$: The worker and the employer negotiate how to split the surplus and whether the same worker continues inside the firm. The probability that the manager makes a take-it-or-leave it offer to the employee is $\alpha > 0$,leaving a probability $1 - \alpha$ that it is the employee who makes the final offer. These probabilities are the same for all periods. Note that the possible outcomes from the bargaining are:

- Agreement: both the worker i_t and the manager agree at t on surplus shares and on contractual relationship and they continue together in the next period (hence $i_t = i_{t+1}$, meaning that in $t+1$ there is an insider in the firm)
- Disagreement: they do not agree on the surplus shares and the worker does not continue inside the firm (hence $i_t \neq i_{t+1}$, meaning that in $t+1$, with probability q_t, there is an entrant in the firm)

Possibilities like that agreement on surplus was reached but the worker did not want to continue inside the company in $t+1$, ore that there was no agreement on surplus at t but the worker wants to continue being employed by the manager in $t+1$, are not credible.

$t.5$: In case of agreement, production and surplus are generated and payoffs are distributed. Otherwise, there is no production.

2.3 Expected Utilities

Utilities of both the employer and the worker depend on each other present and past decisions. Both know that the other will choose their respective levels of investments rationally. This will define the subgame perfect equilibrium path for the utility functions. The employer decides the optimal investment in searching for a possible entrant: $\hat{q}_t$. This investment is observed by the employee and hence it will influence his choice of optimal effort, $\hat{e}_t$, in the present period. The employee's optimal effort will afterwards have an impact on the level of surplus produced in the following period, $\hat{s}_{t+1}$.

Note that the employee observes $\hat{q}_t$. He will incorporate this valuable information into his choice of effort, hence effort will depend on the manager's investment in flexibility: $e_t = e_t(q_t)$.

The subgame perfect equilibrium utility functions of both agents, I and M, in each period are composed of the present immediate utility $P(\cdot)$ and the future utility, $F(\cdot)$. The functions can be written as follows

$$VM_t(q_{t-1}, e_{t-1}) = \max_{q_t} \left\{ P^M\left(q_t, e_t(q_t)\right) + \delta F^M\left(e_t(q_t)\right) \right\}$$

$$VI(q_{t-1}, e_{t-1}) = \max_{e_t} \left\{ P^I(e_t) + \delta F^I(e_t) \right\}$$

The utilities of the agents are shaped by the expectations and outcomes at the negotiation stage. The outcome of the negotiation is a share of surplus. For a given t, the surplus is different depending on the type of agent who has produced it. We define:

$s_t^I \equiv s_t(e_t, e_{t-1}; i_t, i_{t-1})$ where $i_t = i_{t-1} = j, k, l, \ldots$ and $t > 0$ as the surplus of the insider

$s_t^E \equiv s_t(e_t, e_{t-1}; i_t, i_{t-1})$ where $i_t, i_{t-1} = j, k, l, , \ldots$ but $i_t \neq i_{t-1}$ and $t > 0$ as the surplus of the entrant

$s_0^E \equiv s_0(e_0; i_0)$ as the surplus of the period when the firm is set up and the first worker is contracted

Note that because of assumptions (A1) to (A4)

$$s_t^I(e_t, e_{t-1}) \geq s_t^E(e_t, e_{t-1}) \qquad t = 1, \ldots, T \tag{2.1}$$

2.3.1 Negotiation stage

To understand the expected utilities of the agents at each period it is useful to analyse the form of their proposals at the negotiation stage. The employer's expected utility at period t with an insider is denoted VM_t^I (VM_t^E with an entrant). The expected utility of the insider is denoted VI_t.

Let us start with the manager and let us assume that she bargains with an insider[4]. When the manager has the bargaining power, she demands for herself:

[4] Bargaining with an entrant would be very similar.

$$\begin{cases} s_0(e_0) - \delta p(e_0)\, r + \delta V I_1(q_0, e_0) & t = 0 \\ s^I_t(e_t, e_{t-1}) - \delta p(e_t)\, r + \delta V I_{t+1}(q_t, e_t) & 0 < t < T \\ s^I_T(e_T, e_{T-1}) & T \end{cases} \tag{2.2}$$

note that she demands the present value of the firm minus the outside opportunity of the worker and minus what she expects to get in the future. With this proposal she leaves the worker with his outside option.

When the employee has the bargaining power and the manager does not accept his proposal, her outside option would be:

$$\begin{cases} \delta\, q_t\, V M^E_{t+1}(q_t, e_t) & t < T \\ 0 & T \end{cases}$$

from $t = 0$ to $t = T - 1$, with probability q_t, she finds an outsider and she contracts him at the beginning of the next period, $t + 1$. In the last period she has no outside option.

The problem becomes recursive: her outside option is an entrant (E) with whom she is going to bargain at $t+1$ and thus to threaten him with another entrant (E') who would be recruited at $t + 2$, and so on[5].

When the worker has the bargaining power he makes the following proposals:

$$\begin{cases} s_0(e_0) + \delta\, V M^I_1(q_0, e_0) - q_0 \delta\, V M^E_1(q_0, e_0) & t = 0 \\ s^I_t(e_t, e_{t-1}) + \delta\, V M^I_{t+1}(q_t, e_t) - q_t \delta\, V M^E_{t+1}(q_t, e_t) & 0 < t < T \\ s^I_T(e_T, e_{T-1}) & T \end{cases} \tag{2.3}$$

[5] That is $V M^E_{t+1}(e_t, q_t) = \alpha \left(s^E_{t+1}(e_{t+1}, e_t) - \delta\, p(e^E_{t+1})\ r + \delta V I_{t+2}(e_{t+1}, q_{t+1}) + \delta V M^I_{t+2}(e_{t+1}, q_{t+1}) \right) +$ $(1-\alpha) q_{t+1} \delta V M^{E'}_{t+2}(e_{t+1}, q_{t+1}) - f(q_{t+1})$. Note that the entrant becomes an insider after one period.

He demands the present value of the firm minus what he expects to get in the future and minus the employer's outside option. Additionally, with this proposal he stays inside the firm and hence he receives the resulting expected utility: δVI_{t+1}.

When he does not have the bargaining power he is left with his outside option $\delta\, p(e_{t+1})\; r\; \forall t$.

2.3.2 Utility Functions

The subgame perfect equilibrium path of the utility functions is defined as follows

$$\begin{aligned} VM_t^I(q_{t-1}, e_{t-1}) &= \alpha \left[s_t^I(e_t(q_t), e_{t-1}) - \delta p(e_t(q_t)) + \delta VI_{t+1}(q_t, e_t)\right] + \\ &\quad + (1-\alpha)\, q_t \delta VM_{t+1}^E(q_t, e_t) - f(q_t) \end{aligned} \tag{2.4}$$

$$\begin{aligned} VI_t(q_{t-1}, e_{t-1}) &= \alpha\delta p(e_t) + \\ &\quad + (1-\alpha)\left[s_t^I(e_t, e_{t-1}) + \delta\, VM_{t+1}^I(q_t, e_t) - q_t \delta\, VM_{t+1}^E(q_t, e_t)\right] \\ &\quad - c\,(e_t) \end{aligned} \tag{2.5}$$

Note that the function $s_t(e_t, e_{t-1})$ is concave in both efforts (for both the entrant and the insider), function $p(e_t)$ is linear, and cost efforts $f(q_t)$ and $c\,(e_t)$ are convex. Hence the first order conditions of the utility functions are sufficient to identify the solution to the optimisation problem.

2.4 Incentive Effects of Investing in Outside Options

From expressions (2.1) and (2.4) we get the following result:

Remark 1. *Worker i, contracted at $t = 0$, remains in the firm until the end of his contract, at $t = T$.*

The manager's expected proportion of the surplus is the same independently of the worker being an insider or an entrant. Inequality (2.1) tells that the expected surplus is larger when an insider is working in the firm. Hence, bargaining with an insider gives the owner a proportion of a bigger surplus (see manager's offer in equation (2.2)) than bargaining with an entrant.

$$VM_t^I(e_{t-1}, q_{t-1}) \geq VM_t^E(e_{t-1}, q_{t-1}) \qquad \text{for} \qquad t \in \{1, \ldots, T\}$$

■

The equilibrium conditions of the bargaining process lead to an efficient negotiation.

It is easy to check that the insider is also better off when staying inside the firm than when choosing his outside options.

Remark 2. *By searching for alternative entrants, the manager is able to retain a bigger proportion of the future value of the firm.*

The intuition behind the result can be verified through expression (2.4). The search for suitable candidates for the firm allows her to enjoy a stronger position at the bargaining stage.

Through the distribution of the bargaining power, agents distribute as well the value of the firm. However, note that the employer is able to retain an additional proportion of this value through the expected surplus that she could get from an entrant.

This search for outsiders, however, may have perverse effects on the employee's incentives to exert effort.

Proposition 1. *Consider assumptions (A1) to (A4) and the utility functions (2.4) and (2.5), then* $\frac{\partial e_t}{\partial q_t} < 0$

The first order condition of the worker's value function (2.5)

$$\begin{aligned} \frac{\partial c(e_t)}{\partial e_t} &= (1-\alpha)\frac{\partial s_t^I(e_t, e_{t-1})}{\partial e_t} + \\ &+\delta\alpha\,\frac{\partial p(e_t)}{\partial e_t} r + \delta\alpha(1-\alpha)\left[\frac{\partial s_{t+1}^I(e_{t+1}, e_t)}{\partial e_t} - q_t\,\frac{\partial s_{t+1}^E(e_{t+1}, e_t)}{\partial e_t}\right] \end{aligned} \tag{2.6}$$

The Implicit Function Theorem shows that the manager's investment in flexibility has a negative effect on the employee's effort

$$\begin{aligned}\frac{\partial \hat{e}_t}{\partial q_t} \;=\; & -\left(-\delta\ \alpha\ (1-\alpha)\ \frac{\partial s^E_{t+1}(e_{t+1},e_t)}{\partial e_t}\right)\cdot \\ & \left((1-\alpha)\frac{\partial^2 s^I_t(e_t,e_{t-1})}{\partial e_t^2}+\delta(1-\alpha)\alpha\frac{\partial^2 s^I_{t+1}(e_{t+1},e_t)}{\partial e_t^2}\right. \\ & \left.-\delta q_t\alpha(1-\alpha)\frac{\partial^2 s^E_{t+1}(e_{t+1},e_t)}{\partial e_t^2}-\frac{\partial^2 c(e_t)}{\partial e_t^2}\right)^{-1}<0\end{aligned} \tag{2.7}$$

Note that $\frac{\partial s_{t+1}(e_{t+1},e_t)}{\partial e_t} > 0$ and $\frac{\partial^2 s_t(e_t,e_{t-1})}{\partial e_t^2} < 0$ for both the entrant and the insider, (A4) states that $\frac{\partial^2 s^I_{t+1}(e_{t+1},e_t)}{\partial e_t^2} \geq \frac{\partial^2 s^E_{t+1}(e_{t+1},e_t)}{\partial e_t^2}$, and $\frac{\partial^2 c(e_t)}{\partial e_t^2} > 0$. Therefore the whole derivative is negative. The implication is that the employer's search for outsiders has negative effects on the productivity of the worker.

■

Equation (2.6) gives the effort made by the insider: $\hat{e}^I_t(q_t)$. The first term on the right hand side, $(1-\alpha)\frac{\partial s^I_t(e_t,e_{t-1})}{\partial e_t}$, is the marginal increase in the revenue that the worker receives from the present period, while the whole expression in the second line of the equation, $\delta\alpha\ \frac{\partial p(e_t)}{\partial e_t} r + \delta\alpha(1-\alpha)\left[\frac{\partial s^I_{t+1}(e_{t+1},e_t)}{\partial e_t} - q_t\ \frac{\partial s^E_{t+1}(e_{t+1},e_t)}{\partial e_t}\right]$, is what he gets from the future. Because he engages in a learning process, increasing present effort means larger surplus in the future. This is true for all t, except $t = T$, when he retires and does not have the possibility of benefiting from learning.

For $t \in \{0, \ldots, T-1\}$ the worker receives positive incentives from the possibility of producing $s^I_{t+1}(e_{t+1}, e_t)$. But these incentives are weakened by the possibility that it is not him, but an outsider who profits from e^I_t by producing $s^E_{t+1}(e_{t+1}, e_t)$. Therefore, as equation (2.7) shows, the more the manager invests in flexibility, the less keen the worker is to work hard. The employee feels expropriated of the future outcome of his effort. His response to this fact is to be less productive.

The motivation of the worker also decreases with the entrant's ability to recover his effort, $\frac{\partial s^E_{t+1}}{\partial e_t}$. Hence the more specific the employee's effort is, the smaller is the threat that he feels from an entrant. When the outsiders (and hence entrants) and insiders are very similar (ie $\frac{\partial s^I_{t+1}}{\partial e_t}$ and $\frac{\partial s^E_{t+1}}{\partial e_t}$ are very close), the latter are more afraid of being expropriated and as a consequence exert less effort.

This leads us to the next proposition.

Proposition 2. *Given utility functions (2.4) and (2.5) and given Proposition 1, the manager needs to balance her zeal for more bargaining power with the disincentive she gives to the worker.*

The optimal $\hat{q}_t$ can be computed from the first order condition of expression (2.4):

$$\begin{aligned}\frac{\partial f(q)}{\partial q_t} &= \delta(1-\alpha)VM^E_{t+1}(q_t, e_t) + \\ &+ \left[\alpha\frac{\partial s^I_t(e_t, e_{t-1})}{\partial e_t} + \alpha\delta\frac{\partial s^I_{t+1}(e_{t+1}, e_t)}{\partial e_t} - \alpha\delta\frac{\partial p(e_t)}{\partial e_t}r + \right. \\ &\left. +(1-\alpha)q_t\,\delta\,\frac{\partial s^E_{t+1}(e_{t+1}, e_t)}{\partial e_t}\right]\frac{\partial e^I_t}{\partial q_t}\end{aligned} \tag{2.8}$$

By investing in flexibility, the employer gains more valuable outside options and gets more at the bargaining stage – this is showed by the first term on the right hand side of (2.8), $\delta(1-\alpha)VM^E_{t+1}(q_t, e_t)$, which is positive.

The negative part of the balance arises form the disincentive in square brackets is (2.7), multiplied by $\frac{\partial e^I_t}{\partial q_t}$. As it can be observed in expression (2.8), the investment in q_t has negative effects on present effort, and through it on present and future surpluses. By investing in outside opportunities, the manager shrinks the surpluses that she will ultimately share with the employee.

■

2.5 Flexibility of Contracts

With the previous framework it is possible to study the possible consequences of labour market reforms similar to those applied in Spain from 1984 onwards.

Before these reforms, workers in Spain enjoyed a high level of protection. Temporary contracts were allowed only in special cases and/or for specific types of workers. Permanent contracts were blocked by large indemnities for the worker in the case he was dismissed.

Coinciding with this very rigid labour market, the Spanish economy bore one of the largest unemployment rates amongst the developed countries. It was thought that one of the causes behind the high level of unemployment was the large redundancy payments. Due to these large indemnifications that employers were obliged to pay if they had to make a worker redundant, they were reluctant to contract workers. Therefore, high unemployment persisted.

To alleviate this situation, from 1984 onwards the government began to introduce new laws with the objective of increasing the flexibility of labour contracts. These reforms eliminated those special cases for temporary contracts, and allowed the use of fixed term contracts to hire any type of worker and at any time. The indemnities associated with these contracts in case of termination were much lower. The only restriction was that they could be used for a certain period of time[6] for the same vacancy and/or worker. This section of the chapter aims to explore the incentive effects of the flexibilisation of contracts.

Proposition 3. *Consider the parameter φ, that makes searching less costly, then when φ increases, worker's productivity decreases.*

We link this proposition with the reform that makes the labour market more flexible. Since the reform has been exogenous, we capture it by means of parameter φ, which makes searching among outsiders, $f(q_t;\varphi)$,less costly. The parameter φ can be interpreted as the "degree of flexibility" of the labour market: the easier it is to change the current employee and contract a new one, the higher is φ and the lower the cost of searching, $f(q_t;\varphi)$.

We identify the date of the reform with $t = t^R$. Flexibility of the labour market before and after the reform is captured by φ^0 and φ^1:

$$\varphi = \begin{cases} \varphi^0 & : \quad 0 < t < t^R \\ \varphi^1 & : \quad t > t^R \end{cases}$$

[6]In 1984 the minimum was 6 months and the maximum 3 years. After this period the worker had to be contracted on a permanent basis or dismissed. These time limits have been changed in subsequent laws.

which for a given t imply:

$$\varphi^0 < \varphi^1 \qquad \Rightarrow \qquad f(q_t;\varphi_0) > f(q_t;\varphi_1)$$

Let $\hat{q}_t^0$ and $\hat{q}_t^1$ be the search levels related to φ^0 and φ^1 respectively.
Note that because of equation (2.8)

$$\hat{q}_t^0 < \hat{q}_t^1$$

Equation (2.7) tells us that an increase in the search intensity, q, reduces the first period effort, and hence the worker's productivity and total production[7].

■

Therefore, labour market reforms which eliminate restrictions when contracting new employees, might have the positive effect of reducing unemployment. However, these reforms might also induce employees to perceive that they are easier to replace, meaning that it is not profitable for them to invest in being more productive.

2.6 Availability of entrants

This section aims to explore in a very straightforward manner the consequences of the availability of alternative workers. The quantity of possible entrants able to work in the company might dictate how easy it is for the manager to replace the worker. This can be linked to unemployment. In situations of high unemployment, the manager might find suitable candidates without having to search too intensively. On the other hand, when unemployment is low, the search for workers might prove more costly.

[7]In our model, only one agent, the worker, invests and thus bears the incentive consequences of the employer's search. Let us imagine that the surplus depended positively on some effort related investment made by the employer. This investment could be for example in marketing the product. The marketing effort, m_t, made at t would be related to the sale of the production of the following period. Then surplus would be $s_t(e_t, e_{t-1}; i_t, i_{t-1}m_{t-1})$. It is straightforward to understand that this investment is positively related to the investment in q_t. The more the employer invests in the search for an alternative worker, the smaller is the possibility that the insider holds her up for her investment in m. Therefore, here it would be unclear whether total production diminishes. It would depend on the balance between the insider's disincentives and the employer's incentives to invest in effort.

Proposition 4. *Consider parameter U, that captures the availability of outsiders, then as U increases, worker's productivity decreases.*

Consider first the case of high availability of outsiders, which can be linked to high unemployment, $\bar{U}$. With high unemployment, the manager has a bigger pool of outsiders and hence it is more likely that she finds the candidate that suits her. The cost of searching would diminish as unemployment rises: $\frac{\partial f(q_t,U)}{\partial U} < 0$ with $f(q_t, U) = 0$ for $U \geq \bar{U}$. Under high unemployment the probability of the employer finding suitable candidates, $q^{\bar{U}}$, would be close to one.

On the other hand the employee would find it very difficult to find another job: $\frac{\partial p(e_t,U)}{\partial U} < 0$ with $p(e_t, U) = 0$ for $U \geq \bar{U}$.

In the extreme case where $q^{\bar{U}} = 1$ and $p(e, \bar{U}) = 0$, equation (2.6) would look as follows:

$$\frac{\partial c(e_t)}{\partial e_t} = (1-\alpha)\frac{\partial s_t^I(e_t, e_{t-1})}{\partial e_t} + \delta\alpha(1-\alpha)\left[\frac{\partial s_{t+1}^I(e_{t+1}, e_t)}{\partial e_t} - \frac{\partial s_{t+1}^E(e_{t+1}, e_t)}{\partial e_t}\right]$$

Effort in this case, $e^{\bar{U}}$, would be lower, than $\hat{e}$ above.

Notice that in this extreme case, the only incentive coming from period $t+1$ is the difference in the ability to learn or the ability of the insider in differentiating himself from the potential entrants. In occupations where there is little on-the-job learning or specialisation and where the manager can easily find replacements for their workers, the model concludes that the worker gets little incentive from investing in human capital that is pays out in the future.

Next, consider the case of scarcity of entrants. We capture it through $\underline{U}$. The manager does not have any suitable candidates unless she pays extremely high recruitment costs or undergoes a very time consuming search. In this opposite extreme case, $f(q_t, U) = \infty$ for $U \leq \underline{U}$, with $q^{\underline{U}} = 0$. Additionally $p(e_t, U) = 0$ for $U \leq \underline{u}$. Then, under $\underline{U}$, effort $e^{\underline{U}}$ would be determined by:

$$\frac{\partial c(e_t)}{\partial e_t} = (1-\alpha)\frac{\partial s_t^I(e_t, e_{t-1})}{\partial e_t} + \delta\alpha r + \delta\alpha(1-\alpha)\frac{\partial s_{t+1}^I(e_{t+1}, e_t)}{\partial e_t}$$

Comparing the three levels of effort:

$$e^{\bar{U}} < \hat{e} < e^{\underline{U}}$$

■

Surpluses under the three cases would follow the same pattern.

Hence, the higher the availability of similar possible workers, the weaker the incentives of the insider and vice-versa.

2.7 Concluding remarks

This chapter explores the incentive effects of actively investing in outside options. We model this investment through a manager who has the possibility of investing in the recruitment of alternative candidates for the worker-insider that she has initially contracted. The availability of suitable worker-entrants will enable her to enjoy a stronger position when negotiating how to divide the surplus with the insider. On the other hand, the insider exerts effort, and as he does so he learns how to be more productive in the following period. However, seeing that he might be replaced by one of those candidates, he has fewer incentives in exerting effort and learning. Therefore, the manager needs to balance her desire of a stronger bargaining position with the negative incentives that it gives to the worker.

The model also studies how several aspects of the labour market might impact incentives inside the company and thus the surplus. The first case considers the effects of labour legislation that makes it easier for employers to replace workers. As the worker feels that his job is less secure he has less incentives in learning for future periods and becomes less productive. The second case analyses how the availability of suitable candidates affects effort and surplus. This is linked to unemployment. In situations of high unemployment it might be easier to find alternative candidates, hence the insider will be more reluctant to invest in effort and learning. The opposite is the case for periods of very low unemployment, where candidates are scarce and hence the insider feels his job more secure and would be keener to exert effort.

One of the conclusions in the model is that the more able the worker is to differentiate himself from the outside candidates, the more he will offset the disincentives of the manager's search. A possible extension of the model would be that where the worker is able to invest in this differentiation - investing in how much more productive he can be than the possible outside candidates.

Chapter 3

Contracting Externalities and Multiple Equilibria in Sectors: Theory and Evidence

Written in collaboration with Diego Rodríguez Palenzuela and Juan José de Lucio

There is an economy where the production technology has constant returns to scale but where in the decentralised equilibrium there are aggregate increasing returns to scale. The result follows from a positive contracting externality among firms. If a firm is surrounded by more firms, employees have more opportunities outside their own firm. This improves employees' incentives to invest in the presence of ex post renegotiation at the firm level, at no cost. Our leading result is that if a region is sparsely populated and/or if the degree of development in the region is low enough, there are multiple equilibria in the level of sectoral employment. We identify an interaction between the scale of a regional economy and its level of development. From the theoretical model we derive an econometrical model. Our results are strongly consistent with the multiple equilibria hypothesis and the existence of a sectoral critical scale. The scale of the regions' population and the degree of development reduce the critical scale of the sector.

3.1 Introduction

In recent years there has been increasing interest in models of the agglomeration of economic activity. The largest proportion of papers that have attempted to explain agglomeration have referred to explanations based on fixed costs of starting economic activities, that is, based on aggregate or disaggregate technological increasing returns to scale. For an introductory survey to theories of localization of economic activities, see chapter 2 in Krugman (1991).

A second branch of the literature has focused on externalities that do not affect production technologies but instead affect transaction technologies. In Acemoglu (1996) search externalities arising from decentralized factor markets lead to benefits of agglomeration. Our chapter relates to this second branch of transacting externalities[1].

We consider an economy where the production technology has constant returns to scale, but where in the decentralized equilibrium there are aggregate increasing returns to scale. The result follows from a positive *contracting* externality among firms. If a firm is surrounded by more firms, employees have more opportunities outside their own firm. Increasing outside options improves employees' incentives to invest in the presence of ex post renegotiation at the firm level, *at no cost*: outside opportunities are not used in equilibrium.

In our model there are no direct or technological externalities across firms. Our theory starts from a simple observation. As the scale of an economy increases, the number of inefficient reallocations of factors increases exponentially. Inefficient reallocations serve as outside options to agents when bargaining for the terms of trade. Although these options do not directly contribute to social welfare, they change agents' incentives to engage in human capital investments. With transaction costs deriving from inefficient ex post bargaining, we find that in the decentralized equilibrium there are

[1]Another more qualitative branch of literature that deals with the concentration of economic activities is the one related to clusters led by Michael E. Porter. In Porter (2000) a cluster is defined as "*geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries and associated institutions (such as universities, standards agencies, trade associations) in a particular field that compete but also cooperate*". Clusters include activities related to several sectors that benefit from research institutions and demand conditions that provides incentives to innovate. Examples are Silicon Valley and wine producing in California.

generally increasing returns to scale.

Possibly, the best way to introduce the main idea of the chapter is through an example. Consider an economy based on football teams. Teams are composed of eleven first team players plus a number of reserve players. Production requires certain investments by the players, like training or sticking to a special diet. It is difficult to monitor whether these investments are in conformity with the interest of the team. Furthermore, there is a significant coordination in the investment activity (players train jointly). Hence, at the time of production it is not efficient to reallocate players across teams: they are more efficient in the team where they trained.

Now imagine that at the beginning of the football season the players bargain with the club for the distribution of the total club's revenues. The anticipation of ex post bargaining distorts somewhat the incentives to invest correctly. Clearly, the opportunities to transfer to another team matters, both to determine the terms of trade and the level of investments. Outside opportunities for a given player are likely to increase as the economy grows (as there are more teams around, players are more likely to find opportunities to be productive in some different team to their own). Although there is only one efficient allocation of players to teams at the production stage (namely, to remain in the original team), the number of *inefficient* allocations grows with the number of teams. In particular, the number of inefficient allocations when one player deviates unilaterally from the efficient allocation is equal to the total number of teams minus one.

In summary, if and only if transaction costs (arising from agents' inability to commit on future wages) matter, outside opportunities present an option value for each of the players. Outside opportunities replicate naturally as the size of the economy expands, but players' competition to take them remains constant (and nil), since they present a less attractive alternative than staying with the original team. To repeat, under transaction costs, there is a benefit that freely accrues to each player as the economy grows: her options outside her team. This improves her incentives to invest and, if players' investments are complementary, the effect is mutually reinforced.

We present a model that demonstrates this mechanism precisely. To keep the model tractable, we introduce specific assumptions on the production function. We distinguish between *team production*, and *ex post production*. Team production is the output of a team that "trained jointly" and whose team members sunk investments in human capital that are specific to physical assets. In particular, we introduce assumptions such that the optimal size of team production is equal to two members. This allows us to avoid complex multilateral bargaining solutions like the Shapley Value or the one in Stole and Zwiebel (1996).

Ex post production means that firms can hire additional workers (beyond the optimal size of two) at the production stage. But marginal returns to human capital inside the firm are decreasing, and the *ex post workers* have a *low* marginal productivity. Ex post production does not occur in equilibrium, since it is a worse option for any team member, but it is a credible outside alternative.

Our main result is that the level of interaction between the population of a region and its degree of development are linked to sectorial employment. When this population and/or the level of development in the industrial sectors of the region are low enough, there are multiple equilibria in the level of total sectorial employment. One of these equilibria corresponds to the absence of sectorial activity. On the other hand, if the scale of the region (in terms of total population) is large enough or the level of development is high enough, there is a unique employment level equilibrium in the industrial sectors of the region. In the unique equilibrium there is positive industrial activity. This result is a consequence of the reinforcement effect between total activity and incentives to invest inside the firm. In particular, outside activity is shown to relax an incentive compatibility (IC) constraint to exert effort of the *worker* (not asset owner), without affecting the constraint of the *manager* (asset owner). This asymmetry between the effect of total activity on the two IC constraints is due precisely to the fact that the effect works through the outside opportunities.

From the theoretical model we derive a econometrically tractable equation of the evolution of sectorial employment in regions. We specify a non-linear first-order censored difference equation for sectorial employment. The existence of a unique or multiple equilibria has implications for the parameter values of the difference equation. Our results are strongly consistent with the multiple equilibria hypothesis. The average sector in Spanish regions has three steady states, two stable and one unstable. One stable steady state is associated with the absence of activity (no sectorial employment). The other stable steady state is associated with a positive employment level, greater than the level of the unstable steady state. We call the estimated unstable steady state the critical mass of the sector. If in a region a shock sets the sectorial employment level below the critical mass, the industry follows a delocation process that ends with the collapse of sectorial employment in the region.

We find moreover that there are significant differences across Spanish regions. The more developed, densely populated regions of Barcelona and Madrid are found to have a stable steady states with greater sectorial size, and smaller critical sizes. In particular, for Barcelona we find that there is no critical mass and therefore there is no possibility of delocation. For ten sparsely populated and less economically developed regions we find that the critical mass of the average sector ranges from 600 to 900 employees. These results are confirmed when we substitute regional fixed-effects for regions' characteristics in our tobit estimation. This second estimation shows that economic development *or* scale of the population are each sufficient to reduce the probability of industrial delocation.

It is important to emphasise that our empirical findings can be explained by other theories of aggregate increasing returns, as well as our theory based on contracting externalities. At this stage we make no attempt to select empirically the best theory to explain the data. We use the model as a frame to yield an econometric specification and to interpret the results. We conclude that our empirical results are consistent with theories of aggregate increasing returns, like the one we propose, but they are inconsistent with models with complete contracts and constant returns.

The rest of the chapter is organised as follows. Section 2 lays out the model and the welfare-maximizing allocation. Section 3 introduces our assumptions on transaction costs and derives the decentralised equilibrium. In section 4 the main empirical implications of the model are discussed and the data set is described. Section 5 shows the results from the maximum likelihood estimation. The chapter concludes with section 6 which includes the final remarks.

3.2 The Model

There is a continuum of heterogeneous, risk neutral agents in the economy. Agents are indexed by a an efficiency parameter θ, uniformly distributed in $[\underline{\theta}, \overline{\theta}]$, with $\overline{\theta} - \underline{\theta} = 1$. The total mass of agents is N. The parameter θ gives information on how efficient is the effort that each agent invests in human capital. This effort invested in acquiring human capital is a discrete variable $(e \in \{\underline{e}, \overline{e}\})$. Effort can either be high $(e = \overline{e})$ or low $(e = \underline{e} \in (0, \overline{e}))$. The cost of exerting high effort for an agent of type θ is $c(\overline{e}, \theta) > c(\underline{e}, \theta) = 0$, with $c_\theta(\bar{e},\cdot)<0$, $c_{\theta\theta}(\bar{e},\cdot)<0$.

3.2.1 Technology and surplus

Production requires human capital, e, and one unit of physical capital, k that costs[2] c_k.

Initially firms are formed by two agents who acquire one unit of physical capital (at cost c_k) and exert effort. Once the firm is formed, both agents decide whether to make effort in acquiring human capital. Effort is an investment in human capital that is specific to the physical asset and to the team where it originated. This implies that once at the production stage an agent is relatively more productive at her initial firm than at a different firm with similar characteristics. In order to model specificities as simply as possible we assume that the production function has two distinct components, depending on whether the agents that produce are or are not part of the initial team:

- *Team production, y*: Call e_θ the human capital of agent θ; then $y(e_\theta,e_{\theta'}\mid\theta,\theta')$ is the initial team's output of two agents (θ,θ') that pool their human capital $(e_\theta,e_{\theta'})$ at the production stage.

  Team production y depends on the identity of the agents in the firm at the investment stage (θ,θ') and on the human capital, e_θ, of the agents who remain in the firm at the production stage. If agent θ is a member of a team but is not present at the production stage, we write $e_\theta=0$. Note that team production will be:

  $$y\in\{y(e_\theta,e_{\theta'}\mid\theta,\theta'),y(0,e_{\theta'}\mid\theta,\theta'),y(e_\theta,0\mid\theta,\theta'),y(0,0\mid\theta,\theta')\}$$

  Team production is determined by the agents who invested in human capital together. Hence, if θ'' is not a team member her effort does not affect team production[3] : for all $e_{\theta''}$: $y(e_\theta,e_{\theta'},e_{\theta''}\mid\theta,\theta')=y(e_\theta,e_{\theta'}\mid\theta,\theta')$.

  Bearing in mind that effort is a discrete variable we make the following assumptions:

[2]Recall that the "units" of physical and human capital are arbitrarily small. c_k is the cost of a marginal unit of physical capital. We assume that the production technology has constant returns to scale (see below).

[3]Although she affects ex post production.

(A1) The team production function y is symmetric and the low effort level is also productive. For all θ, θ':

$$y\left(\underline{e}, \overline{e} \mid \theta, \theta'\right) = y\left(\overline{e}, \underline{e} \mid \theta, \theta'\right) \geq y\left(\overline{e}, 0 \mid \theta, \theta'\right) \geq y\left(\underline{e}, 0 \mid \theta, \theta'\right) > 0$$

where $e_\theta = 0$ indicates that agent θ is not present in the firm at production stage.

(A2) The team-production function y satisfies a strict complementarity condition: the output in one firm when both agents exert high effort is greater than the sum of the outputs when only one exerts high effort and the other exerts low effort[4]:

$$y\left(\overline{e}, \overline{e} \mid \theta, \theta'\right) > y\left(\overline{e}, \underline{e} \mid \theta, \theta'\right) + y\left(\underline{e}, \overline{e} \mid \theta, \theta'\right) \tag{3.1}$$

(A3) When at least one team member exerts only low effort the firm is not viable:

$$y\left(\overline{e}, \underline{e} \mid \theta, \theta'\right) < c\left(\overline{e}, \overline{\theta}\right) + c_k \tag{3.2}$$

- *ex post production*: This is the output of employees ($\theta'' \notin \{\theta, \theta'\}$) who do not belong to the initial team, but who may join the firm at the production stage.

  If an agent θ'' that is not a member of the original team (θ, θ') joins the firm at the production stage, the total production of the firm, f, is the sum of team production, y, and ex post production[5]:

  $$f\left(e_\theta, e_{\theta'}, e_{\theta''} \mid \theta, \theta'\right) = y\left(e_\theta, e_{\theta'} \mid \theta, \theta'\right) + \phi e_{\theta''}$$

  where $\phi < 1$ is interpreted as the fact that agent θ'' is less productive outside her initial team due to human capital specificities.

  Introducing the possibility of ex post production implies that if a member θ of a given team (θ, θ') quits, she has a positive productivity in other existing firms.

(A4) Ex post production is not viable ex ante even for the most efficient agent:

$$\phi e_{\theta''} \leq c\left(e_{\theta''}, \overline{\theta}\right) \tag{3.3}$$

[4]This assumption is satisfied for instance by the Cobb-Douglas production function $y = \left(e_\theta + \beta\right)^\alpha \left(e_{\theta'} + \beta\right)^\alpha \left(\overline{k}\right)^{1-2\alpha}$ with $\beta > 1$.

[5]The number of vacancies for ex post production in each firm could be arbitrarily large and we would yield identical implications.

3.2.2 First-best allocation

Given the mass of agents in the economy N, the planner's problem is to introduce human capital e and physical capital k as long as the marginal firm contributes non-negatively to social surplus. Clearly, under the first-best there is only team production and there is no ex post production.

Call $y^* = y(\overline{e}, \overline{e} \mid \theta, \theta')$ the teams' output when both agents exert effort and remain in the team. The total number of 2-member teams or firms in the economy is x and the number of firms "per capita", $\widetilde{x} \equiv x/N$. Social welfare is:

$$SW(N,x) = N\left(\int_{\left(\overline{\theta}-\frac{2x}{N}\right)}^{\overline{\theta}} \left[\frac{1}{2}(y^* - c_k) - c(\overline{e}, s)\right] ds\right) \equiv N\sigma(\widetilde{x})$$

from which it follows that the optimal number of firms $\widetilde{x}^*$ per capita is independent of N and satisfies:

$$(y^* - c_k) = 2c\left(\overline{e}, \overline{\theta} - 2\widetilde{x}^*\right) \tag{3.4}$$

Given N, the social welfare is a concave function of the total number of firms introduced, $x : SW_{xx}(N,x) = \frac{4}{N}\frac{\partial c\left(\overline{e},\overline{\theta}-2\widetilde{x}\right)}{\partial\theta} < 0$, for $\widetilde{x} \in \left[0, \frac{\overline{\theta}-\underline{\theta}}{2}\right]$. Finally, the first-best social welfare and optimal number of firms (x^*) are proportional to the mass of agents in the economy:

$$\begin{aligned} x^* &= N\widetilde{x}^* \\ SW^*(N,x) &= N\sigma(\widetilde{x}^*) \end{aligned}$$

which follows from our assumption of constant returns to scale in the team production technology.

3.3 Incomplete contracts

We now analyse the decentralised outcome when two-members team cannot write complete contracts. We follow the incomplete contracting literature in assuming that parties can only contract on a limited number of variables ex ante. In particular we assume that they can only allocate property rights over physical assets at the first stage. They are not able to avoid bargaining for the division of surplus at the production stage. Bargaining introduces the possibility of mutual "hold-up" among team members, which distorts their incentives to exert effort. Our setup is a particular case of Hart and Moore (1990), except that outside opportunities are endogenous in our model.

The timing of the game is as follows:

1. *Introduction of assets.* At $t = 1$ firms are formed. Firms are contracts that specify ex ante transactions between team members (θ, θ'), and property rights over identifiable physical assets[6]. Agents face no liquidity constraints, nor imperfect information, when they set up the firm.

2. *Investments.* At $t = 2$ agents exert effort. Following the incomplete contracting literature we assume that effort, although observable, is not a verifiable variable.

3. *Bargaining.* At $t = 3$ bargaining takes place. With probability $\alpha_m \geq \frac{1}{2}$ the owner makes a take it or leave it offer to the non-owner (that is, asset owners have at least the same bargaining power as non-owners). With probability $\alpha_w = 1 - \alpha_m$ the reverse offer takes place.

4. *"Search" and production.* At $t = 4$ production takes place. If s agents did not reach an agreement at $t = 3$, they search for vacancies in ex post production. The probability for each of these agents to find a vacancy is $\widetilde{\lambda}(s, x) < 1$, where x is the total number of vacancies in ex post production. The matching function[7] satisfies $\widetilde{\lambda}_x(.) > 0$, $\widetilde{\lambda}_{xx}(.) < 0$ and $\widetilde{\lambda}_s(.) < 0$ and for $m > 0 : \widetilde{\lambda}(s, x) = \widetilde{\lambda}(ms, mx)$.

Definition 1. *Let*

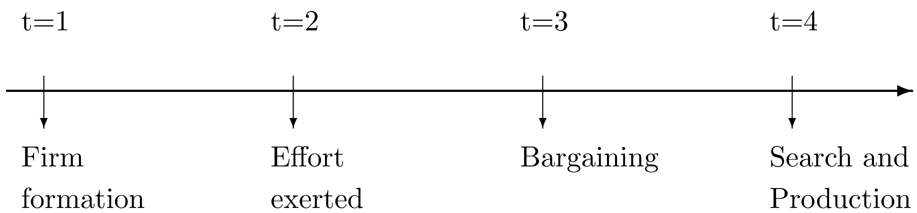
$$\lambda(x) \equiv \lim_{\varepsilon \to 0} \widetilde{\lambda}(\varepsilon, x)$$

$\lambda(x)$ is the matching function when there are x vacancies but there is only "one" worker searching.

[6] Our argument is robust to the alternative assumption that agents do not meet until the production stage and are unable to write contracts before, as in Acemoglu (1996).

[7] It is important to note that the function λ can have different interpretations from a matching function. It can also be interpreted as reflecting the worker's bargaining power when there are x firms looking for workers and s workers looking for vacancies in a decentralised market.

The timing is summarised as follows:



3.3.1 Equilibrium allocation

Consider the bargaining stage, $t = 3$. Following Hart and Moore (1990), we can rule out joint ownership of the physical asset[8]. We will refer to the owner (or manager) as θ_m, and to the worker as θ_w. For two agents (θ_m, θ_w) that formed a team at $t = 1$, the surplus to be divided when bargaining is given by: $y\left(e_{\theta_w}, e_{\theta_m} \mid \theta_m, \theta_w\right)$. The outside option for the owner when the team breaks down is to produce with the physical asset (that she controls) and obtain $y\left(e_{\theta m}, 0 \mid \theta_m, \theta_w\right)$. For the worker the best option outside the firm is to search for a vacancy and engage in ex post production. This gives: $\phi\widetilde{\lambda}(s, x)e_{\theta_w}$, which leads to:

Remark 3. *For any allocation of bargaining power, in equilibrium, team*

[8]Maskin and Tirole (1999) show that in this context the first best can be achieved if agents can use revelation mechanisms based on subgame perfect implementation. In their words, we focus on this simple institutional set-up on a priori grounds. Yet, it should be said that what is central to our argument is the existence of transaction costs from a hold-up problem, rather than the optimal allocation of property rights per se. We believe that our argument can also be made with similar effect if, as in Grout (1984) and Acemoglou (1996), agents sink their investments before they meet and before they are able to write contracts. That is, if the market failure is caused by market incompleteness rather than contract incompleteness. In this second setting the particular interaction between the hold-up problem and outside opportunities that we focus on is likely to be similar than in our setting. Yet, we develop on the Hart-Moore framework since we believe it provides a very useful benchmark.

members in all firms trade at $t = 3$ $(s = 0)$ *and the relevant matching function at* $t = 4$ *is* $\lambda(x)$

Remark 3[9] implies that as the number of firms in the economy becomes larger, the number of workers' job options outside their initial firm also increases. Since these options are worse than the utility from remaining in the original team, they are never used in equilibrium. This introduces an asymmetry between the growth of options (vacancies for ex post production) as a function of the scale N, and the growth of the number of workers that effectively search for a job ex post, that remains nil independently of N. Although the options are worse than the team positions, they have value when there is an agency problem at production, because the outside options affect the incentives to invest. The endogenous asymmetry in the search function is what produces increasing aggregate returns to human capital in the decentralised allocation.

Call V_m and V_w the expected payoff from bargaining to the manager and the worker respectively. V_w and V_m are given by:

$$\begin{aligned} V_w(e_{\theta m}, e_{\theta_w}) &= \alpha_w \left[y\left(e_{\theta_w}, e_{\theta_m} \mid \theta_m, \theta_w\right) - y\left(e_{\theta_m}, 0 \mid \theta_m, \theta_w\right) \right] + \alpha_m \lambda\left(x\right) \phi e_{\theta_w} \qquad (3.5) \\ V_m(e_{\theta_m}, e_{\theta_w}) &= \alpha_m \left[y\left(e_{\theta_w}, e_{\theta_m} \mid \theta_m, \theta_w\right) - \lambda\left(x\right) \phi e_{\theta_w} \right] + \alpha_w y\left(\underline{e}, 0 \mid \theta_m, \theta_w\right) \end{aligned}$$

From expression (3.5) the number of firms in the economy has distributive effects, as it changes the terms of trade between owners and workers inside the firm. We show that this externality has effects on agents' incentives to provide high effort.

Consider the incentive compatibility constraint of a type-θ owner, given that w exerts e_w. This is given by:

$$V_m(e_w, \overline{e}) - c(\overline{e}, \theta_m) \geq V_m(e_w, \underline{e}) - c(\underline{e}, \theta_m) = V_m(e_w, \underline{e}) \quad \Leftrightarrow$$

[9] Remark 3 is straightforward since for all $(e_{\theta_M}, e_{\theta_M}, x, s)$, from (3.1) and (3.2) and since $\lambda(s, x) < 1$, we have :

$$y\left(e_{\theta m}, e_{\theta w} \mid \theta_m, \theta_w\right) > y\left(e_{\theta_m}, 0 \mid \theta_m, \theta_w\right) + \widetilde{\lambda}(s, x) \phi e_{\theta_w}$$

$$\begin{aligned} & \alpha_m \left[y\left(\overline{e}, e_{\theta_w} \mid \theta_m, \theta_w\right) - \lambda\left(x\right)\phi e_{\theta_w}\right] + \alpha_w y\left(\overline{e}, 0 \mid \theta_m, \theta_w\right) - c(\overline{e}, \theta_m) \\ \geq \; & \alpha_m \left[y\left(\underline{e}, e_{\theta_w} \mid \theta_m, \theta_w\right) - \lambda\left(x\right)\phi e_{\theta_w}\right] + \alpha_w y\left(\underline{e}, 0 \mid \theta_m, \theta_w\right) \end{aligned}$$

This simplifies to the following incentive compatibility condition:

$$\begin{aligned} c\left(\overline{e}, \theta_m\right) \;\; \leq \;\; & \alpha_m \left[y\left(\overline{e}, e_{\theta_w} \mid \theta_m, \theta_w\right) - y\left(\underline{e}, e_{\theta_w} \mid \theta_m, \theta_w\right)\right] \\ & + \alpha_w \left[y\left(\overline{e}, 0 \mid \theta_m, \theta_w\right) - y\left(\underline{e}, 0 \mid \theta_m, \theta_w\right)\right] \end{aligned}$$

The incentive constraint for the type-θ_W worker, when the manager exerts effort e_M is:

$$V_w(e_m, \overline{e}) - c(\overline{e}, \theta_w) \geq V_w(e_m, \underline{e}) - c(\underline{e}, \theta_w) = V_w(e_m, \underline{e}) \Leftrightarrow$$

$$\begin{aligned} & \alpha_w \left[y\left(\overline{e}, e_{\theta_m} \mid \theta_m, \theta_w\right) - y\left(\overline{e}, 0 \mid \theta_m, \theta_w\right)\right] + \alpha_m \lambda\left(x\right)\phi\overline{e} - c(\overline{e}, \theta_m) \\ \geq \; & \alpha_w \left[y\left(\underline{e}, e_{\theta_m} \mid \theta_m, \theta_w\right) - -y\left(\underline{e}, 0 \mid \theta_m, \theta_w\right)\right] + \alpha_m \lambda\left(x\right)\phi\underline{e} \end{aligned}$$

what simplifies to the IC condition for the worker:

$$\alpha_w \left[y\left(e_{\theta_m}, \overline{e} \mid \theta_m, \theta_w\right) - y\left(e_{\theta_m}, \underline{e} \mid \theta_m, \theta_w\right)\right] + \alpha_m \phi\lambda\left(x\right)\left(\overline{e} - \underline{e}\right) \geq c\left(\overline{e}, \theta_w\right)$$

These IC inequalities make clear the effect of market externalities on incentives inside the firm. These effects are asymmetric for the owner and the worker:

Remark 4. *The incentive constraint of the manager is not (directly) affected by the total number of firms in the economy. On the other hand, increases in the total number of firms improve the worker's incentive to exert effort.*

In order to obtain the total number of firms in equilibrium, the following definitions will be useful:

Definition 2. *We call the worker's threshold type, $\widetilde{\theta}_w\left(x\right)$, the minimum value of θ such that an agent who is the owner of the asset in a firm will invest when the manager invests:*

$$\begin{aligned} c\left(\overline{e}, \widetilde{\theta}_w\left(x\right)\right) \;\; \equiv \;\; & \alpha_w \left[y\left(\overline{e}, \overline{e} \mid \theta_m, \theta_w\right) - y\left(\overline{e}, \underline{e} \mid \theta_m, \theta_w\right)\right] \\ & + \alpha_m \lambda\left(x\right)\phi\left(\overline{e} - \underline{e}\right) \end{aligned} \tag{3.6}$$

Definition 3. *We call the manager's threshold type,* $\widetilde{\theta}_m$*, the minimum value of* θ *such that an agent that is the owner of the asset in a firm will invest when the worker invests:*

$$\begin{aligned} c\left(\overline{e},\widetilde{\theta}_m\right) \equiv\ & \alpha_m\left[y\left(\overline{e},\overline{e}\mid\theta_m,\theta_w\right)-y\left(\underline{e},\overline{e}\mid\theta_m,\theta_w\right)\right] \\ & +\alpha_w\left[y\left(\overline{e},0\mid\theta_m,\theta_w\right)-y\left(\underline{e},0\mid\theta_m,\theta_w\right)\right] \end{aligned} \tag{3.7}$$

These threshold types set an upper bound on the total number of firms. From assumptions (3.1) and (3.2) it is clear that $\widetilde{\theta}_m \leq \widetilde{\theta}_w(x)$ for all values of x.

The total number of firms satisfies $x \leq N\frac{1}{2}\left(\overline{\theta}-\widetilde{\theta}_m\right)$, since agents with type $\theta < \widetilde{\theta}_m$ do not exert effort in any case as team members. On the other hand, if in equilibrium $\widetilde{\theta}_w(x) \geq \frac{1}{2}\left(\overline{\theta}+\widetilde{\theta}_m\right)$ the number of firms is given by $N\left(\overline{\theta}-\widetilde{\theta}_w\right)$ since for each individual that is eligible to be a worker there is an agent that is eligible to be a manager, but not vice versa. These conditions together with a fixed point condition on x, yield the total number of firms:

Proposition 5. *The total number of firms in the equilibrium with incomplete contracts,* x^e*, is a solution to:*

$$x^e = N\max\left\{0,\min\left[\left(\overline{\theta}-\widetilde{\theta}_w\left(x^e\right)\right),\frac{1}{2}\left(\overline{\theta}-\widetilde{\theta}_m\right)\right]\right\} \equiv \Lambda\left(x^e\right) \tag{3.8}$$

Moreover, all agents with $\theta \in \left[\overline{\theta}-2x^e,\overline{\theta}-x^e\right]$ *participate in the firm as managers (asset owners) and all agents with* $\theta \in \left[\overline{\theta}-x^e,\overline{\theta}\right]$ *participate as workers (not-owners).*

For two agents (θ, θ'), the condition:

$$(*) \equiv \left[\theta \geq \widetilde{\theta}_w\left(x\right) \text{and} \theta' \geq \widetilde{\theta}_m\right]$$

is sufficient for them forming a firm.Condition ($*$) is necessary for them forming a firm from Proposition 1. So we can restrict ourselves to pairs of agents that satisfy condition ($*$). In particular, agents with $\theta' \in \left[\widetilde{\theta}_m,\overline{\theta}\right]$ are potential managers only (PMO): they would never exert effort as workers. Agents with $\theta \in \left[\widetilde{\theta}_w, \overline{\theta}\right]$ are potential managers and workers (PMW): they would exert effort both as workers if matched with a manager with $\theta' \in \left[\widetilde{\theta}_m, \overline{\theta}\right]$ and also as managers, as long as matched with a worker with $\theta'' \in \left[\widetilde{\theta}_w, \overline{\theta}\right]$. Since $\widetilde{\theta}_m < \widetilde{\theta}_w$, there are three possible situations: 1) blocked entry. If $\widetilde{\theta}_w > \overline{\theta}$. In this case there are no agents that would exert effort as workers even if managers would exert effort. No managerial firms can enter. 2) scarce workers. If $\overline{\theta} - \widetilde{\theta}_w \leq \widetilde{\theta}_w - \widetilde{\theta}_m$. There are not enough workers for the number of (PMO). The number of managerial firms is set by the number of PMW. 3) scarce managers. If $\overline{\theta} - \widetilde{\theta}_w > \widetilde{\theta}_w - \widetilde{\theta}_m$. PMO are fewer than PMW. Some of the latter can be given property rights and matched with other (necessarily more efficient) PMW. The number of managerial firms is $1/2\left(\overline{\theta} - \widetilde{\theta}_w\right)$, such that all $\theta's$ with $\theta \geq \widetilde{\theta}_w$ are involved in a firm.

■

It is clear from the comparison of the efficiency condition (3.4) and the equilibrium condition (3.8) that x^e will in general be inefficient (x^e is in general suboptimal, since a team will not be formed if it does not generate positive surplus without agency problems).

The solution to (3.8) depends on the position of the mapping $\Lambda(x)$ relative to the identity mapping. It is straightforward to show:

Corollary 1 *From the concavity of* $\Lambda(x)$[10] *at least one solution always exists and the number of solutions is not bigger than three. If there are three equilibria* (x^o, x^{ue}, x^{se}) *we have:* $x^o = 0 < x^{ue} < x^{se}$ *and* (x^o, x^{se}) *are stable equilibria but* (x^{ue}) *is an unstable equilibrium.*

Consider the case where there are three equilibria: $(0 < x^{ue} < x^{se})$. The possibility of multiple equilibria is a direct consequence of incentive externalities: under no renegotiation (first best) there is only one equilibrium in the industry.

[10] $\Lambda''(x) \leq 0$ since:

$$\Lambda''(x) \in \left\{0, -\frac{\alpha_m \lambda''(x)\,\phi \Delta e c_\theta\left(\overline{e}, \theta(x)\right) - c_{\theta\theta}\left(\overline{e}, \theta(x)\right) \alpha_m \lambda'(x)\,\phi \Delta e}{\left(c_\theta\left(\overline{e}, \theta(x)\right)\right)^2} < 0\right\}$$

Under incomplete contracts, if agents believe that other agents will not enter, then human capital is not a "liquid" asset in the secondary market (ex post production): workers face poor outside opportunities and therefore high expropriation. Incentives are poor and agents do not start firms. The initial beliefs are confirmed. If agents believe that there will be many firms in the industry, the converse happens, good incentive conditions are anticipated and agents enter the industry.

■

3.3.2 Comparative statics

In this section we analyse the interaction between the mass of agents, N, and the degree of development of an economy. Parameter ϕ determined the efficiency of ex-post production. Let ψ and ρ be two additional parameters also related to efficiency:

- ψ is an index of efficiency in the cost function $c(\overline{e}, \theta, \psi)$, such that $c\left(\overline{e}, \overline{\theta}, \psi\right) = \underline{c}(\overline{e})$ and:

$$0 < \frac{\partial c(\overline{e}, \theta, \psi)}{\partial \theta} < \frac{\partial c(\overline{e}, \theta, \psi')}{\partial \theta} \Leftrightarrow \psi > \psi'$$

- ρ is a parameter of "efficiency" in the matching function $\lambda(x, \rho)$ such that

$$\forall x \in \left[0, \frac{1}{2}N\right], \qquad 1 > \lambda(x, \rho) > \lambda(x, \rho') \geq 0 \Leftrightarrow \rho > \rho'$$

Comparative statics allow us to analyse the interaction between these variables.

Proposition 6. *If*

$$c\left(\overline{e}, \overline{\theta}\right) > \alpha_W \left[y(\overline{e}, \overline{e} \mid \theta_M, \theta_W) - y(\overline{e}, \underline{e} \mid \theta_M, \theta_W)\right] \tag{3.9}$$

then, $x^{se} = 0$ *is a solution to (3.8). Moreover,*

a. *for* $z = \{N, \psi, \rho, \phi\}$ *there is a 'critical value'* $\widehat{z} = \left\{\widehat{N}, \widehat{\psi}, \widehat{\rho}, \widehat{\phi}\right\}$ *such that:*

$$\begin{aligned} \textit{for} \quad z &< \widehat{z}, x^{se}(z) = x^{o}(z) = x^{ue}(z) = 0 \\ \textit{for} \quad z &> \widehat{z}, x^{se}(z) > x^{ue}(z) > x^{o}(z) = 0 \\ \textit{and}\, x^{se}(z) &> 0 \quad \textit{otherwise} \end{aligned}$$

b. *Moreover, for increments in* z *beyond* $\widehat{z}$ *we have:*

$$\frac{\partial x^{se}}{\partial z} \geq 0 \ \textit{and} \ \frac{\partial x^{ue}}{\partial z} \leq 0$$

From condition $c\left(\overline{e}, \overline{\theta}\right) > \alpha_w \left[y\left(\overline{e}, \overline{e} \mid \theta_m, \theta_w\right) - y\left(\overline{e}, \underline{e} \mid \theta_m, \theta_w\right)\right]$ it is clear that the most efficient type $\overline{\theta}$ cannot enter as a worker when $x = 0$. With no workers in the economy there are no firms and $x^e = 0$ is an equilibrium. But $\Lambda(x)$ is strictly increasing in x : there exist a number of firms x_o such that $\Lambda(x) = 0$ for $x \leq x_o$ and $\Lambda(x) > 0$ for $x > x_o$. Since $\Lambda(x)$ is linear in N the proposition follows.

■

Proposition 6 shows the existence of increasing returns to scale in the economy with incomplete contracts, even if the underlying technology is of constant returns to scale.

From Proposition 6 there is a discontinuity in the relationship between the development characteristics of the economy and industrial activity. Below a certain development level there is no activity. Beyond that level there are equilibria that support positive industrial employment. In particular, the stable equilibrium implies a greater level of employment in the economy. As the size of the economy increases (or as the economy becomes more efficient) the employment level implied by the stable equilibrium increases, whereas the employment level in the unstable equilibrium decreases.

Since the transaction costs and the inefficiency in the economy are proportional to the critical mass, $\widehat{N}$, proposition 6 shows a connection between technological progress and transaction costs. Technological progress reduces transaction costs, since it reduces the critical size of the economy required to start production. Moreover, if we interpret this to mean that the density of the economy in a region increases the efficiency if the matching function λ, increases in economic density reduce transaction costs inside the firm and reduce the minimum start-up scale of a sector.

3.4 Empirical Implications

The main finding of the previous section is that under incomplete contracts (and therefore aggregate increasing returns) there are in general (if levels of development and/or population are sufficiently low) multiple equilibria, with industrial delocation as one of the equilibria. On the other hand, in the economy with complete contracts and constant returns technology, industries have one equilibrium level of employment that is positive. In this section we explore this theoretical implication: it is more likely to find evidence of multiple equilibria and industrial delocation in less developed regions than in more developed regions[11].

We distinguish between regions, $i \in \{1, ..., I\}$, productive sectors, $j \in \{1, ...j\}$, and time periods, $t \in \{0, ...T\}$. Let y_t^{ij} be the number of employees[12] in sector j, and region i, at time t. A region i at time t is characterised by its population mass N_{it},and its degree of technological development or efficiency, (ψ_{it}, ϕ_{it}).

With a straightforward dynamic interpretation to the schedule in (3.8), given y_t^{ij} the subsequent number of firms, y_{t+1}^{ij},is[13]:

$$y_{t+1}^{ij} \equiv \Lambda_i \left(y_t^{ij}, z_{it} \right)$$

Total sectorial employment in the next period in region i depends non-linearly on this period's existing sectorial employment and on the character-

[11]It is important to notice that, if this empirical pattern is true, it can be explained by other theories of aggregate increasing returns different to our theory based on contracting externalities. We make no attempt here of empirically selecting the best theory to explain multiple equilibria. We simply argue that multiplicity of equilibria is inconsistent with the constant returns/complete contracts model and it is not inconsistent with the constant returns(at firm level)/incomplete contracts setting.

[12]In the model y is proportional to the number of teams x, equal to $\frac{1}{2}y = x$.

[13]It is straightforward to show that $\Lambda(y_t)$ is the actual number of employees at $t+1$ if the model described in the theoretical section represents the economy at period t and there is an arbitrary and discrete number of periods.

istics of the region. In order to approximate the mapping Λ, we specify the following equation:

$$\tilde{y}_{t+1}^{ij} = \max\left\{0, \left(a_0 + a_1\tilde{y}_t^{ij} + a_2\left(\tilde{y}_t^{ij}\right)^2 + \sum_{r=1}^{R} b_r\ z_t^i(r) + \tilde{\varepsilon}_t^{ij}\right)\right\} \tag{3.10}$$

The censored structure of (3.10) follows from (3.8) and from y_t^{ij} being a stock. We assume independence and normality of the error term: $\tilde{\varepsilon}_t^{ij} \sim N(0, \sigma^2)$. The coefficients (a_0, a_1, a_2) capture the non linearities[14] in Λ. The coefficients $(b_1, ..., b_r, ..., b_R)$ capture the dependence of Λ on the regional scale and development characteristics: $\{z_t^i(r)\}_{r=1}^{R}$, as predicted by Proposition 2.

Table 1 exhibits the necessary conditions for the parameters (a_0, a_1, a_2) in (3.10) to be consistent with the existence of only one equilibrium and multiple equilibria in the industry:

Table 1

Restriction a_0, a_1, a_2

One equilibrium	**Multiple equilibria**
$a_0 > 0$	$a_0 < 0$
$a_1 \geq 0$	$a_1 > 1$
$a_2 < 0$	$a_2 < 0$

If there are three equilibria, we call the unstable equilibrium $y^{ue} \in (0, y^{se})$ the *critical mass* of the sector, since the industry has $y_t < y^{ue}$ sectorial employment converges to zero (or the sector follows a *delocation process*).

From Proposition 3, we expect the coefficients $(b_1, ..., b_r, ..., b_R)$ related to development effects to be positive. The coefficients in b_r are interpreted as correlations between the development and scale characteristics of the region and the increase of sectorial employment. Positive values of b_r shift upwards the $\Lambda()$ schedule, implying that industry dynamics in large or developed regions have a smaller critical size (unstable steady state x^{ue}) in industry size.

Our empirical strategy is as follows. We construct in the first place proxy variables to implement equation (3.10) and show descriptive statistics. We

[14]We expect $\Lambda()$ to be concave: see footnote 9.

estimate the censored endogenous variable (*tobit*) model in (3.10) by maximum likelihood. We test the unique versus multiple equilibria hypothesis, according to the definition in Table 1.

3.4.1 Data

We have collected data from a number of sources: the data on the employment stock in sectors, regions and years is extracted from the Active Population Survey (*Encuesta de la Población Activa*) of the National Institute for Statistics (*INE*), the data on regions' unemployment rate is taken from the *Regional Accounts* of the Spanish Ministry of Economy; and the figures for regions' populations are from the Census. Finally, the data on regional gross product is from the BBV Foundation's Statistical Sourcebook. More precisely, our proxy variables are constructed as follows:

- $\tilde{y}_t^{it}$ is defined as the total number (in tens of thousands) of employed individuals in (i, j) in year t, as recorded in the Spanish Population Survey
- N_{it} is the population size of region i at time t
- ψ_{it}, ϕ_{it} are related to the technological efficiency of the economy. We use the gross product per capita statistic and the number of patents issued in region i as proxy variables
- We introduce in addition a number of control variables. In particular we use information on the regional unemployment rate and an index of region's specialisation (constructed from the employment data)

Table 2 the descriptive statistics of the proxy variables, the controls and some of their cross-products.

Table 2

Descriptive statistics of the proxy variables in equation (3.10)

Variable	**Mean**	**Std Dev**	**Min**	**Max**
$\frac{\textit{Stock employed}}{10{,}000} \equiv \left(y_{t+1}^{it}\right)$ Period [1987-92]	0.19	0.56	0.00	9.40
$\frac{\textit{Lagged stock employed}}{10{,}000} \equiv \left(y_{t}^{it}\right)$ Period [1986-91]	0.20	0.56	0.00	9.58
$\left(\frac{\textit{Lagged stock employed}}{10{,}000}\right)^2 \equiv \left(y_{t}^{it}\right)^2$	0.35	3.19	0.00	91.77
Gross product per capita$_{it}$ in m Ptas	1.09	3.83	0.48	2.15
log of population$_{it}$	13.19	0.80	11.45	15.43
Income per capita x log of population	14.41	4.43	6.44	30.02
Number of patents issued$_{it}$	39.94	107.00	0.00	729.00
Index of specialisation$_{it}$	0.16	0.56	0.01	1.00
Unemployment rate$_{it}$	18.01	1.59	16.21	20.53

3.4.2 Estimation results

The main inferences from our model are the existence of multiple equilibria in industry dynamics and the negative correlation between the critical size of industrial sectors (measured by unstable steady state size of the industry) and the scale and the development of the region. There is a reinforcement effect where regional development and scale reduce the probability of industrial delocation. The reinforcement effect arises because the larger scale of the economy improves incentives conditions, directly fostering the formation of firms.

Table 3 shows the result of estimating the censored endogenous variable (*tobit*) model in equation (3.10) by maximum likelihood, with different subsets of the variables in Table 2. Model 2 estimates the region's fixed effects. The significant fixed effects coefficients from Model 2 are reported in Table 4.

Table 3

Estimation of (3.10)

Number of observations: 7309

	Model 1	**Model 2**	**Model 3**	**Model 4**
Log likelihood	-1,366	-1,404	-1,399	-1,410
Variable:				
Constant	-0.5298 (0.0190)*	-0.0306 (0.0108)*	-1.0440 (0.1169)*	-1.1761 (0.1215)*
y_{t-1}^{ij}	1.0834 (0.0052)*	1.0561 (0.0064)*	1.0649 (0.0062)*	1.0588 (0.0063)*
$\left(y_{t-1}^{ij}\right)^2$	-0.0139 (0.0009)*	-0.0097 (0.0010)*	-0.0100 (0.0009)*	-0.0100 (0.0009)*
Income per capita			0.7403 (0.1013)	0.9372 (0.1103)*
log(population)			0.0747 (0.0088)*	0.830 (0.0090)*
Income p.c. × log(pop)			-0.0554 (0.0076)	-0.0706 (0.0084)*
Number of patents				0.0001 (0.00003)*
Unemployment rate				0.0012 (0.0012)
Especialisation				0.0105 (0.0126)
Regional dummies	no	yes	no	no

(*): significant at 1% level

In all four models shown in Table 3 we reject the null hypothesis that there is a unique industrial steady state, since the intercept term, a_0, is negative and significant, the slope of Λ at the origin, a_1, is greater than one (at 1% level) and the estimated $\Lambda(y_t)$ mapping is concave in y_t (a_2 is negative and significant). Given the estimated hypothesis, we find that there are three equilbria in the average industry: no activity, $y = 0$, being an equilibrium and two more equilibria, y^{ue} and y^{se}, that satisfy the estimated equation $(y^{ue}, y^{se}) = E\hat{\Lambda}\ (y^{ue}, y^{se})$. The stable equilibrium is greater than the unstable one ($y^{ue} < y^{se}$).

Are sectorial dynamics different in developed regions and less developed regions? Model 2 introduces a regional fixed effect, that measures the difference of the regional intercept with the intercept of the excluded region[15]. We find ten regions with an intercept a_0 significantly smaller than that of the excluded regions (that was already negative). This means that the Λ schedule shifts downwards for these ten regions and that they have greater critical mass of industry and a smaller steady state. These ten regions are listed in Table 4 below the entry for Barcelona.

Table 4 shows the difference between the intercepts of the included regions and the intercept of the excluded region ($a_{0i} - a_{01}$), the smaller root of the estimated difference equation (the critical mass x^{ue}), the regions' populations (in level) and the gross product per capita as of 1987. Notice that all ten regions are sparsely populated (the average population of the regions is 535,000 inhabitants) and have product per capita smaller that the national average of 1.09 mPtas (see Table 2). The estimated sectorial critical mass for the sparse regions ranges from 620 employees in Cáceres to 903 in Zamora (to be compared with the absence of a critical mass in the large scale region of Barcelona).

At the other extreme of the spectrum we find that the fixed effect of Barcelona's region os significantly greater that the excluded region (this is also the case for Madrid, but the coefficient is not significantly different to zero). The intercept term for Barcelona is estimated as non-negative. This implies that for this region we accept the hypothesis that there is only one steady state and a critical mass of the industry does not exist.

[15] The excluded region in the regression is Álava, a relatively industrial and developed region. This explains why most of the estimated fixed effect coefficients in Model 2 are negative.

Table 4
Dummy variables estimated in Model 2
that are significant at 5% level

Region	$a_{0i} - a_{01}$ (std dev)	x_i^{ue}	N_i	**Product p.c.**
Barcelona	0.005 (0.173)	$\emptyset$	4,629,176	0.9561
Cáceres	-0.0347 (0.0168)	620	422,347	0.6982
Albacete	-0.0348 (0.0159)	620	346,793	0.5867
Soria	-0.0382 (0.0169)	652	97,915	0.8511
Teruel	-0.0414 (0.0169)	682	149,423	0.8459
Almería	-0.0427 (0.0170)	695	446,200	0.7183
Lleida	-0.0438 (0.0168)	705	352,350	1.0793
Ávila	-0.0454 (0.0171)	720	182,634	0.6508
Lugo	-0.0461 (0.0170)	727	406,123	0.6204
Cuenca	-0.0588 (0.0173)	847	213,812	0.6023
Zamora	-0.0647 (0.0176)	903	222,240	0.6712

A clearer picture of the relationship between the scale of the regions and development on one hand and the size of the industrial mass on the other hand, can be drawn from Model 3 and Model 4 in Table 3. The coefficients for gross product per capita and logarithm of population are positive and significant. Scale and development alter industry dynamics, reducing the critical mass x^{ue}. But absolute scale and development do not complement each other to reduce critical mass, as revealed by the negative (and significant) interaction term *Income p.c.* $\times$ *log (pop)* in Model 3 and in Model 4. Large scale *or* development are each by themselves sufficient to reduce the probability of industrial delocation. That is, regions with a sufficiently large population but a small gross product per capita have a small critical mass in industries. Conversely, small regions with sufficiently large gross product per capita are likely to avoid a "delocation trap". However, regions that are *both* small in size and have a small gross product per capita have a large sectorial critical mass. Table 4 exhibits in rows 2 to 12 the ten regions with the largest critical size. In these ten regions a negative sectorial shock that sets the level of employment below its critical mass x^{ue} starts a delocation process that can lead to the end of sectorial activities in the region.

In the remaining 39 regions, the intercept term is not statistically different to the one of the excluded region (Álava) equal to -0.0306, the constant in Model 2 in Table 3. This intercept term implies a critical size of 210 employees, a middle ground between the case of Barcelona and the ten sparse regions in Table 4.

3.5 Conclusions

We have derived a theory of increasing returns to human capital that does not arise directly from the assumptions on the productive technology. Our theory starts from a simple observation. As the scale of an economy increases, the number of inefficient re-allocations of factors increases exponentially. Inefficient re-allocations serve as outside options to agents when bargaining for the terms of trade. Although these options do not directly contribute to social welfare, they change agents' incentives to engage in human capital investments. With transaction costs deriving from inefficient ex post bargaining, we find that in the decentralised equilibrium there are generally increasing returns to scale.

As opposed to other theories of agglomeration based on transaction costs derived from ex post bargaining (Acemoglou (1996)), our theory does not rely on search externalities. It does not rely either on the idea of distorting the capital-labour ratio from the optimal ratio, so as to make labour "scarce" and force capital to compete for labor. In our setting there are centralised factors' markets ex ante (although there is search -out of the equilibrium path- for secondary markets) and the proportion of factors at production is the efficient one. The source of increasing returns relates to the fact that the economy produces for free a good that is valuable under transaction costs:

the possibility of inefficient re-allocation of factors.

We have shown how to use the theoretical model to restrict the data. In particular, our fixed-point equilibrium condition is used to specify a dynamic equation of the number of new firms as a function of scale and measures of activity, in a region and sector. The theory leads to a censored first-order non-linear difference equation for the level of sectorial employment in regions. Our estimates of the difference equation are consistent with the existence of multiple steady states in sectors and with the existence of a sectorial critical mass. In particular, if a sector suffers a shock that sets total sectorial employment below the critical size, industrial delocation follows and leads to the collapse of sectorial employment in the region.

We find substantial differences across regions. In densely populated or developed regions the average critical size of sectors is smaller (even non-existent in one case) than in sparsely and less developed regions. There is a positive reinforcement effect in development, in the sense that greater development reduces the probability of industrial delocation.

On the other hand we are not able at this stage to empirically distinguish between our theory of agglomerations and other theories.

Chapter 4

Interaction amongst Agents with Moral Hazard and Adverse Selection

There is a principal who faces adverse selection and moral hazard simultaneously. The agents have private information about which is the best organisation – either working together or separated – for a given project. The agents, since they are risk averse, are willing to work together to insure each other. The principal has two basic problems. The first is to motivate the agents so that they work hard on their own projects. The second is to avoid that agents work together when it detrimental for the success of projects. We find a solution in which the risk given to solve the moral hazard solves as well the adverse selection problem.

4.1 Introduction

A principal has two projects to delegate to two different agents. She faces a twofold challenge. First, *moral hazard*, that is, to promote the best level of effort on each project in order to maximise profits. The second, *adverse selection,* is related to the organisation of both projects. The principal has to decide whether to place the agents working together, say for example in the same office, or to separate them. This depends on the nature of the projects. There are certain tasks which are better performed by being with other workers doing similar tasks. In this model, when interaction is beneficial, positive synergy arises between the agents. This synergy increases the likelihood of a good outcome. On the other hand, other types of tasks are not benefited or are hindered by interaction, meaning that no positive synergy appears between the agents.

In our model, the principal does not have sufficient knowledge to decide whether the agents will perform better working together or separated. The principal is unsure whether the synergy effect will or will not outweigh the mutual insurance effect. Conversely, the agents, who are specialists in their own field, know precisely what will be the effect on the project of working with someone else, but always want to work together to insure against possible bad outcomes. The principal has to design a contract that gives incentives to the agents to self-select.

The solution to the model is such that the risk given to solve the moral hazard in the possible team organisation for the project is enough to get rid of the adverse selection. In other words, the contract that gives incentives to exert high effort also induces agents to self-select.

The literature has widely studied the problem with a principal and several agents. I. Macho (1991) is extensive on this subject. She explains what are the incentives and contracts in the case where there is only information about the output of the team versus where the information is on the individual output. She also explains the best action to take in cases where collaboration among agents is harmful for the principal or in cases where it is good. Tirole (1986) proposes a model where coalitions are harmful. He describes the behavior of an agent and his supervisor. When facing their principal, they manipulate the information, which benefits themselves and has bad consequences for the principal. On the other hand, there are articles which show that, when there exist complementarities between agents, it is profitable to the principal that they work together. These models analyse the question under the problem of moral hazard. For instance, Itoh (1991) models a principal with two agents who may cooperate or not. He describes situations in which collaboration between the agents is desirable and computes incentive schemes for individual workers and for teams. I. Macho and D. Pérez (1993) study the case where cooperation between two agents is profitable, and compare the different cases depending on agents' cooperative behavior. However, none of these models takes into account that, in many situations, it is the agent himself who better knows whether collaboration is beneficial or not. In other words, the agent is more able than the principal to tell whether projects are better performed by working with someone else or not. This chapter aims to be a contribution in that direction. Additionally, in the literature, the adverse selection problem usually arises because of efficiencies in costs. In our model, we explore the case of the efficiency being translated into higher probability of success rather into lower costs.

The next section in the present chapter describes the model. In section 3 we provides the solution to the case where agents and projects are symmetric. First, we solve the problem of moral hazard, and then we show that the (second) best contract under moral hazard solves the adverse selection problem. In section 4 we summarise the main conclusions.

4.2 Description of the Model

A risk-neutral principal has two similar projects to delegate. Separately, she contracts two risk averse agents, $j = 1, 2$, and assigns one project to each one of them. The monetary outcome of each project, x_i^j, is observable and can be either a success or a failure ($i = S, F$, with $x_S^j >> x_F^j$ for all j). We denote $x_{ik} = x_i^1 + x_k^2$, where $i, k = S, F$.

Each agent chooses an action (effort), unobservable to the principal and to the other agent, from the set $e \in \{e^h, e^\ell\}$, where $e^h > e^\ell$. e^h represents the situation where the agent works "hard" and e^ℓ where he is lazy. With the level of effort spent on the project, the agents determine the probabilities associated to the outcomes. Let $p^h = p_S(e^h)$ be the probability that outcome x_S takes place when the agent chooses high effort (the probability associated to outcome x_F is then $p_F^h = 1 - p^h)$). Similarly, we define $p^\ell = p_S(e^\ell)$ when the agent chooses low effort.

(A1) We assume $p^h > p^\ell$, hence the monotone likelihood property is satisfied

— when the principal observes x_S, she can infer that the agent may have chosen e^h rather than e^ℓ.

(A2) The probabilities associated with the outcomes change depending on the type of project and on the organisation of work the principal decides to implement. She can either separate the agents or put them together. If they are together, they interact with each other and this affects the probability distribution over the final outcomes. Only the agents know the most appropriate type of organisation for the projects by recognising if the project may be better performed with collaboration. Projects are be said to be of type θ^+ when they are better performed with interaction, and of type θ^- when interaction has no effect.

Good interaction means that the probability of x_S increases under high effort, and remains the same under low effort. We denote $\tau(e)$ as the probability of x_S under interaction with projects of type θ^+, with

$$1 > \tau^h > p^h > 0$$

With low effort the probability of success stays p^ℓ. And when projects are of type θ^-, the probabilities remain the same, $p(e)$.

(A3) Agents' reservation utility is $\bar{U}$ and their utility function is of the von Neumann-Morgernstern type

$$U(w, e) = u(w) - v(e)$$

where $v(\cdot)$ determines the cost of effort to the agent[1]. We set $v(e^\ell) = 0$ and $v(e^h) = v$. We will assume that the probabilities, $p_i(e)$ and $\tau_i(e)$, and the outcomes, x_i, are such that the principal wants to implement high effort[2]. Hence, the first problem the principal has to solve is moral hazard. She has to design the appropriate incentives so that the agents work hard.

Let m be the monetary wage that the agents receive by working in the project. We assume that both agents are risk averse, $u_m > 0$ and

[1]Models in which agents collaborate in their colleagues' projects assume that this collaboration has a cost. In our model we are talking about "interaction". Even if agent j may feel concerned about agent $-j$'s project, he does not spend any effort on it. Interaction has no cost or a negligible one.

[2]Given $v, u(\cdot), \bar{U}$ for this is enough to assume $x_S - x_F$ to be large enough.

$u_{mm} < 0$. They know that one way to better bear the risk is to receive insurance from someone else. By giving one part of his wage, m^j, when he has a success and getting a part of m^{-j} when he has a failure and the other gets a success, he will be better off.

The conflict between the principal and the agents appears because the principal is willing to split the workers up when interaction does not have any good effect for the project. By interacting, agents would insure each other and, thus, affect the incentives they have to work hard. On the other hand, the agents, are risk averse and willing to work together to diversify their risks.

Since the principal wants the agents to self-select, she proposes a different wage scheme to each agent depending on the type of organisation. Let $r \equiv \{r_S, r_F\}$ be the wages that the principal proposes to the agent if he wants to work alone. And $w \equiv \{w_{SS}, w_{SF}, w_{FS}, w_{FF}\}$, when he interacts with the other agent[3]. Since agents insure each other, they do not consider w_i^j directly into their utility function because they know that by insuring they get a proportion of the sum of wages (ie, $\alpha^j(w_{ik}^j + w_{ik}^{-j})$, where α^j stands for the proportion of the team-wage that agent j gets).

4.3 Solution of the Symmetric Case

This section assumes that projects have the same monetary outcomes, that both agents have the same utility function over wages, have the same cost of effort and that they are paid the same[4]. We focus on the symmetric outcome where $x_{SF} = x_{FS}$ and $w_{SF} = w_{FS}$. Also, since agents receive the same wage for the same outcome and it is natural to assume that they have the same power of negotiation, they share payoffs with $\alpha = \frac{1}{2}$ when they work together.

First we investigate the first best solution. This solution shows us that under perfect information, ie, when the principal distinguishes types and

[3]In the literature, when a principal wants to encourage collaboration between two agents, she designs the wages such that w^j depends on x^j and on x^{-j}, then agent j feels involved in $-j$'s project. In this case we do not need to impose this dependence because it arises naturally. The reason is that we are talking mainly about "interaction". The probabilities increase and decrease because agents are actually together.

[4]This assumption simplifies the analysis. The case where agents are different and projects pay different outcomes would not affect the main conclusions.

verifies the level of effort and the project type, there is optimal risk sharing. The risk neutral participant in the contract, the principal, completely insures the risk averse agents by giving the same constant wage independently of the outcome.

Afterwards we solve the problem when there is imperfect information about effort in both cases, when agents are separated and when they are together. We get a menu of two contracts, one for each type of organisation.

Finally we study the cases where this menu of contracts is already self-selective.

4.3.1 The First Best

The solution when there are no asymmetries of information provides the first best. When the principal can verify agents' efforts and is able to tell whether interaction between agents is better for the projects, she only has to give incentives so that the agents participate.

Because information is symmetric and the principal wants to maximize profits, she will pay the agent a wage that just covers the effort cost plus the reservation utility. The wage is the same in both cases, when projects are of type θ^+ and when they are of type θ^-.

$$m^B = u'^{-1}(\bar{U} + v) \qquad \forall i, k = S, F$$

In the first best solution the principal gets the maximum expected profits and the agent bears no risk and gets no extra rents.

4.3.2 Imperfect Information

First we see how the principal solves the moral hazard and calculates the incentives she gives to the agents so that they choose e^h for their own project. Then, we analyse whether the contract is self-selective.

The Moral Hazard Problem

The principal, independently of the type of organisation, wants that the agents work hard. She has to solve the moral hazard in both cases, when agents are separated and when agents are together.

(a) Agents working separated

Since both agents are equal and projects pay the same, the principal has only to solve the problem for one of them and she gets the solution for both.

The optimization program is the following:

$$\max_{\{r_S, r_F\}} \left\{ p^h(x_S - r_F) + (1 - p^h)(x_F - r_F) \right\}$$

subject toto

Participation Constraint:

$$p^h u(r_S) + (1 - p^h)u(r_F) - v \geq \bar{U} \tag{4.1}$$

Incentive Compatibility Constraint:

$$p^h u(r_S) + (1 - p^h)u(r_F) - v \geq p^\ell u(r_S) + (1 - p^\ell)u(r_F) \tag{4.2}$$

Constraint (4.1) ensures that the expected utility that agents receive is at least their reservation utility level. Now effort is not observable. Hence the principal needs to constrain more the optimisation program. The second constraint, (4.2), guarantees that agents choose e^h rather than e^ℓ.

Two results can be derived from both constraints[5].

Remark 5. *The principal gives to the agents a expected utility level equal to* $\bar{U}$.

This remark means that the first constraint of the optimisation program is binding. This comes from the fact that the principal wants to maximise profits. Hence she insures the minimum to the agents, only to make sure that they agree to participate.

[5]Since these results have been largely discussed in the literature (for a more detailed and rigorous discussion about them the reader should refer to Hölmstrom (1979)). We only give the intuition behind them.

Remark 6. *In the case where agents are separated, wages depend on outcomes. The complete insurance they got when the principal could verify effort and types does not take place anymore with asymmetric information.*

Wages increase with i because there is a "noisy" causality between effort and outcomes – if high wages are an incentive to make high effort, and if with high effort the successful outcomes are more likely to happen, wages have to be increasing in with the outcomes.

This maximisation allows to calculate the wages (ie the contract) that eliminate the problem of moral hazard, $r^\star \equiv \{r_S^\star, r_F^\star\}$.

Note that there is no optimal risk sharing anymore. Agents receive a payoff when the outcome is x_S and another when it is x_F. Hence, the risk neutral principal gives risk to the risk averse agents. Furthermore, while the agents get the same expected utility, the principal receives less expected profits. Thus, we get a *second best* solution.

(b) Agents working together

The principal would like the agents to work together only when the probability of a good outcome becomes τ^h. Then, the contract that the principal offers to agents working together arises from the following maximisation problem[6].

$$\max_{\{w_{SS}, w_{SF}, w_{FF}\}} \left\{ \tau^{h^2}(x_{SS} - 2w_{SS}) + 2\tau^h(1-\tau^h)(x_{SF} - 2w_{SF}) + (1-\tau^h)^2(x_{FF} - 2w_{FF}) \right\}$$

subject toto

Participation constraint:

$$\tau^{h^2} u(w_{SS}) + 2\tau^h(1-\tau^h)u(w_{SF}) + (1-\tau^h)^2 u(w_{FF}) - v \geq \bar{U} \tag{4.3}$$

Incentive compatibility constraint:

[6] As before, we only need to solve the problem for one agent. Since agents are equal, the solution for one of them can be directly applied to the other one.

$$\tau^{h^2} u(w_{SS}) + 2\tau^h(1-\tau^h)u(w_{SF}) + (1-\tau^h)^2 u(w_{FF}) - v \geq \tag{4.4}$$

$$\tau^h p^\ell u(w_{SS}) + \tau^h(1-p^\ell)u(w_{SF}) + p^\ell(1-\tau^h)u(w_{SF}) + (1-\tau^h)(1-p^\ell)u(w_{FF})$$

Constraint (4.3) ensures the minimum expected utility to the agent. Constraint (4.4) tells us that each agent's best response to his colleague'ss high effort must be high effort as well[7].

Setting λ_2 and μ_2 as the Kuhn-Tucker multipliers, the first order conditions of the maximisation problem are the following:

$$\begin{aligned} \frac{2(\tau^h)^2}{u'(w_{SS})} &= \lambda_2(\tau^h)^2 + \mu_2\left[(\tau^h)^2 - p^\ell\tau^h\right] \qquad (4.5) \\ \frac{4\tau^h(1-\tau^h)}{u'(w_{SF})} &= 2\lambda_2\tau^h(1-\tau^h) + \mu_2\left[2\tau^h(1-\tau^h) - (p^\ell(1-\tau^h) + (1-p^\ell)(\tau^h))\right] \\ \frac{2(1-\tau^h)^2}{u'(w_{FF})} &= \lambda_2(1-\tau^h)^2 + \mu_2\left[(1-\tau^h)^2 - (1-p^\ell)(1-\tau^h)\right] \end{aligned}$$

From these[8] we derive Remark 3 and Remark 4, which are the related to Remark 1 and Remark 2, but applied to the case when agents work together.

Remark 7. *In the case that agents interact, the expected utility they get is the reservation utility level.*

For that to be the case, constraint (4.3) has to be binding and hence the multiplier $\lambda_2 > 0$. It can be shown by adding up the first order conditions (4.5) over i and over k we have

[7]This could be related to a Nash equilibrium. We assume that, if agents indifferent between (e^{ℓ^1}, e^{ℓ^2}) and (e^{h^1}, e^{h^2}), they choose what is better for the principal.

[8]Note that the one in the middle is in fact the sum of two conditions. This is because $w_{SF} = w_{FS}$.

$$\sum_i \sum_k \frac{2\tau_i^h \tau_k^h}{u'(w_{ik})} = \lambda_2 \qquad \forall i, k = S, F$$

which shows that λ_2 can only be positive. The expected utility that agents receive is equal to $\bar{U}$. As we explained above, this is consistent with the goal of the principal of maximising profits.

Remark 8. *Wages w_{ik} are increasing with the outcome.*

The first order conditions (4.5) can be rewritten as follows:

$$\begin{aligned}
\frac{2}{u'(w_{SS})} &= \lambda_2 + \mu_2 \left(1 - \frac{p^\ell}{\tau^h}\right) \\
\frac{2}{u'(w_{SF})} &= \lambda_2 + \mu_2 \left(1 - \frac{p^\ell(1-\tau^h) + (1-p^\ell)(\tau^h)}{2\tau^h(1-\tau^h)}\right) \\
\frac{2}{u'(w_{FF})} &= \lambda_2 + \mu_2 \left(1 - \frac{(1-p^\ell)}{1-\tau^h}\right)
\end{aligned} \tag{4.6}$$

If $\mu_2 = 0$ the wage would be constant for every i and for every k. This would be inconsistent with the principal's wish to implement e^h. With a constant wage and non-verifiable effort agents would choose to be lazy. Hence the multiplier must be $\mu_2 \neq 0$. Furthermore, the quotients of joint probabilities in equations (4.6) satisfy the Monotone Likelihood Ratio property, with higher effort the quotient becomes smaller. Therefore, if the wage has to increase with the outcome μ_2 has to be positive. Note that:

$$\frac{1}{u'(w_{SS})} + \frac{1}{u'(w_{FF})} = \frac{2}{u'(w_{FS})} \tag{4.7}$$

From this maximisation, the contract $w^\star \equiv \{w_{SS}^\star, w_{SF}^\star, w_{SS}^\star\}$ can be calculated.

The Adverse Selection Problem

The parameter the agents know is the type of the projects. The conflict appears when agents want to be together to insure each other even if projects are of type θ^-, because in this case the principal wants them to work separately.

To analyse this situation the following definitions will be useful

Definition 4. *We define the principal and agents' possible expected utilities depending on the project types and the contract the agents choose:*

- $E\Pi_t^+(w^\star)$*: The expected profits for the principal when projects are of type* θ^+ *and agents choose to work together*

  $E\Pi_t^+(w^\star) = \tau^{h^2}(x_{SS} - 2w^\star_{SS}) + 2\tau^h(1-\tau^h)(x_{SF} - 2w^\star_{SF}) + (1-\tau^h)^2(x_{FF} - 2w^\star_{FF})$

- $E\Pi_s^-(r^\star)$*: The expected profits for the principal when projects are of type* θ^- *and agents work separated*

  $E\Pi_s^-(r^\star) = 2\left((p^h(x_S - r^\star_S) + (1-p^h)(x_F - r^\star_F)\right)$

- $EU_t^+(w^\star)$*: The expected utility for the agent when projects are of type* θ^+ *and he interacts with the other agent*

  $EU_t^+(w^\star) = \tau^{h^2}u(w^\star_{SS}) + 2\tau^h(1-\tau^h)u(w^\star_{SF}) + (1-\tau^h)^2u(w^\star_{FF}) - v$

- $EU_s^-(r^\star)$*: The expected utility for the agent when projects are of type* θ^- *and he works alone*

  $EU_s^-(r^\star) = p^h u(r^\star_S) + (1-p^h)u(r^\star_F) - v$

- $EU_t^-(w^\star)$*: The expected utility for the agent when projects are of type* θ^- *and he interacts with the other agent*

  $EU_t^-(w^\star) = p^{h^2}u(w^\star_{SS}) + 2p^h(1-\tau^h)u(w^\star_{SF}) + (1-p^h)^2u(w^\star_{FF}) - v$

In the previous subsection, the solution to the moral hazard problem is such that the expected utility that the agent receives is always equal to $\bar{U}$ both if they work together and if they work separately.

$$EU_t^+(w^\star) = EU_s^-(r^\star) = \bar{U} \tag{4.8}$$

Now we want to know if this solution to moral hazard is already self-selective. Or if, on the contrary, the principal will have to distort wages even more to motivate the agents to tell the truth about project types.

The situation we are going to analyse is the one where projects are of type [9] θ^-. So that a conflict between the agents and the principal arises, the following must happen:

$$E\Pi_s^-(w^\star) \quad < \quad E\Pi_s^-(r^\star) \tag{4.9}$$

$$EU_t^-(w^\star) \quad > \quad EU_s^-(r^\star) \tag{4.10}$$

That is, when projects are of type θ^-, the principal expects more profits if agents choose the menu of contracts $\{r_S^\star, r_F^\star\}$ (thus, choose to work separated), while the agents would get more expected utility by choosing $\{w_{SS}^\star, w_{SF}^\star, w_{FF}^\star\}$.

Proposition 7. *The risk given to solve the moral hazard is also a self-selective mechanism. That is, it solves the adverse selection problem as well.*

Equations (4.9) and (4.10) mean that the agents would lie to the principal if the following was true:

$$EU_s^-(r^\star) = EU_t^+(w^\star) < EU_t^-(w^\star) \tag{4.11}$$

We have seen that the way to solve moral hazard is to give risk to the agents. Since, outcomes are positively correlated with the effort chosen, wages are increasing with outcomes[10], $w_{SS} > w_{SF} > w_{FF}$. From equation, (4.4), it can be checked that the agent is not able to afford high effort when he interacts under a θ^- project. Additionally, from the participation equations (4.1) and (4.3) it can be checked that the agents are not willing to exert e^ℓ simultaneously. They never choose to be together when projects are of type θ^- because they are not able to bear the higher risk of contract $\{w^\star\}$, since their expected utilities would be smaller than $\bar{U}$.

[9] Note that when projects are of type θ^+ no adverse selection conflict appears.

[10] See Remark 2 and Remark 4

4.4 Concluding Remarks

This chapter analyses a principal who decides what incentives solve two problems arising from asymmetries of information. The first, is moral hazard. The principal wants each agent to do a specific level of effort on his own task. Since effort is costly, she transfers risk to the agents so that they have incentives to work hard. The second problem she has to solve is the adverse selection one. In the literature studying organisations, there are models which show that collaboration among agents is harmful because they are able to manipulate the information they submit to the principal or they may insure each other and, thus, have less incentives to work hard[11]. Other models conclude that collaboration is good when agents have skills which complement each other. In our model the source of adverse selection is precisely this one. The principal does not know whether the success of the projects is more likely to happen when agents work together or separated. The agents, since they know better the production technology, can tell what is the best organisation. However, since they are risk averse, without any self-selective device, they would always prefer to work together just to insure each other against the possibility of failure.

To solve the moral hazard problem the principal offers wages to each agent which are increasing with outcomes. This is the usual solution when a principal cannot verify effort, and effort is costly to the agent. To solve the adverse selection, the principal offers two wage schedules to the agents. One for each type of projects. This is also a well known result in contract theory. The innovation lies in the fact that the most efficient type (ie the situation where contracts are better performed with interaction) does not give rents to agents from their private information.

We have a solution in which the risk given to solve moral hazard eliminates as well the adverse selection. On one side, when projects are of the positive type, the probability of getting a success is larger and agents insure each other, hence the principal has to give more risk with the wages so that agents choose high effort. On the other side, when projects are of the negative type, the probability of a success is lower and agents do not receive insurance from each other, thus the principal offers wages comparatively not as risky. Therefore, if projects are of the negative type agents would never choose to work together because they would receive the wages related to failure

[11]See Tirole (1986)

with the higher probability, and they would not attain the reservation utility level. Also, when projects are of the negative type the principal can avoid the perverse consequences of interaction.

Usually, in an environment with adverse selection and moral hazard at the same time, the principal would lose rents because of two reasons: the incentives she has to give to get her desired effort level and because she wants that agents reveal their information. However, even if she gets less expected profits due to the risk she has to give to the agents, she does not lose rents because of adverse selection.

Two interesting extensions arise from this model. The first is related to effort. We wonder what would happen if effort was continuous. Would the principal ask for the same effort level when agents are working together and when agents are working separated? Since probabilities in these two situations change, it would be possible that she asks for different levels of effort. Second, it would be interesting to analyse a generalisation of this solution. That is, to study if with two dimensions of asymmetric information —adverse selection and moral hazard— with the first one affecting the probabilities related to the outcomes, the solution to solve the moral hazard problem is also a solution to the adverse selection one. Hence, to study whether, by giving risk to the agents so that they feel motivated to work hard, they will self-select automatically.

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