Knowledge Codification and the Boundaries of the Firm: Internal Opportunism versus External Competition.

Mathias Thoenig - CERAS and CEPR
Thierry Verdier - DELTA and CEPR

FIRST DRAFT (Please do not quote)
August 1, 2003

Abstract

This paper investigates the links between the nature of contractual relationships within firms, the form of informational flows spreading between economic units and the dynamics of technological competition. In particular, we focus on the corporate incentives to design information and monitoring systems based on tacit versus formal informational flows. The feedback effects on macroeconomic growth are investigated.

In a given competitive environment, should a firm codify its production and innovation processes through formalized procedures and hard information? Or should it rely on the existence of tacit\implicit knowledge and soft information shared within its organizational structures? How is the nature of informational flows within organizations affected by the degree of external competitive pressures? What are the consequences for the optimal governance structure of the firm? What are, in return, the implications of tacit versus codified knowledge for the dynamics of innovation and macroeconomic growth? These are important questions to be answered at the time of the explosion of the Internet and Information and Communication Technologies. These issues are also important to discuss in a world where information flows and knowledge management are increasingly recognized as been crucial determinants of socioeconomic relationships.¹ As illustrated, for instance by its last VIth framework programme on understanding the determinants and socio-economic evolution of the "Knowledge Based Society", these questions are high on the research and policy agenda of the European Commission.

Economists have for long recognized the special nature of information as an economic item. Following Arrow (1962), an entire generation of economists has considered knowledge as sharing

¹The belief of the increasing importance of knowledge for society is shared by many authors in several disciplines. See for instance Drucker (1993), Reich (1991) or Castells (1996)
some generic public good characteristics. It is non rival, often non excludable and, once created, easily transferable. As discussed by many authors, these properties generate typical problems of appropriability for the creation of knowledge. They are also source of informational spillover effects in innovation processes, on which models of endogenous growth often crucially depend (see Romer (1990)). The view of frictionless transferability of knowledge builds on the idea that a piece of information created by one person can actually be easily appropriated, verified and used at low cost by another person. It therefore implicitly assumes that knowledge is perfectly codified and formalized.

This view contrasts somehow with the perspective of practitioners of the firm and the sociology of science which has, for long, emphasized the fact that knowledge is partially tacit and only partially transferable. Polanyi (1958) is the classic reference for being one the first to demonstrate the existence a component of knowledge which is essentially tacit. He pointed out to the contextual dimension of knowledge embodied in somebody’s mind, which remains unarticulated and not easily expressible to someone else. Nelson and Winter (1982) have also followed this line of thought, emphasizing the importance of information tacitness in skillfull activities.

More recently, economists have further discussed the nature of knowledge tacitness (Cowan, David, and Foray 1999)\(^4\). An important focus has concerned a better understanding of the determinants of knowledge tacitness. While it seems clear that certain dimensions of knowledge may remain irreducibly unarticulable\(^5\), other components are in principle codifiable. The degree of knowledge transferability across economic units hinges then on the specifics of technological constraints (costs of codification, costs of communications) and the socio-economic incentives and environment that these economic units face (Cowan, David and Foray, 2000).

\(^2\)They recognize that "the knowledge that underlies skillful performance is in large measure tacit knowledge, in the sense that the performer is not fully aware of the details of the performance and finds it difficult or impossible to articulate a full account of those details". (p. 73).

\(^3\)The concept of tacit knowledge has also been popularized by the school of Sociology of Scientific Knowledge emphasizing the idea that some kind of knowledge deployed in scientific inquiry (ie. reading and interpreting the data, design of experimental instruments,...) was not transmitted among researchers through explicit and formalized statements. See Collins (1974) for the construction of the TEA laser or more recently McKenzie and Spinardi (1995) for the importance of tacit knowledge in the design and construction of nuclear weapons in the US during WWII.

\(^4\)See also Von Hippel (1994) for his concept of "sticky information" and Nickerson and Zender (2002) for some exploration of the role and implications of knowledge tacitness for the design of optimal corporate governance structures.

\(^5\)The irreducibility of knowledge tacitness may come from our cognitive incapacity to retrieve some piece of information posited in our unconsciousness. It may also be related to the way one piece of knowledge interacts with other pieces of knowledge. As Polanyi (1958) noted: "The particular of a skill appear to be unspecifiable, but not this time in the sense of our being ignorant of them; For in this case we can ascertain the details of our performance as well, and its unspecifiability consists in the fact that the performance is paralyzed if we focus on these details".
The purpose of this paper is to reconsider this endogenous dimension of tacit versus codified knowledge and to explore some of its implications for the design of organizational structures, the nature of informational flows spreading across economic units and the dynamics of technological competition. Our approach starts from the fact that in any socio-economic relationship, a piece of tacit information cannot be, by definition, easily appropriated and therefore verified by a third party. Because of this, tacitness of information can be a source of contract incompleteness, generating scope for standard problems of opportunism, hold up and transaction costs a la Williamson. By the same token however, tacitness also reduces the capacity of knowledge transferability and appropriation in the rest of the economy. Reducing informational spillovers, this can provide protection against external competition, and in particular, against technological competition where informational spillovers may be so crucial.

To the extent that formalization of informational flows is an endogenous decisions by firms, the two sided nature of information tacitness, both as a source of contract incompleteness inside a relationship and as a source of protection against external technological competition, raises then an important tradeoff in terms of the incentives for a firm to design information and monitoring systems. Interestingly, this trade-off exists even in the absence of direct costs of codification\(^6\). Knowledge management (ie. the decision to codify) is shaped by a tension between internal conflicts and outside pressure. \(^7\). The existence of this tradeoff provides then a natural channel through which the degree of external technological competition affects the firm’s internal organizational structure. As a matter of fact, the decision by the firm to keep tacit some informational flows will determine the extent of contractual incompleteness inside the organization and therefore the optimal governance structure to deal with such problems.

At the aggregate level, one gets some feedback effects from the nature of informational flows inside organizations to the strength of external innovation competition. The extent through which firms tend to codify and formalize information to solve their internal organizational problems, affect the degree of transferability of the knowledge in their possession. This in turn, affects the extent of informational spillovers and therefore the pattern of innovation and creative destruction in the economy.

In order to analyze these issues, we consider a simple schumpeterian growth model with quality ladder a la Aghion and Howitt (1998) or Grossman and Helpman (1991). We embed in

\(^6\)See Cowan, David and Foray (2000), who argue, in a informal way, that the decision to codify knowledge is endogenous and depends on the fixed cost of writing a codebook. Hence in stable environments codified knowledge has a lot of benefits but in turbulent and rapidly changing times the fixed cost of codification may become unbearable

\(^7\)This is quite consistent with the management literature which emphasizes that knowledge management is a key dimension of organizational choice and may conflict partially with the agency theory of organization (see Nickerson 2003)).
such framework a model of internal organization of the firm characterized by some endogenous dimension of contract incompleteness related to the nature of informational flows. More precisely, we consider that once a project is discovered, all the information relevant to the complete implementation of production is initially tacit and fully appropriated by the discovering firm. However, because of overloading, in order to be successfully implemented, the firm needs to hire a manager and share that information with him. This can be done in two ways. First, the firm may codify the information and write down a blueprint of that information (and what are the relevant actions to be undertaken under all contingencies). To enlight the most transparent way the role the external environment on the decision by the firm to codify its informational flows, we assume that codification costs are null. As formalized information is verifiable by a third party, a formal contract can then be specified stating how much the manager should receive. The problem of such strategy is the fact that formalization of information also facilitates transferability and information leakages to technological competitors, reducing therefore the expected lifetime of the firm.

A second strategy for the firm is to provide information to the manager on a tacit face-to-face basis. The advantage of such a strategy is to reduce informational leakages to potential competitors. On the other hand, the difficulty with such an approach is that, knowledge remaining tacit, it cannot be easily verified by a third party and one therefore cannot contract upon it. Given that it is costly to the manager to undertake the right actions, an hold up problem arises where the firm may refuse to pay the manager once the right action is made or where the manager may pick up a wrong action a low cost, once being paid by the firm. One way to solve this problem inside the firm is to use relational employment contracts between the firm and the manager (a la Baker, Gibbons and Murphy, 2002). In order to be sustainable, these relational contracts have to satisfy some incentive compatibility conditions for the agent and the firm.

In such a context, we characterize the equilibrium nature of informational flows inside corporate organizations and show that they will crucially be affected by technological external competitive pressures. Given that costs of codifications are null, the firm would ideally like to have complete tacitness of its informational flows in order to minimize informational leakages. This, however, may be prevented by the incentive compatibility constraints of the relational contract inside the organization. In that case, competitive technological pressures will have two opposite effects on the degree of tacitness in the firm. First, at the microeconomic level, an increase in technological competition (due say to an increase in the pool of resources devoted to R&D or to the introduction of Communication Technologies) will tend to reduce the time horizon of the firm and therefore make the sustainability of relational contracts based on tacit
information more difficult. This *creative destruction effect* implies a need for more formalization of information in the firm in order to restore the manager’s incentives through formal contracts. Second, at the macroeconomic level, a higher rate of creation destruction implies a larger growth rate in the economy, which increases the asset value of the firm. This makes future cooperation more valuable and promotes the sustainability of relational contracts. This *capitalization effect* relaxes the incentive compatibility constraints of internal relational contracts and allows the firm to keep more tacit information. Depending on which effect dominates, the degree of informational tacitness in the economy may increase or decrease with respect to the degree of competitive pressure. This in turn, by affecting the degree of informational spillovers, has feedback effects on aggregate growth. In particular when, the capitalization effect dominates, this feedback effect leading to more informational tacitness in the economy is going to mitigate any positive exogenous shock stimulating innovation in the economy.

An alternative way to solve the problems of contractual incompleteness inside the firm is to empower the manager by giving him ownership over some parts of the production process (outsourcing). Without additional costs of communication, this form of joint organizational structure helps to sustain a higher degree of tacitness of information between the two agents, at the cost of ex-post bargaining and sharing of rents.

The degree of external technological competition will then clearly affect the firm’s choice of organizational mode. In particular, we show that, under some conditions, the outsourcing configuration becomes more profitable to the firm after some threshold of external competitive pressures has been reached. Outsourcing and the intensity of competition are then positively linked. The economy may then exhibit a U shape relationship between the amount of resources devoted to R&D and the degree of information tacitness. For low levels of resources in the R&D sector, a relational employment contract inside the firm is the equilibrium organizational form of a firm. With a strong enough creative destruction effect, information tacitness for such an organizational form decreases and the degree of formalization of employment relationships increase. After a threshold however, the outsourcing organizational form starts to emerge. Allowing firms to sustain a higher degree of information tacitness, this regime implies less informational spillovers in the economy and a growth slowdown.

This paper is related to several economic literatures. Clearly, a significant amount of work emphasizes the importance of technological spillovers in models of endogenous growth, development, international trade and economic geography. It is also well know that results emanating from these models are drastically affected by the specification of these spillovers (local vs global,). In most of these theories, the nature of these spillovers is always exogenously given and does not react to the structure of the economy. Our model is a first step towards endogenizing
this aspects by providing some micro-foundations of some information generation activities.

More importantly, our work contributes to the recent emerging literature analyzing the links between the internal organization of the firm and macroeconomic growth (Aghion, Acemoglu and Zilibotti (2002), Francois and Roberts (2003a), 2003b)), Martimort and Verdier (2000, 2003a), 2003b)). This literature discusses how the internal structure of contracting is influenced by the outside macroeconomic environment (technological frontier, growth, creative destruction) and how in return the internal structure of contracting (in house production, outsourcing, internal coalitions) has implications for the incentives to innovate and aggregate growth. We discuss a new channel through which the external competitive environment of the firm has some impact on its internal contracting structure. Indeed, our setting emphasizes the importance of knowledge management inside the organization as the mechanism reflecting the conflict between internal endogenous contract incompleteness and external competitive pressures. The implications for information transferability and endogenous informational spillovers generate then a feedback effect of the microstructure of the firm on macroeconomic growth.

Our approach emphasizing the importance of the information tacitness is also consistent with the empirical literature on technology spillovers and diffusion (Keller 2002). Among some of the stylized facts pointed out by that literature is the fact that knowledge spillovers are spatially localized (for statistical evidence see Keller 2002 or Audretsch and Feldman, 1996) and that this spatial effect is linked to the existence of tacit knowledge (Feldman and Lichtenberg 1997, Von Hippel 1994) 89.

In our framework, the degree of contractual incompleteness is endogenous. This is also related to some recent work by Battigali and Maggi (2002) which address this issue. In this piece of work, the limit to contractual completeness comes from the direct cost of writing contracts. Our argument is different as we emphasize the importance of information leakages and outside competition in affecting the extent of contractual incompleteness inside the firm.

Our model endogenizes the mix between formal aspects of organization (understood as job description, formal contracts, etc.) and the informal aspects (as relational contracts, reputation, and non contractual dimensions, etc.). This mix is a crucial feature of organizations; it has long been emphasized by the sociological literature and more recently addressed by the economic literature (see Baker, Gibbons and Murphy (2002) who argue that "Roughly

8The transferability of knowledge in a non formal way is enhanced if it is sustained by the existence of social networks and strong social discipline [see Saxenian 90 and 94 for evidence on the culture of gift/counter gift in the Sillicon Valley; the survey by Rauch about the role of trade networks in information spreading];

9Cohen, Nelson and Walsh (2000) show that there has been a change in firms patenting policies in the 90s: firms rely more and more on trade secrecy despite the fact that their environment became more and more competitive. This is consistent with our results if trade secrecy is positively correlated to an increase in tacitness and tacitness increases with competitive pressure
speaking, the formal structure is the organization chart whereas the informal structure is the way things really work”). Our paper contributes to this line of research by highlighting that this formal/informal mix is endogenous and shaped by the policy of knowledge management at the firm level; in particular we emphasize how this mix basically balances inside opportunism vs outside competition.

The paper is organized as follows. Section 2 presents the basic framework. In section 3, we consider relational employment contracts inside the firm. We characterize the endogenous degree of information tacitness chosen by firms and derive the stationary growth path of the economy. Simple comparative statics are then performed in section 4. Section 5 introduces the possibility of outsourcing and investigates the implications for the equilibrium nature of informational flows as well as aggregate growth. Section 6 finally concludes.

1 The framework

We consider a discrete time model à la Grossman and Helpman (1991). There are two types of production factors: an amount $H + 1$ of entrepreneurs and $L$ of labor. There is a perfect credit market.

Goods and Preferences

There is a numeraire competitive final good $Y_s$ using a continuum of intermediate goods $x_s(i)$ on the interval $[0, 1]$ under a Cobb-Douglas technology $\log Y_s = \int_0^1 \log x_s(i).di$. As usual, the instantaneous demand for intermediate good $i$ with price $p_s(i)$ is given by:

$$x_s(i) = \frac{Y_s}{p_s(i)}$$

The representative consumer is endowed with the following intertemporal separable utility function: $U_t = \sum_{s=t}^{\infty} (1 + \beta)^{-(s-t)} [Y_s - \psi_s e]$ where $Y_s$ corresponds to date $s$ consumption of $Y$ and $\psi_s e$ to the nominal cost of effort. We assume that the shadow price of effort increases at the growth rate of this economy: $\psi_{s+1} = (1 + g_s)\psi_s$. There is also equality between the interest rate and the discount factor $\beta = r$.

Technological Change

For each industry $i$, there are $H + 1$ entrepreneurs who can do R&D in their sector or be involved in production. After discovering a new project entrepreneurs must implement it by creating a firm and hiring workers. When ruling her firm an entrepreneur cannot undertake research effort.
At each date there is an endogenous probability $\theta$ that a new project is discovered by another entrepreneur: In that case the firm is destroyed and the entrepreneur goes back to research activity. For the moment imitation is impossible: firms fully protect their property rights by patenting their project. The very act of patenting exogenously reveals some information on the technological know-how; but despite this feature we assume that every firm decides to patent.

A new project enhances the quality of the previous leading-edge project by a parameter $\delta > 1$. Due to limit-pricing in Bertrand competition between the new project and the previous one, we get that the price $p_s(i)$ charged by the new firm is equal to $\delta \bar{w}_s$ where $\bar{w}_s$ is the unit cost of production at time $s$. Using (1) this means that each project generates a cash-flow equal to

$$\pi_s = (1 - \delta^{-1})Y_s$$

(2)

In each industry, research is done by the $H$ entrepreneurs which are not currently managing a firm. And the competitive pressure $\theta$, which stands for the probability a new project is discovered in an industry $i$, is given by:

$$\theta = \tilde{\theta}(\varepsilon_i).H$$

(3)

where $\varepsilon_i$ is a parameter standing for the endogenous degree of knowledge spillovers within the industry $i$ and $\tilde{\theta}(\cdot)$ is concave and increasing in $\varepsilon_i$. We discuss below how the spillover parameter $\varepsilon_i$ can be partially manipulated by the leading edge firm in order to reduce the probability of being destroyed.

**Implementation of projects and production**

Once discovered a project must be implemented. At each date this consists in a two stage "quality-quantity" process. Firstly a continuum $a_j \in [0, 2]$ of strategic actions must be undertaken in order to adapt the production process to changing environmental conditions: if a task is not correctly done, the overall level of quality cannot be achieved and the firm’s cash-flow is null. Due to overloading in management an entrepreneur can supervise only a subset $[1, 2]$ of those tasks $j$. The remaining share $[0, 1]$ must be supervised by a agent hired by the firm from the common pool of workers. Secondly once the quality of the good is successfully implemented thanks to these continuum of actions, some workers are hired in order to produce the desired quantity of good.

More formally we assume that, after successful implementation, the production function, for each variety $i$, at time $t$ is:

$$y_i = \delta^{n(t)}l$$
if there have been \( n_i(t) \) innovations in sector \( i \), \( \delta^{n_i(t)} \) is the quality of the \( n_i \)-th innovation on variety \( i \), and \( l \) is the amount of workers hired for production. The index for successful implementation of the production process is given by

\[
\text{qual.} = \min_{j \in [0,2]} 1(a_j, t)
\]

where \( 1(a_j, t) \) is a binary function measuring the quality of the action \( a_j \) such that: \( 1(a^*_j, t) = 1 \) where \( a^*_j \) is the date \( t \) ”correct” action and \( 1(a_j, t) = 0 \) when \( a_j \neq a^*_j \). When \( \text{qual.} = 0 \), production cannot be implemented while production may start when \( \text{qual.} = 1 \).

Note that the correct action \( a^*_j \) is time-dependent and an agent\(^{10}\) ignoring ex-ante \( a^*_j \) has no chance to achieve the correct quality \( 1 \) (the set of actions is supposed to be wide). The cost (in term of labor disutility) of an action \( a_j \) is \( 1(a_j, t) e \) : there is always\(^{11}\) a wrong action which has no cost whereas the correct action has always a cost \( \psi_t e \).

The total cost in term of effort for the agent is consequently given by:

\[
C_t = \psi_t e \int_{0}^{1} 1(a_j, t) dj
\]

>From the contracting point of view we assume that actions \( a_j \) are verifiable by outside party but neither their quality (correct or wrong) nor their costs. This is a crucial feature of our framework. Indeed in absence of a blueprint or a contract specifying ex-ante what are the correct actions \( a^*_j \) at each date \( t \), there is an hold-up problem: If the agent undertakes the correct action \( a^*_j \) at the cost \( \psi_t e \), the firm has incentive to deny the quality of her action in order not to compensate her ex-post. Anticipating this, the agent has incentives to undertake a wrong action at zero cost.\(^{12}\) This hold-up inefficiency disappears when a contract simply specifies ex-ante the correct \( a^*_j \).

In the quantity stage the unit cost of production is equal to \( c_t = l.\bar{w}_t \) where \( \bar{w}_t \) is the competitive wage prevailing on the labor market.

**Knowledge sharing and tacitness**

The technological know-how of a firm can be summarized by the set of knowledge \( K = \{ a^*_j, j \in [0,2], t \in (1,2,...) \} \). Initially knowledge is fully appropriated by the entrepreneur when he

\(^{10}\)We assume that learning by the agent is not possible.

\(^{11}\)This feature of the model is innocuous. It only simplifies the computations by cancelling out any stochastic element.

\(^{12}\)Contracts could be contingent to the quality of the product or the amount of sales. The hold up problem would then disappear. In that case, to restore it, we would have to assume that there are \( n \) managers per firm and that quality is the result of the joint effort of the \( n \) managers. Hence the impact of a particular manager on the total quality could not be inferred.
discovers the project. But at each date \( t \), for each task \( j \), the overall quality can be achieved only if the agent knows the correct actions \( a^*_j_t \). There are two ways for the agent to get this know-how:

- **face-to-face interaction**: at each date \( t \) the entrepreneur transmits to the agent \( a^*_j_t \), which is the bit of information relevant for the current period only.

- **codification**: at the beginning of their relationship, the entrepreneur can decide to codify her know-how by transmitting the full algorithm \( \{a^*_j_t\}_{t \in [0, +\infty[} \) to the agent under the form of a blueprint. However, writing this blueprint induces some information sharing as the entrepreneur transmits to the agent the full know-how of the task \( j \). This corresponds to the standard view of codified knowledge\(^{13}\).

The firm chooses a share \( \gamma \) of the continuum \([0, 1]\) of actions \( j \) which is kept under tacit knowledge and a share \((1 - \gamma)\) which is codified. Fixing this degree of tacitness \( \gamma \) is done at the beginning of the relationship, it is irreversible and it involves no (direct) cost of writing the code.

Codification of knowledge has a cost in terms of information sharing but it has a benefit in terms of internal efficiency. Indeed once a share \((1 - \gamma)\) has been codified under the form of a blueprint this information will automatically and costlessly spread across a share \( 0 < \phi < 1 \) of the economy\(^{14}\). In turn this will increase the degree of knowledge spillover in the industry and thus increase the probability of being leapfrogged at a rate \( \theta \).

More precisely the intensity of knowledge spillovers\(^{15}\) is endogenous and given by:

\[
\varepsilon = \phi . (1 - \gamma)
\]

\(^{13}\)This is a specific definition. See David and Foray [1999] for a broad definition of tacit knowledge (Polanyi, etc.)

\(^{14}\)Codified knowledge \( \{a^*_j_t, j \in [1-\gamma, 1] t \in (1, 2, ...)\} \) (ie. an algorithm) spreads under the form of a blueprint. And it spreads costlessly to the whole market because there is a duopoly on the market of codified knowledge [due to information sharing both the entrepreneur and the manager own the information]. As a blueprint is costless to produce, the equilibrium in this duopoly game is that information is sold for free to everybody.

Another mechanism is that the third party (ie. the lawyer or consultant who writes down the contract) cannot commit not to reveal to an outside competitor the codified information enclosed in the contract.

Whatever the underlying story, what is important is that information leakage cannot be contracted upon in the sense that information leakage is neither observable nor verifiable: “I can always transmit some information pieces to an outside competitor in a very informal way without being convicted”.

This view of codified knowledge as a non rival, non appropriable, public good is consistent with the standard (neoclassical) view about knowledge spreading [see Arrow 1962 on the problem of appropriability of knowledge].

\(^{15}\)A more general form is

\[
\varepsilon = \phi . (1 - \gamma) + \tau . \gamma
\]

with \( \phi > \tau \).

In this general form \( \tau . \gamma \) corresponds to the share of information which spreads when the entrepreneur decides to patent.
such that the competitive pressure $\theta$ is equal to

$$\theta = \tilde{\theta}(\phi.(1 - \gamma)).H$$

Note that hereafter we rather adopt the following notation $\theta = \theta(\gamma).H \equiv \tilde{\theta}(\phi.(1 - \gamma)).H.$ with $\theta(.)$ decreasing concave.

The benefits of knowledge codification are quite indirect but nevertheless important. From our previous discussion we know that there is an internal inefficiency within the firm which takes the form of a hold-up problem. This inefficiency can be removed when a blueprint is used in order to write down a formal contract specifying ex-ante the set of correct actions $\{a^*_{jt}\}$ which must be undertaken by the agent. But this can be done only if knowledge has been codified.

As a consequence with regards to the share $\gamma$ of tacit knowledge, the opportunism problem cannot be solved in a straightforward way (ie. on a spot market with a complete contract) and hold-up and internal inefficiency remain. However we show below how this opportunism problem can be partially alleviated by relational contracts as defined in Baker et alii [2002] (ie. repeated interactions between the firm and the agent). Whereas this second solution has no direct cost in term of information leakage, it cannot always be sustained in our context where the average duration of relational contracts decrease with $\theta$ the intensity of technological competition.

To sum up the endogenous degree of knowledge tacitness $\gamma$ stands either for the degree of contractual incompleteness and the size of spillovers. This dual aspect of tacitness comes basically from the fact that designing a contract induces information sharing which in turns promotes information leakage. In other words knowledge tacitness reduces information leakages and competitive pressure but generates hold-up and internal inefficiency.

**Steady-state**

We focus on steady-state symmetric growth path equilibria such that:

$$\begin{align*}
Y_t &= (1 + g)^t Y \\
\bar{w}_t &= (1 + g)^t \bar{w} \\
\psi_t &= (1 + g)^t \psi_0
\end{align*}$$
where $g$ is the stationary growth rate prevailing in the economy and equal to:

$$g = \tilde{\theta}(\varepsilon) \cdot H \log \delta$$

Finally we assume for the sake of computational simplicity that the growth rate $g$, the interest rate $r$ and the creative destruction rate $\theta$ are small with respect to 1. This amounts to saying that the length of periods is short enough so that our discrete model behaves almost as a standard continuous time models of growth.\footnote{As the reader will soon figure out, the focus on discrete time is motivated by our desire to model the relationships within the firm as a repeated game, the analysis of which is much easier in discrete time.}

## 2 The basic results

### 2.1 Spot employment Contracts

It is clear that as long as the share of tacit knowledge $\gamma$ decided by the firm is strictly positive, there is a clear hold up problem in the spot employment relationship between the firm and the agent. If the agent accepts to undertake the right action on all the $\gamma$ tasks under tacit information, there is afterward a strong incentive for the firm not to compensate the manager for these actions, as their quality is not verifiable by a third party. Anticipating this, the agent will not undertake these actions, unless he receives due payment before making them. But then the hold up problem is just the opposite way. After receiving payment for the right actions on the $\gamma$ tacit information tasks, given that their quality is not verifiable, the agent has a strong incentive to choose an wrong action at low cost. Anticipating that this will prevent any successful implementation of the production process, the firm will not offer such a wage contract to the agent. In the end, the only sustainable outcome under spot employment contracts is with all tasks being verifiable and the share of tacit knowledge is equal to $\gamma = 0$.

### 2.2 Knowledge management at the firm level

Consider now relational employment contracts inside the organization. At the beginning of the relationship the firm designs a contract. This contract writes down the correct actions $\{a_{jt}^*\}$

\footnote{The steady-state growth rate $g$ is computed as in Grossman and Helpman (1991) (see chapter 4 for details). Denoting $n_i(t)$ the degree of quality prevailing at date $t$ in industry $i$. From limit pricing we get that the price in each industry is equal to $p_{it} = \tilde{w}_t / \delta^{n_i(t)-1}$ where $\tilde{w}_t$ is the competitive wage. Remind that the price index, $P_t$, is equal to: $\log(P_t) = \int_0^1 \log(p_{it}) \, di$. As $Y$ is chosen as a numéraire, we get that $\log \tilde{w}_t = \int_0^1 \log \left( \delta^{n_i(t)-1} \right) \, di$ and the stationary rate of growth is given by $g = \theta \log \delta = \tilde{\theta}(\varepsilon) \cdot H \log \delta$}
for a share \((1 - \gamma)\) of the tasks and a wage schedule \(\{w_t\}\) which has to be paid to the agent whenever these tasks are correctly done. Hence the contractual payment \(\{w_t\}\) is contingent to only a share of the total set of tasks. With regards to the tacit part of know-how, the firm will communicate at any future date \(t\) the efficient actions \(\alpha^*_t\) to the agent. The agent will be "free" to undertake them (at a total cost \(\gamma \psi_t c\)) as this part of the job is not described in the contract.

The underlying opportunism problem can be solved through relational contracts. More precisely, the agent is willing to undertake the correct tacit actions (despite the threat of hold-up) if he expects to get a compensation for his non contractual effort. This compensation can take two forms. First, it can be a non contractual wage \(\omega_t\) that the firm gives ex-post. Second, it can be included in the contractual wage \(w_t\) under the form of an efficiency wage where \(w_t\) is larger than the reservation wage \(\bar{w}_t\). In that case the agent cooperates on the tacit part otherwise he would be fired and he would loose his future efficiency wage premium \((w_t - \bar{w}_t)\).

We make the following informational assumptions. All workers and firms know the identity of firms and employees in all previous periods as long as the firm is still in business. As soon as the employer’s project is leapfrogged and disappears, the reputation of that particular firm and all the agents who have been employed by that employer vanish. Both agents go back to anonymity. In other words, we suppose that reputation is match-specific.

At each date, a worker knows all his history of wage payments \(\omega_t\) and \(w_t\) and work performances in a given employment relationship. He also knows whether a firm, which he has been employed in any past period, has delivered any promised non contractual payment \(\omega_t\).

At each date, each firm knows the history of past wage payments \(\omega_t\) and \(w_t\) paid to all his past workers and also knows the work performances history of its employees whilst employed with the firm.

Clearly, as long as there are tacit informational flows inside the firm, there is scope for two sided opportunism between the firm and the manager. An employment relational contract specifies that the agent must undertake at each date \(t\) the right action on the full set of tasks \([0, 1]\) and will receive in exchange a sequence of wage payments \((w_t, \omega_t)\) where \(w_t\) is the formal wage; \(\omega_t\), i.e. a non-contractual wage which is paid ex-ante; and \(\omega_t\), i.e. a non-contractual wage which is paid ex-post.

\(^{18}\)Note that in all generality the contractual schemes could have three components: \(w_t\), i.e. the contractual wage; \(\omega_t\), i.e. a non-contractual wage which is paid ex-ante; and \(\omega_t\), i.e. a non-contractual wage which is paid ex-post.

However a rapid look at the analysis about the optimal contractual schemes (see infra) should convince the reader that the role of \(\omega_t\) in term of incentives’ provision is similar to the the role of \(w_t\): both acts as commitment devices from the firm’s point of view.

Hence we can focus only on 2 dimensions schemes \((w_t, \omega_t)\) without any loss of generality [a more formal analysis may be available from the authors upon request].
component payed when the agent has made the right verifiable action on the share \((1 - \gamma)\) of the codified tasks and \(\omega_t\) is a promised non contractual wage paid when the agent has made the part of the job on the \(\gamma\) remaining tacit tasks. That contract need to be self enforcing for the two parties and therefore should satisfy some incentive compatibility constraints.

**Agent’s incentive constraint:**

Let consider an agent hired at date \(t\). At any further date \(t + s\), the incentive compatibility constraint of the agent should make sure that the agent derives a higher discounted utility from not shirking than shirking. This can be written as:

\[
w_{t+s} - (1 - \gamma)\psi_{t+s}e + \sum_{\tau=1}^{\infty} \frac{(1 - \theta)^\tau}{(1 + r)^\tau} \bar{w}_{t+s+\tau} \leq w_{t+s} + \omega_{t+s} - \psi_{t+s}e + \sum_{\tau=1}^{\infty} \frac{(1 - \theta)^\tau}{(1 + r)^\tau} \left[ w_{t+s+\tau} + \omega_{t+s+\tau} - \psi_{t+s+\tau}e - \bar{w}_{t+s+\tau} \right]
\]

Assuming that the firm pays the relational contract in each period, when the agent does not shirk, he will earn \(w_{t+s+\tau} + \omega_{t+s+\tau} - \psi_{t+s+\tau}e\) with \(\tau \geq 0\) as long as the project remains on the leading edge. If he cheats at \(t + s\), he undertakes an effort only on the codified share of tasks, faces a cost \((1 - \gamma)\psi_{t+s}e\) and receives only the contractual wage \(w_{t+s}\). However he will be dismissed by the firm and goes back to the market with a "bad" reputation.\(^{19}\) He will get only the reservation wage \(\bar{w}_{t+s+\tau}\) as long as the project is on the leading edge for \(\tau > 0\). This condition can be written as:

\[
\gamma\psi_{t+s}e \leq \omega_{t+s} + \sum_{\tau=1}^{\infty} \frac{(1 - \theta)^\tau}{(1 + r)^\tau} \left\{ w_{t+s+\tau} + \omega_{t+s+\tau} - \psi_{t+s+\tau}e - \bar{w}_{t+s+\tau} \right\}
\]

Along a steady state growth path and restricting ourselves to contracts specifying a constant growth rate for contractual \(w_s = (1 + g)^{s-t}w_t\) and non contractual wages \(\omega_s = (1 + g)^{s-t}\omega_t\), this constraint takes a simpler form:

\[
\gamma\psi_{t+s}e \leq \omega_{t+s} + \sum_{\tau=1}^{\infty} \frac{(1 - \theta)^\tau (1 + g)^\tau}{(1 + r)^\tau} \left\{ w_{t+s} + \omega_{t+s} - \psi_{t+s}e - \bar{w}_{t+s} \right\}
\]

This incentive constraint must be true at any date \(t + s\) after the hiring. Together with the steady state condition, the agent’s incentive constraint becomes then (in detrented value):

\[
\gamma\psi_{0}e \leq \omega + \frac{(1 - \theta)(1 + g)}{(1 + r)} \left( w + \omega - \psi_{0}e - \bar{w} \right)
\]

\(^{19}\)We assume here that the market "sanctions" breaking matches by avoiding to deal with them. Firms will not hire the "deviant" manager as a manager and workers will not want to work as managers in a "deviant" firm. As the reason for the break is because of some cheating on the "tacit" part of the contract, there is always an ambiguity on who is responsible for such a break. In equilibrium, as managers will only receive their reservation payoffs, it is then a weakly dominant strategy for managers and firms in the market to avoid dealing with the parties which separated.
Note that when (10) holds, (9) holds for any date \( t + s \) after the hiring. Hence if the incentive compatibility constraint is satisfied at the beginning of the relationship, it is also satisfied for periods thereafter. For small values of \( r, \theta \) and \( g \), (10) becomes:

\[
\gamma \psi_0 e \leq \frac{1 + r + \theta - g}{r + \theta - g} \omega + \frac{w - \psi_0 e - \bar{w}}{r + \theta - g}
\]

From this equation we get that there are basically two instruments to incentivize the agent: a/ the non-contractual wage \( \omega \) is given ex-post by the firm when the agent has correctly undertaken an effort on the non codified tasks; the cost of this instrument is that the firm may renegate and not pay the compensation despite the agent’s cooperation; hence we expect that this instrument is difficult to enforce from the firm’s point of view (see below). b/ the second instrument, \((w - \psi_0 e - \bar{w})\), is an “efficiency wage” in the sense that the firm gives a total wage above the reservation wage in order to incite the agent to cooperate; this second instrument is easier to enforce from the firm’s point of view (because it is done through the contractual wage \( w \)) but it is costlier to the firm.

**Firm’s incentive constraint:**

Let us consider now the incentive compatibility constraint of the firm. Consider again a relationship beginning at date \( t \). The firm’s incentive constraint corresponds to the case where at any further date \( t + s \) after the hiring date \( t \), the return to cooperation always dominates the return to cheating. This can be written as:

\[
\pi_{t+s} - w_{t+s} + 0 \\
\leq (1 - \theta)^r \sum_{\tau=1}^\infty \left[ \frac{1}{1 + r} \right]^r \pi_{t+s+\tau} - w_{t+s+\tau} - \omega_{t+s+\tau}
\]

At any further date \( t + s \), a cooperative firm receives \( \pi_{t+s} \) and compensates the agent by giving her the contractual wage \( w_{t+s} \) and the non-contractual wage \( \omega_{t+s} \). In that case cooperation between the firm and the agent is sustained through time and the relationship lasts with the project. If the firm decides to cheat at date \( t + s \), the firm receives \( \pi_{t+s} \), gives the contractual wage \( w_{t+s} \) to the agent but reneges on the noncontractual wage \( \omega_{t+s} \) despite the agent’s cooperation. However at any further date \( t + s + \tau \), the firm’s reputation of being non reliable will spread through the market and no agent will accept to cooperate with this firm; as the degree of codification is fixed only once (at date \( t \)), this means that the firm will be unable to produce correctly and she will get zero cash-flow as long as the project is on the leading edge for \( \tau > 0 \).
Using again stationary contracts along a stationary growth path, we can rewrite the firm’s incentive constraint in detrended terms as:

$$\omega < \frac{(1 - \theta)(1 + g)}{(1 + r)} \left( \frac{\pi - \omega}{1 - (1-\theta)(1+g)(1+r)} \right)$$

or

$$\frac{1 + r + \theta - g}{r + \theta - g} \omega \leq \frac{\pi - \psi_0 e - \bar{w}}{r + \theta - g} - \frac{w - \psi_0 e - \bar{w}}{r + \theta - g}$$

(ICP)

This equation clearly illustrates the trade-off in term of incentives from the firm’s point of view. The larger is the ex-post non-contractual wage $\omega$, the more the firm wants to renegade. The larger is the net surplus of the relationship (ie. total surplus minus the efficiency wage) the more the firm wants to cooperate. Comparing agent’s and firm’s incentives constraints we see that efficiency wage costs to the firm in term of incentives whereas it benefits to the agent’s incentives.

**Agent’s participation constraint:**

Finally it is clear that the contract has to satisfy the agent participation constraint. When hired by a firm, the agent undertakes an effort $\psi_t e$ for a compensation scheme $w_t + \omega_t$; his reservation wage (ie. employed as a production worker) is $\bar{w}_t$. When the firm is destroyed, with a probability $\theta$, the agent goes back to the labor market. Hence the agent’s participation constraint writes as:

$$\sum_{\tau=0}^{\infty} \frac{(1 - \theta)^\tau}{(1 + r)^\tau} \{w_{t+s+t} + \omega_{t+s+t} - \psi_{t+s+t} e\} \geq \sum_{\tau=0}^{\infty} \frac{(1 - \theta)^\tau}{(1 + r)^\tau} \bar{w}_{t+s+t}$$

Along a stationary growth path and with stationary contracts, the agent’s participation constraint collapses to:

$$w + \omega - \psi_0 e \geq \bar{w}$$

(PC)

After innovation, the firm decides once for all for its level of informational tacitness. It will therefore maximize with respect to tacitness $\gamma$ the intertemporal value of the relationship such that the cooperation is sustained through a well designed labor contracts $\{w_s, \omega_s\}_{s\geq t}$ where $\{w_s\}$ is the contractual wage and $\{\omega_s\}$ is the non-contractual compensation:

$$V_t = Max_{\{w_s\}, \{\omega_s\}, \gamma} \sum_{s=t}^{+\infty} \frac{(1 - \theta)^{(s-t)}}{(1 + r)^{(s-t)}} [\pi_s - w_s - \omega_s]$$

(11)
where the competitive pressure $\theta$ is given by [5] and [6]. When contracts are stationary along a balanced growth path, the firm’s objective function (11) rewrites as:

$$ V = \max_{w,\omega,\gamma} \frac{\pi - w - \omega}{r + \theta(\gamma)H - g} $$

The firm prefers the largest value of tacitness $\gamma$ which is sustainable through a relational contract $(w, \omega)$. We characterize hereafter the set of contracts which can sustain a given level of tacitness $\gamma$.

**The set of contracts sustaining a given degree of tacitness $\gamma$**

Let’s consider a given degree of tacitness $\gamma$. The set of relational contracts $(w, \omega)$ which can sustain cooperation between the agent and the firm for this degree of tacitness is described by the constraints (PC)-(ICM)-(ICP).

\[
\begin{align*}
    w + \omega & \geq \psi \psi c + w \\
    \omega [1 + r + \theta - g] + w & \geq \psi \psi c [r + \theta - g] + \psi \psi c + \bar{w} \\
    \omega [1 + r + \theta - g] + w & \geq \pi
\end{align*}
\]

This set of contracts is depicted on diagram [1] and it is not empty as long as the agent’s constraint is below the firm’s constraint. Simple computations show that it is the case iff:

$$ \gamma \psi \psi c \leq \frac{\pi - \psi \psi c - \bar{w}}{r + \theta - g} \quad (12) $$

For a given $\gamma$ it is clear that the firm prefers to pay the smallest compensation scheme $w + \omega$. This corresponds to contracts located on the segment $OO'$ where the agent’s participation constraint is binding\(^{20}\). Hence as soon $\gamma$ as is sustainable (ie. condition [12] is satisfied) the participation constraint is binding $w + \omega = \psi \psi c + \bar{w}$ and the firms captures the whole surplus of the relationship. In other words the efficiency wage policy is always dominated by the ex-post compensation policy: for a given $\gamma$, the firm always prefers to incite the agent through $\omega$ rather than through the efficiency wage $(w - \psi \psi c - \bar{w})$. The reason is that the latter one is costly whereas both instruments are perfectly similar in terms of incentive provision [ie. they are substitute either in the agent’s incentive constraint (see condition ICM) and in the firm’s

\(^{20}\)The case where the manager’s constraint does not intercept the manager’s participation constraint is not possible because this corresponds to the impossible case where:

$$ \frac{\gamma \psi \psi c [r + \theta - g] + \psi \psi c + \bar{w}}{1 + r + \theta - g} \geq \psi \psi c + \bar{w} $$
incentive constraint (see condition ICP)]. Basically this result is linked to the fact that agent’s reputation does not last more than the firm’s reputation. They value the future the same way.

**The optimal degree of tacitness for a given growth rate \( g \)**

Let’s now determine the optimal degree of tacitness \( \gamma \) chosen by the firm. If \( \gamma < 1 \), we know from the previous analysis that the participation constraint is binding. Let’s assume for the moment that either the agent’s or the firm’s incentive constraint is not binding. As a consequence the two binding constraints are not similar and the dimension of the set of sustainable contracts is 2 (see diagram [1]): unambiguously this implies that the condition [12] cannot be an equality. This last point means that it is possible to find a marginally larger degree of tacitness, \( \gamma + \Delta \gamma \), which can be sustained by a relational contract (i.e., which satisfies the condition [12]). As a consequence \( \gamma \) cannot be the optimal contract.

To sum up, the firm prefers the largest value of tacitness \( \gamma \) which is sustainable through a relational contract \((w, \omega)\). This value corresponds either at a case where \( \gamma = 1 \) or at a case where \( \gamma < 1 \) and all constraints are binding. Using equations [PC]-[ICM]-[ICP], this means that the optimal degree of tacitness is given by the following implicit equation:

\[
\gamma = \text{Arg} \max_{0 \leq \gamma \leq 1} \gamma \quad \text{s.t.} \quad \gamma \psi e \leq \frac{\pi - \psi e - \bar{w}}{r + \theta(\gamma).H - g} \tag{13}
\]

The largest sustainable degree of tacitness \( \gamma \) is restricted by the fact that the non contractual compensation \( \omega \) has a limited impact: A large \( \omega \) always provides to the agent the correct incentives for cooperating (see ICM), but not to the firm who may have interest to renegade on \( \omega \) instead of rewarding the agent [this is the case when the immediate benefits of cheating become larger than the future benefits of cooperating; see equation [ICP] with a large \( \omega \)]. Hence the degree of cooperation is partially limited by the fact that the firm cannot always commit to give the non-contractual compensation.

> From equation (13) we may find out \( \gamma(g) \), the optimal degree of tacitness with respect to the growth rate. The LHS and the RHS of this equation are depicted in graphic [2]. Both curves are increasing in \( \gamma \) and the RHS is convex\(^{21}\). As a consequence it is straightforward to

\(^{21}\)The fact that the RHS of (13) is convex comes from our assumption that there are decreasing returns of codified information to R&D informational spillovers. Indeed we assumed that \( \theta(\gamma) = \tilde{\theta}(\phi(1-\gamma)) \) with \( \tilde{\theta}(.) < 0 \) meaning that \( \theta''(\gamma) < 0 \) and \( \frac{\pi - \psi e - \bar{w}}{r + \theta(\gamma).H - g} \) being a convex function of \( \gamma \). Intuitively, at high levels of tacitness, the effect of codified knowledge on informational spillovers is very high; A marginal increase in codified knowledge , induces a high variation of the rate of creative destruction on the incumbent firm. In such a region, a marginal increase in tacitness provides then a large return in terms of protection against technological competition; The marginal returns to tacitness are therefore increasing, implying the convexity of \( \frac{\pi - \psi e - \bar{w}}{r + \theta(\gamma).H - g} \).
see that $\gamma(g)$ is increasing in $g$ for low growth rate and that there exists a threshold value of the growth rate, $\hat{g}$, such that for $g > \hat{g}$, $\gamma(g) = 1$. The curve $\gamma(g)$ is depicted on graphic [3]. The intuition for the shape of this curve is the following. The larger is the growth rate $g$, the more valuable are future cash-flows and wages; hence it is important both for the firm and the agent not to renegade now in order to enjoy future cooperation. Hence cooperation is easier from both sides and consequently a larger degree of tacitness is sustainable. We call capitalization effect this positive impact of growth on tacitness.

Finally at the optimal degree $\gamma$ we know that the agent’s incentive constraint and the firms’ incentive constraint are binding. Consequently: $\gamma \psi e = \omega$ and $w = (1 - \gamma) \psi e + \bar{w}$. As a consequence the value of the firm is given by:

$$V^{in} = \frac{\pi - \psi e - \bar{w}}{r + \theta(\gamma).\bar{H} - g}$$

(15)

All this discussion can be summed up as follows:

Result 1: The contractual wage $w$ compensates the agent for the codified share of know-how only. The non contractual wage $\omega$ compensates for the non verifiable and non contractual share of know-how $\gamma$. Finally the degree of tacitness $\gamma(g)$ is an increasing function of the growth rate $g$ and there exits $\hat{g}$ such that for $g > \hat{g}$, $\gamma(g) = 1$.

Finally it is useful to check that under spot labor contracts, a strictly positive degree of tacitness cannot be sustained. Indeed such a case corresponds analytically to the case where $\theta = +\infty$ in (ICM) and (ICP). From [13], this immediately drives that $\gamma = 0$.

2.3 Macroeconomic equilibrium

Closing up the model requires to clear the labor market as the reservation wage $\bar{w}_t$ plays an important role in equation [13]. The demand for labor has two components: a demand for agent which is always equal to 1 and a demand for producers, which is, under limit pricing, equal to $Y_t/\delta \bar{w}_t$. Consequently the labor market clearing condition is:

$$L = 1 + Y_t/\delta \bar{w}_t$$

(16)

Along a stationary growth path, $Y_t$ and $\bar{w}_t$ grow at the same rate $g$ with $Y_t = (1 + g)^t Y$ and $\bar{w}_t = (1 + g)^t \bar{w}$. It follows that $L = 1 + Y/\delta \bar{w}$. From limit-pricing by monopolies and the fact that the final good is the numeraire, we get that $\delta \bar{w} = P = 1$. Hence $Y = L - 1$. From equation
(2) we get the detrended profit value \( \pi = (1 - \delta^{-1})(L - 1) \). The equilibrium level of tacitness is given by (13) and (16):

\[
\gamma \psi_0 e = \frac{S}{r + \theta(\gamma).H - g} \text{ for } g < \hat{g}; \quad \gamma = 1 \text{ for } g > \hat{g}
\]  

where \( S \) is the spot surplus of the match at the equilibrium and is equal to: \( S \equiv (1 - \delta^{-1})(L - 1) - \psi_0 e - \delta^{-1} \). The aggregate stationary rate of growth is simply given by:

\[
g = \theta(\gamma).H.\log \delta
\]  

The equilibrium is described by [17] and [18] and is depicted on graphic [3]. Hereafter we focus on interior equilibrium only where \( \gamma < 1 \). For this to be true, we must assume that:

\[
\left\{ \begin{array}{l}
2. \left[ (1 - \delta^{-1})(L - 1) - \psi_0 e - \delta^{-1} \right] / r < \psi_0 e \\
\frac{\theta(\gamma)}{\theta(0)} > \log \delta
\end{array} \right.
\]  

Result 2: Under assumption (A3), the equilibrium always exists, is unique and is an interior one.

2.4 Comparative Statics

This section analyses the impact of competitive pressure and the introduction of ICT on the degree of tacitness which can be sustained at the firm level.

2.4.1 An increase in competition through \( H \)

Differentiating [17] we get:

\[
\frac{d\gamma}{dH} = \theta(\gamma). \left[ -S^{-1} \gamma^2 \psi_0 e + (S^{-1} \gamma^2 \psi_0 e. \log \delta - 1/\theta') \right]
\]  

The effect on the degree of tacitness of an increase in \( H \) is ambiguous. The first term channel \(-S^{-1} \gamma^2 \psi_0 e\), is negative. It reflects the *creative destruction effect* and stands for the fact that an increase in \( H \) directly increases competitive pressure at the microeconomic level (see the term \( \theta(\gamma^*).H \) in equation [17]); this in turn makes relational contracts less sustainable and the degree of tacitness decreases. The second term \((S^{-1} \gamma^2 \psi_0 e. \log \delta - 1/\theta')\), is positive. It corresponds to the *capitalization effect*, and stands for the fact that an increase in \( H \) increases the macroeconomic growth rate \( g = \theta(\gamma^*).H.\log \delta \); this makes future cooperation more valuable from the
firms’ and agent’s point of view; in turn this makes relational contracts more sustainable (see result 1).

Moreover the growth rate may react non straightforwardly to an increase in $H$ because the growth rate depends on the intensity of knowledge spillovers which in turn react to a change in $H$. Indeed differentiating [8] we have:

$$\frac{dg}{dH} = \left[ \frac{\partial g}{\partial \gamma} \frac{\partial \gamma}{\partial H} + \frac{\partial g}{\partial H} \right]$$

The direct impact of $H$ on the growth rate $\frac{\partial g}{\partial H}$ is positive but there is an indirect (and eventually negative) impact $\frac{\partial g}{\partial \gamma} \frac{\partial \gamma}{\partial H}$ through the change in tacitness $\gamma$ which may reduce the scope of knowledge spillovers and thus the growth rate. All this discussion may be stated as follows:

**Result 3:** When $\log \delta < 1$, the creative destruction effect dominates and $d\gamma/dH < 0$; When $\log \delta > 1$, the capitalization effect dominates and $d\gamma/dH > 0$. In both cases the growth rate increases with $H$ : $dg/dH > 0$. However the elasticity of growth to $H$ is less than 1 when the capitalization effect dominates: $dg/dH < g/H$.

Note that the result in the case $\log \delta < 1$ is rather counter-intuitive. Indeed we would expect that more competitive environment induces firms to control more closely information leakages and thus reduce the degree of codification of their know-how. Here this is not the case because firms are limited by the constraint of sustainability of tacitness.

### 2.4.2 The effect of ICT

We must remind that the expression of knowledge spillovers is $\bar{\theta}(\phi(1 - \gamma)).H$ (see equation [6]) where $\phi$ may be interpreted as a parameter standing for the efficiency of ICT. Differentiating [17] with respect to $\phi$, we get:

$$\frac{d\gamma}{d\phi} = (1 - \gamma). \left[ -\bar{\theta}'S^{-1}\gamma^2\psi e + (\bar{\theta}'S^{-1}\gamma^2\psi e \cdot \log \delta + \phi^{-1}) \right]$$

Hence both creative destruction effect and capitalization effect are at work in the same way than in the previous section. An increase in ICT fosters knowledge spillovers which increases the competitive threat $\theta$; this in turn diminishes the sustainable degree of tacitness (creative destruction effect). An increase in ICT fosters knowledge spillovers which increases the aggregate growth rate; this in turn reinforces the sustainable degree of tacitness (capitalization effect). As previously we can establish the following result.
Result 4: When \( \log \delta < 1 \), the creative destruction effect dominates and \( d\gamma/d\phi < 0 \); when \( \log \delta > 1 \), the capitalization effect dominates and \( d\gamma/d\phi > 0 \). In both cases the growth rate increases with \( \phi : dg/d\phi > 0 \). However the elasticity of growth to \( \phi \) is less than 1 when the capitalization effect dominates: \( dg/d\phi < \gamma/\phi \).

3 Development and codification: Multiple equilibria

Let assume now that there are cross industry knowledge spillovers [as emphasized in Glaeser et alii 1992]. It means that in each industry, knowledge spillovers can be written as:

\[
\varepsilon_i = \phi(1 - \gamma_i) + \kappa \int_0^1 (1 - \gamma_j) dj
\]

where \( \kappa \) stands for the cross-industry spillovers with \( \kappa < \phi \) and \( \gamma_{-1} \) is the average degree of tacitness within the economy. Using equation [17] and [8] the level of tacitness chosen by a firm is now equal to:

\[
\gamma^*_{\psi|\theta} = \frac{S}{r + \theta(\gamma^* + \kappa\gamma_{-1})H - \theta((1 + \kappa)\gamma_{-1})H \cdot \log \delta} \tag{20}
\]

Note that each incumbent firm in its sector takes as given the level of tacitness chosen in the other sectors. Also the aggregate growth rate of the economy \( g = \theta((1 + \kappa)\gamma_{-1})H \cdot \log \delta \) is taken as a given by each individual firm.

Simple inspection of this equation reveals that \( \gamma \) is an increasing function of \( \gamma_{-1} \) through \( \theta(.) \) but decreasing through the impact of \( \gamma_{-1} \) on the growth rate \( g = \theta((1 + \kappa)\gamma_{-1})H \). The more tacit are other industries, the smaller are cross-industry knowledge spillovers, the less stringent is technological competition and the less likely will be the firm leapfrogged. This reduced creative destruction effect allows firms to sustain a higher level of tacitness in their relational employment contract with their manager. At the same time however, smaller spillovers reduce the aggregate growth rate of the economy. The capitalization effect of growth on the asset value of the firm is smaller. This in turn makes relational cooperation more difficult inside the firm. As a consequence, a smaller level of information tacitness can be sustained. In other words, the capitalization effect induces some strategic substitutability between the level of tacitness of the different sectors whereas the creative destruction effect induces some strategic complementarity.

When the degree of cross-sector knowledge spillovers is large enough\(^{22} \), one can show however

\(^{22}\text{Note that there are two interpretations of the parameter } \kappa. \text{ Either } \kappa \text{ can be seen as a cross-industry spillovers [which is empirically relevant, see Glaeser et alii., 92] or } \kappa \text{ stands for the fact that firms do not completely internalize the impact of } \gamma \text{ on knowledge spillovers within their industry. We may expect } \kappa \text{ to be large in case of spatial concentration, informal communications enforced by social discipline, etc.} \)
that strategic complementarity will arise.

Result 5: When \( \kappa \), the cross industry spillover, is sufficiently large, i.e. \( \kappa > \hat{\kappa} \) with \( \theta'(0)/\theta'(1) \equiv \log \delta.(1 + \hat{\kappa})/\hat{\kappa} \), there is strategic complementarity between the choice of informational tacitness across sectors and multiple equilibria may arise.

The firm-level reaction function is depicted on diagram [4] in the case with large enough \( \kappa \) and strategic complementarity across sectors. The level of information tacitness of one firm is upward sloping in the average level of tacitness of the other sectors, up to a threshold level at which full tacitness (i.e. \( \gamma = 1 \)) is sustainable inside the firm. As can be seen in diagram [4], the complementarity allows for the possibility of multiple symmetric equilibria in information tacitness. In that case there is a growth-intensive equilibrium \( G \) with codification (i.e. \( \gamma_G < 1 \)) and high informational spillovers and a stagnant equilibrium \( S \) with tacitness (i.e. \( \gamma_S = 1 \)) and low informational spillovers.

4 Ownership Structure

So far, the problem of two-sided hold up faced inside the firm was solved by the use of relational contracts and reputation based incentives. An alternative way is to make transfer of ownership to the agent. In that case, the firm does not rely on repeated interactions and relational contracts but on static ex-post bargaining power which is transferred to the agent. As noticed already by Baker, Gibbons and Murphy (2002), outsourcing decisions affect the status quo points of the two parties compared to relational employment contracts and therefore may have strong implications on the ex ante incentives. Here we consider only the case of spot outsourcing contracts in which the firm decides to transmit ownership to the agent of the tasks the latter is supposed to produce (the firm keep ownership on the remaining tasks).23. As before, at the beginning of the relationship the firm decides its level of informational tacitness \( \gamma \), taking as given the rest of the economy. A spot outsourcing contract will be a pair \((W, p)\) specifying a formal payment \( W \) between the two parties when the agent achieves the righ effort on the dimensions \( 1 - \gamma \) with formalized-verifiable information. \( p \) is the price at which the agent will sell production to the firm. This price will be negotiated ex post between the two parties at the end of the spot relationship. We assume also that the agent has a limited liability constraint and

23Baker, Gibbons and Murphy (2002) extensively consider also the case of relational outsourcing contracts and discuss how and why the outcomes of the type of contract differ from those of relational employment contracts. Looking at relational outsourcing contracts in our setting is an interesting line of investigation for future research.
therefore that $W > 0$.\footnote{This is done to keep the symmetry between outsourcing contracts and employment contracts. As a matter of fact, if $W$ was allowed to be negative, the firm could always achieve its first best contract.} We also assume that outsourcing does not increase communication costs between the firm and the agent.\footnote{This assumption allows us concentrate again on the role of external competitive pressures in the design of the optimal organizational structure of the firm. Clearly all we say will still qualitatively be valid if the increased communication costs between the agent and the firm due to outsourcing are not too large.} As said already, the benefits of outsourcing to the firm come from the fact that the hold up problem is now partially solved in a one-shot interaction. Therefore the firm can sustain a higher level of information tacitness and protect better its incumbent position against technological competition. The cost of outsourcing is the fact that the firm will now loose some rents (whereas in the in-house relationship it was capturing the whole surplus). Consider now the price $p$ at which the agent sells his production to the firm. This price is fixed after a bilateral bargaining stage which maximizes the joint surplus $\pi$. Outside options of both agents are zero and we immediately get that:

$$p = \frac{\pi}{2}$$

Let us assume then that the surplus of the relationship is large enough that $\pi/2 < \psi_0 + \bar{w}$ so that the agent is happy to enter into the relationship. This can be alternatively stated as:

$$\psi_0 < (1 - \delta^{-1})(L - 1)/2 - \delta^{-1}$$

Note then that the agent will always provide the full effort, whatever the degree of tacitness of information. From the firm’s point of view, her surplus is equal to $\pi/2 - W$ at each date. It is clear that it should set $W = 0$. Hence the firm’s intertemporal total surplus is equal to:

$$V_{out} = \arg\max_{\gamma} \frac{\pi/2}{r + \theta(\gamma)H - g}$$

Clearly the solution is to choose an extreme level of tacitness $\gamma_{out} = 1$. Hence

$$V_{out} = \frac{\pi/2}{r + \theta(1)H - g}$$

\[21\]

4.1 The choice of organization

Let us now consider the optimal choice of organizational form between in-house production (based on a relational employment contract) and outsourcing along a stationary growth path characterized by a given growth rate $g$. The firm decides to transfer ownership whenever:

$$V_{out}(g) - V_{in}(g) > 0$$
where $V^{\text{out}}$ is given by [21] and $V^{\text{in}}$ is given by [13] and [15]. This condition can be written as:

$$
\frac{r + \theta(1).H - g}{r + \theta(\gamma^{\text{in}}).H - g} < \frac{\pi}{2S}
$$

(22)

We then have the following result:

**Result 6:** $\exists \tilde{g} \in [0, \tilde{g}(H)],$ such that for $0 \leq g \leq \tilde{g},$ in-house production is preferred while for $\tilde{g} \leq g \leq \tilde{g}(H),$ outsourcing is preferred.

Recall that the relevant range for the growth rate is $g \in [0, \tilde{g}(H)]$ where $\tilde{g}(H) \equiv \log \delta.\theta(0).H.$ Lemma 2 states that for low growth rates, the firm prefers to produce in-house and to rely on relational contracts to sustain tacitness. On the other hand, for large values of the growth rate $g,$ the firm prefers to loose some rents but to rely on a larger level of information tacitness through outsourcing.

The intuition for this result is the following. The relative cost of outsourcing compared to inhouse production comes from a reduced flow of income in each period. The relative advantage of outsourcing for the firm on the other hand comes from the increased capacity to sustain tacitness which reduces the probability to be technologically leapfrogged by a competitor. This in turn increases the expected lifetime of the firm. This relative advantage is all the more valuable to the firm that it enjoys a large capitalization effect of its asset value along its life time. The larger the growth rate, the larger the capitalization effect and the larger the relative advantage of the outsourcing organizational form to the firm. When the growth rate is small, the capitalization effect is weak and in-house production tends to dominate outsourcing because of superior flow of income that the firm receives under this organizational structure. On the other hand, when the growth rate of the economy is large, the capitalization effect is large and more than compensates the disadvantage of reduced income flows per period and outsourcing dominates in-house production.

The firm level choice with respect to $g$ is depicted on graphic [5]. At $g < \tilde{g},$ $\gamma^{\text{in}}(g)$ depict the individual firm’s level of information tacitness as a function of the growth rate when choosing in-house production. It is upward sloping because of the capitalization effect. For $g > \tilde{g},$ the level of tacitness under outsourcing is given by $\gamma^{\text{out}} = 1.$ At $g = \tilde{g},$ firms are indifferent between the two organizational modes and any fraction of firms picking up outsourcing is compatible with firm level organizational incentives. This is represented by the vertical segment $\gamma^{M}(\tilde{g})$ on the diagram.

. Macroeconomic equilibria are then depicted by the intersection of this information tacitness curve $\gamma(g)$ and the downward sloping growth curve: $g = g(\gamma) = \theta(\gamma).H.\log \delta.$ As depicted,
depending where the curves intersect, three types of equilibria may emerge: in-house ownership structure, M: mixed strategy, O: outsourced ownership structure. The mix equilibrium is determined by the condition 

\[ g = \tilde{g} \]

where

\[ \frac{r + \theta(\gamma^{in}).H - \tilde{g}}{r + \theta(1).H - \tilde{g}} = \frac{S}{\pi/2} \]  

(23)

with such an aggregate growth rate, individuals firms play a mixed strategy between outsourcing and in house production. The probability \( \lambda \) of choosing in-house production by a firm, by the law of large numbers, is also the fraction of sectors choosing that organizational structure. It has to be such that the corresponding aggregate growth rate is equal to \( \tilde{g} \). Hence \( \lambda \) is given by:

\[ \tilde{g} = H. \log \delta. \left[ \lambda \theta(\gamma^{in}) + (1 - \lambda)\theta(1) \right] \]  

(24)

### 4.2 Comparative Statics

Let us look at an increase in \( H \). To simplify the computations it is useful to assume that:

\[ \frac{\theta(1/2)}{\theta(1)} > 2. \left[ 1 - (\delta \psi e + 1)/(\delta - 1)(L - 1) \right] \]  

(A4)

**Result 7:** Under assumption A4, when \( H \) increases, the economy gradually switches from a in-house equilibrium to an outsourced equilibrium. One may have a U shape relationship between the level of information tacitness and \( H \). More precisely, when the capitalization effect is dominated by the creative destruction effect, the average degree of tacitness within the economy first decreases, then increases until reaching a complete degree of tacitness. Finally, there is a decrease in the aggregate growth rate during the transition phase from the in-house regime to the outsourced regime (see diagram [6]).

The intuition for this comparative statics is illustrated in figure 7. An increase in \( H \) shifts the growth curve \( g(\gamma) \) to the right as more resource devoted to innovation stimulates growth for a given structure of informational spillovers. At a given growth rate, a increase in \( H \) increases the negative impact of creative destruction on the relational sustainability of in-house production, shifting downward the part \( \gamma^{in}(g) \) of information tacitness of that regime. At the same time, in order to escape the increased pressure of technological competition, firms are more likely to switch to outsourcing production. Indeed this, allows them to increase information tacitness and to reduce thereby as much as possible the spillovers effects on their competitors. This effect
is illustrated on picture 7 by the leftward shift of the threshold value $\tilde{g} = \tilde{g}(H)$. Start then from a in house production macroeconomic equilibrium like $E_0$. As long as the equilibrium stays in the regime with in-house production and that the creative destruction effect dominate the capitalization effect, an increase in $H$ will reduce the level of tacitness in the economy. Given that $\tilde{g} = \tilde{g}(H)$ is decreasing in $H$, a further increase in $H$ makes technological competition very hard and start to induce some firms to shift to the outsourcing mode with a progressive increase in information tacitness in the economy. During the transition stage, the growth rate of the economy is $g = \tilde{g}(H)$ and decreases with $H$: Indeed there is a transitory productivity slowdown because the increase in tacitness reduces knowledge spillovers which in turn negatively impacts growth. This process goes smoothly until we reach an even larger of $H$ such that all firms shift to outsourcing and that the macroeconomic equilibrium is located on the part $\gamma_{out}(g) = 1$ of the diagram.

This comparative statics is broadly consistent with the after war period of economic expansion. The Fordist regime may in our framework correspond to a regime of high growth, high codification and large technogical spilovers whereas postfordism has been characterized by a productivity slowdown and a switch toward more information tacitness. It is also somehow consistent with the dramatic change of corporate structures in the late 80s and during the 90s and the corresponding emergence of outsourcing. Our model suggests that an increase in outsourcing (within the regime OUT) should be accompanied by a decrease in knowledge spillovers (due to an increase in tacit knowledge).

5 Conclusions

The purpose of this paper has been to investigate one facet of the incentives for an organization to keep some of its knowledge tacit and to codify part of it. We have emphasized a trade off shaped by the conflict between internal incentives and external competitive pressures. This provided a natural channel through which the external environment of the firm has some impact on its optimal organizational structure and the nature of its informational flows. Because of the consequences on knowledge spillovers in the rest of the economy, the nature of informational flows inside organizations, had in turn, some feedback effects on macroeconomic performances.

In order to illustrate these mechanisms in the most simple way, we abstracted from many other facets of the problem of tacit knowledge and its diffusion into society. First we astracted from technological constraints related to costs of communication, articulation and codification of tacit knowledge. Introducing them will add another margin the firm will need to take into account in its decisions to codify or not some of its knowledge stock and in principle, could be
introduced into our framework

We also abstracted from learning mechanisms related to tacit knowledge. Indeed, to some extent, tacit knowledge is also associated to processes through which one may informally learn how to do things with some degree of "subsidiary" awareness. Through such a process, an agent exposed to the practice of transmission of tacit knowledge, may also get that knowledge embodied in himself as a new form of tacit knowledge. This capacity of learning generates interesting issues. In particular, the possibility of "tacit" appropriation of tacit knowledge may imply new forms of opportunism and competition between the two parties sharing that piece of knowledge. This in turn will have some implications for the design of informational flows and the organizational structure in which these flows will be implemented.

Our framework also considered very simple contracting settings. One may wish to extend our analysis to more complex environments. For instance, one may think about the role of social networks and communities to stabilize the problems of opportunism based on tacit knowledge. The amount of formalization of information inside and across organizations will then be shaped by the structure of social links. In turn, one may expect the structure of social networks to be dependent on the nature of informational flows spreading between them.

Finally, our setting endogenized knowledge spillovers in a rather crude way. In particular, we did not provide a precise microfounded description of the process through which codified knowledge gets diffused in the society. This could be due to labor market turnover outcomes, migration, industrial spying, informational leakages from enforcing or regulating parties, etc. Understanding precisely these mechanisms is certainly an important line for future research. We hope that incorporating such extensions into our setting could then be helpful to understand the nature of knowledge spillovers and their implications in various economic areas like international trade, FDI, economic geography or development.

\[26^{\text{We}}\text{Tacit knowledge is like letting something become a tool for our usage and allow it to become an extension of us. This process of letting something become subsidiary to one's awareness refers to what Polanyi (1958), describes as "indwelling".}\]
References


APPENDIX

Proof of Result 2

Let define $\dot{g}$ such that for $g > \dot{g}$, $\gamma(g) = 1$. From equation (17), this definition implies that $\psi_{\dot{g}} = \left[ (1 - \delta^{-1})(L - 1) - \psi_{\dot{g}} - \delta^{-1} \right] / [r + \theta(1).H - \dot{g}]$. Now let define $\bar{g} \equiv \log \delta \theta(0)H$. Let show that we always have $\bar{g} < \dot{g}$. If this is true then it is clear that there is one and only one equilibrium (see the graphic [3] for getting the argument).

Let $C(H)$ be $C(H) \equiv 2. [(1 - \delta^{-1})(L - 1) - \psi_{\dot{g}} - \delta^{-1}] / [r + \theta(1)H - \theta(0)H \log \delta] \notag$ From assumption (A3) we get that $C(H)$ is decreasing in $H$. And $C(0) = 2. [(1 - \delta^{-1})(L - 1) - \psi_{\dot{g}} - \delta^{-1}] / r$ which is lower than $\psi_{\dot{g}}$ according to assumption (A3). Hence $\forall H, C(H) < \psi_{\dot{g}}$. This last equation, combined with equation (17) implies that $\bar{g} < \dot{g}$.

Proof of Result 3

> From [19] it is clear that $\log \delta > 1$ implies without ambiguity that $d\gamma/dH > 0$. It is less immediate in the case $\log \delta < 1$. Let set $C(\gamma, H) \equiv -1/\theta' + 2\gamma^2\psi_{\dot{g}} \log \delta - 1/S [x \gamma(H), \gamma(H)$, the degree of tacitness, is given by condition [13] where, at the equilibrium point, the slope of the RHS is less than the slope of the LHS. In analytical terms this means that $\psi_{\dot{g}} + S^{-1} \gamma^2 (\psi_{\dot{g}})^2 \theta' > 0$. From this inequality we straightforwardly get that: $C(\gamma, H) < 0$ which, from [19], corresponds to $d\gamma/dH < 0$.

> From equation [8] we have $g = \theta(\gamma^*).H \log \delta$. Differentiating this equation gives, after some computations:

$$\frac{dg}{dH} = -\frac{S}{\gamma^2 \psi_{\dot{g}}} \frac{1}{1 - \log \delta} \frac{d\gamma}{dH}$$

this straightforwardly drives the results of the proposition.

Proof of Result 5

Let set $\dot{k}$ such that $\theta'(0)/\theta'(1) = \log \delta,(1 + \dot{k})/\dot{k}$. And assume $\kappa > \dot{k}$. Let $RHS(\gamma, \gamma-1)$ be the right hand side of [20]. We have

$$\frac{\partial RHS}{\partial \gamma_{-1}} \equiv S.(r + \theta - g)^2.[-\kappa \theta'(\gamma^* + \kappa \gamma_{-1}) + \log \delta(1 + \kappa)\theta'(1 + \kappa)\gamma_{-1}]$$

which is positive iff $-\theta'(\gamma^* + \kappa \gamma_{-1}) > -\log \delta. \kappa^{-1}.(1 + \kappa)\theta'(1 + \kappa)\gamma_{-1})$. This is the case because $\kappa > \dot{k}$ and $\theta(.)$ is concave. As a consequence $RHS$ is increasing in $\gamma_{-1}$. This implies that $d\gamma^*/d\gamma_{-1} > 0$. There is strategic complementarity. From this last result and the fact that $RHS$ is convex in $\gamma^*$ we deduce that there exists $\hat{\gamma}$ such that $\gamma_{-1} > \hat{\gamma}$ implies $\gamma^*(\gamma_{-1}) = 1$. Finally if $\lim \gamma^*(\gamma_{-1}) < \hat{\gamma}$, there are multiple equilibria.

31
**Proof of Lemma 1**

Let denote \( V(g, \gamma(g)) \) the left-hand side of [22]. Differentiating [17] and \( V(., .) \) we have:

\[
Sg \left( \frac{dV}{dg} \right) = Sg \left[ \theta(1) - \theta(\gamma) - \gamma \theta'(\gamma) \right]
\]

(25)

In the proof of result 3, we have shown that

\[
\forall H, 2. \left[ (1 - \delta^{-1})(L - 1) - \psi_0 e - \delta^{-1} \right] / [r + \theta(1).H - \theta(0).H \log \delta] < \psi_0 e
\]

As \( \theta(\gamma).H \) is decreasing in \( \gamma \), we get that

\[
2. \left[ (1 - \delta^{-1})(L - 1) - \psi_0 e - \delta^{-1} \right] / [r + \theta(1/2).H] - \theta(0).H \log \delta] < \psi_0 e.
\]

Using equation (17) this means that \( \gamma(g) < 1/2 \) for \( g \in [0, \bar{g}(H)] \) where \( \bar{g}(H) \equiv \log \delta. \theta(0).H \).

Moreover \( \theta(\gamma, H) \) is decreasing and concave in \( \gamma \) which induces that \( \forall H, \theta(1) - \theta(\gamma) - \gamma \theta'(\gamma) < 0 \) for \( \gamma \leq 1/2 \). A look at expression (25) shows that \( V(g, \gamma(g)) \) is decreasing in \( g \) on \( [0, \bar{g}(H)] \).

This directly drives the result of the lemma..

**Proof of Result 6**

Remind that \( \tilde{g}(H) \) corresponds to the growth rate where the condition [22] is an equality, ie \( V(\tilde{g}, \gamma^\text{in}(\tilde{g}), H) = 2S/\pi \). Differentiating this equality gives

\[
\frac{d\tilde{g}}{dH} = -\frac{\partial V}{\partial \gamma} \frac{\partial \gamma}{\partial H} + \frac{\partial V}{\partial \gamma} \frac{\partial \gamma}{\partial H} dV \frac{dg}{dg}
\]

> From lemma 1, we know that \( \frac{dV}{dg} < 0 \). Moreover from result 4, we know that \( \frac{\partial \gamma}{\partial H} < 0 \). Hence:

\[
\frac{\partial V}{\partial \gamma} \frac{\partial \gamma}{\partial H} = \frac{\theta'}{r + \theta(1).H - \tilde{g}} > 0
\]

And

\[
\frac{\partial V}{\partial H} = \frac{1}{r + \theta(1).H - \tilde{g}} [\theta(\gamma) - \theta(1)2S/\pi]
\]

> From assumption (A4) we get that \( \frac{\partial V}{\partial H} > 0 \). To sum up we get that

\[
\frac{d\tilde{g}}{dH} < 0
\]

Moreover \( 1 > \log \delta \) induces that \( d\gamma/dH < 0 \). A simple graphical analysis of the macroeconomic equilibrium directly drives the result 7 (see diagram [7]). An increase in \( H \) switches to the right the curve \( g = \theta(\gamma)H \log \delta \) and the curve \( \gamma^\text{in}(g, H) \). But it switches to the left the threshold
\( \tilde{g} \). It means unambiguously that the macroeconomic equilibrium switches from an in-house equilibrium toward an outsourced equilibrium. Finally note that during the transition from the IN equilibrium to the out equilibrium, there is a mixed equilibrium as defined by equations [23] and [24]. In a mixed equilibrium the growth rate is equal to \( \tilde{g}(H) \) which is decreasing with \( H \). Hence, transitory there is a "productivity slowdown". Finally note that the average degree of tacitness in a mixed equilibrium is given by \( \gamma^\text{aver.} = \lambda(H) \gamma^\text{in}(H) + (1 - \lambda(H)) \).1 where \( \lambda \) is the mixed strategy parameter as defined by equation [24]. During the transition stage \( \lambda(H) \) and \( \gamma^\text{in}(H) \) are decreasing in \( H \), hence \( \gamma^\text{aver.} \) increases.
Manager’s participation constraint

Firm’s incentive constraint

Manager’s incentive constraint

Feasible contracts \((w, \omega)\) for a given degree of tacitness \(\gamma\)

Figure 1:
Figure 2: The degree of sustainable tacitness

Figure 3: The equilibrium value of tacitness
Figure 4: Multiple equilibria

Figure 5: Ownership structure with respect to the growth rate.
Figure 6: Ownership Structure and Tacitness.

Figure 7: Comparative Static in $H$