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THE MACROECONOMICS OF KNOWLEDGE MANAGEMENT: INTERNAL HOLD-UP VERSUS TECHNOLOGICAL COMPETITION

Mathias Thoenig and Thierry Verdier

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Mathias Thoenig, CERAS-ENPC and CEPR
Thierry Verdier, DELTA, Paris and CEPR

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Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

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Mathias Thoenig
CERAS-ENPC
48 Boulevard Jourdan
75014 Paris
FRANCE
Tel: (33 1) 4313 6380
Fax: (33 1) 4313 6382
Email: mathias.thoenig@enpc.fr

For further Discussion Papers by this author see:
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Thierry Verdier
DELTA-ENS
48 Boulevard Jourdan
75014 Paris
FRANCE
Tel: (33 1) 4313 6308
Fax: (33 1) 4313 6310
Email: verdier@delta.ens.fr

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=113317

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

September 23, 2004

Abstract

This paper investigates the links between the nature of contractual relationships within firms, the strength of information flows spreading between firms and the dynamics of technological competition. At the firm level, we focus on the corporate incentives to design Knowledge Management policies based on soft versus hard information flows. At the aggregate level, knowledge spillovers are endogenous and feedback effects on macroeconomic growth are investigated.

" Evidence from research conducted since the mid-1960s shows that [...] managers get two thirds of their information to make decisions from face-to-face or telephone conversations; they acquire the remaining third from documents, most of which come from outside the organization", (Davenport, 1994, Harvard Business Review).

1 Introduction

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 knowledge and soft information shared within its organizational structures? How is the nature of information 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 soft versus hard information for the dynamics of innovation and macroeconomic growth?

This paper discusses the role of knowledge codification viewed as the processing of soft information into hard information. We emphasize a basic trade-off: *Codification enables the firm*

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to design more precise contracts and to improve internal efficiency but at a cost of an increase in information leakages toward external competitors. We investigate the aggregate consequences of this firm-level trade-off in term of organizational structures and dynamics of technological competition.

Our motivation relies on the recent attention for Knowledge Management (KM) received within private companies and the academic literature. This concern has been triggered by the rise of the "Knowledge Based Economy" where information flows and innovations are increasingly recognized as being crucial determinants of market success and socioeconomic relationships.[1] For instance a recent study by OECD (2003) attempts to measure the extent of KM in various countries (Canada, Germany, Denmark and France). A survey on the use of 23 KM practices was constructed and was complemented with questions on incentives for using KM practices, results and responsibilities. A noticeable fact is that KM practices now seem to be a widespread phenomenon across countries, concentrated not only in high tech/knowledge-intensive industries but also in more traditional manufacturing industries.

The main goal of KM has been clearly identified by scholars and practitioners of the firms. KM aims at improving static efficiency, increasing opportunities for innovation, and promoting knowledge sharing (within the firm) and knowledge capture (outside the firm). Empirical studies (Hansen, Norhia and Tierney 1999; Quintas 2003) point out that KM policies are basically a mix between two types of strategies: "personalization" where knowledge remains in its tacit form and is shared through face-to-face interaction[2]; and "codification" where information is hard, proceduralized and available to anyone in the company[3]. While both strategies are commonly used by firms, still little is known about the theoretical and the empirical determinants of this mix between codification and personalization.

The starting point of our analysis is that codification of knowledge is a *choice variable* at the firm level. While technological feasibility[4] may limit codification, economic factors, such

[1] The 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)

[2] Quoting Foray and Gault 2003, " [In] Personnalization, knowledge remains in its tacit form and is closely bound to the person who developed it; it is shared primarily through person-to-person contact. To make this strategy work, companies invest heavily in networks of person (mobility, culture of bilateral interaction). In a sense, this strategy is simply another form of the traditional "internal labor market" as a powerful mechanism for capitalizing on, transferring and sharing knowledge [...].

[3] Knowledge Codification usually involves the setup of written documents and regularly updated databases where training manuals, good work practices and more generally the so-called "organizational memory" are stored. Codification is more efficient when supported by the intensive use of ICT.

[4] Indeed it seems clear that certain dimensions of knowledge may remain irreducibly unarticulable. This irreducibility of knowledge tacitness may come from our cognitive incapacity to retrieve some piece of information posited in our inconsciousness. It may also be related to the way one piece of knowledge interacts with other

as external competitive pressures and internal efficiency, play an important role as well. Many examples support this view. Hansen et al., (1999) for instance report differences of KM and codification strategies within the consulting industry. Ernst & Young and Andersen Consulting have developed firm-wide IT systems for document sharing and best practices codification while, on the contrary, McKinsey consultants and Bain&Company rely on networking, face-to-face interactions and an informal culture of experts. Baumard (1999) discusses how, the Australian airline Qantas tried to introduce a new computer-based "KM system" policy favoring documents, manuals and computerized information and faced opposition of pilots preferring non formal circulation of knowledge. In a systematic survey of KM practices across various countries, OECD (2003) reports that most firms undertaking KM strategies and codification procedures, do this with the specific goal of information sharing and information capturing and that, even within an industry (ie. for the same types of products) the KM strategy may vary according to the external business strategy that the firms seek to develop.

Our first main result is that the degree of knowledge codification is closely related to the boundaries of the firm and that a Bell-shaped relationship links codification and the intensity of technological competition. When competition is weak, the optimal KM strategy involves a small degree of knowledge codification sustained by implicit relational contracts. For a medium degree of competition, codification is high and labor contracts are mainly explicit. Finally when competitive pressures get even stronger, codification is again low and is now sustained by workers empowerment through transfer of ownership and joint participation. We believe this result to be roughly consistent with some patterns of long run development of various developed economies: the switch from craftsmanship to mass-production and then a knowledge based economy (which is discussed in Mokyr 2002).

A second result of our analysis relates to the growth literature and the issue of scale effects in growth models. The first generation of endogenous growth models (Romer (1990), Aghion and Howit (1992), Grossman and Helpman (1991)) was characterized by the existence of strong scale effects, namely the fact that growth rates were positively related to the stock of resources available for innovation and R&D. As argued by Jones (2004), while such effects were probably part of any reasonable explanation of growth in a very long run perspective, they do not however seem to match more recent stylized facts of growth patterns over the last century or

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".

so. By endogenizing the nature of information flows (soft versus hard) and the associated structure of spillover in the economy, our approach provides then a new possible explanation for the ambiguity of scale effects in growth models. When the amount of resources devoted to R&D becomes larger, informational spillover tend first to increase (as information becomes "harder"), pushing up the growth rate of the economy. After a threshold however, as technological competitive pressures get even stronger, information flows shift to more softness and are sustained by workers empowerment through joint participation. Knowledge spillover then endogenously tend to decrease and to counterbalance the positive impact on growth. The end result of the comparative statics on R&D resources is a non monotonic relationship between aggregate growth and the size of resources available for innovation. Our framework therefore illustrates how scale effects can be strongly counterbalanced by the changing nature of information flows along the growth process.

1.1 Our story

Our approach begins with the fact that in any socioeconomic relationship, a piece of soft information cannot be, by definition, easily appropriated and therefore verified by a third party. Because of this, softness 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, softness also reduces the capacity of knowledge transferability and appropriation. By reducing informational spillover, this can provide protection against competition, and in particular, against technological competition for which these spillover may be so crucial.

This *two sided nature of information softness*, both as a source of contract incompleteness inside a relationship and as a source of protection against external technological competition, raises an important incentive trade-off for firms: Knowledge Management, viewed as the decision to codify, is shaped by a tension between internal conflicts and outside pressure[5]. As a matter of fact, the decision by firms to keep soft some information flows determines the extent of contractual incompleteness inside the organization and therefore the optimal governance structure to deal with such problems. Moreover the existence of such a trade-off provides a natural channel through which the degree of external technological competition may affect a firm's internal

[5] 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)).

organizational structure. Interestingly, this trade-off exists even in the absence of direct costs of codification[6].

At the aggregate level, there are also feedback effects from the nature of information flows inside organizations to the strength of external innovation competition. The degree of codification affects the extent of transferability of the knowledge in firms' possession. This in turn, affects the scope of informational spillover in the economy and therefore the pattern of innovation and creative destruction.

In order to analyze these issues, we consider a simple schumpeterian growth model with quality ladder a la Aghion and Howitt (1992) or Grossman and Helpman (1991). We embed in such framework a model of internal organization of the firm characterized by an endogenous dimension of contract incompleteness related to the nature of information flows. More precisely, we consider that once a project is discovered, all information relevant to the complete implementation of production is initially soft and fully appropriated by the discovering firm. However, because of overloading, in order to be successfully implemented, the firm needs to hire a agent and share that information with him. In this respect, two different strategies can be followed.

First, the firm may codify information and write down a blueprint or a code book (describing the relevant actions to be undertaken under all contingencies). The benefit of such a strategy is the fact that codified information is hard and verifiable by a third party. Hence, a formal contract can be specified stating how much the agent should receive. The problem of such a strategy on the other hand, is the fact that codification also facilitates transferability and information leakages to technological competitors, thereby reducing the expected lifetime of the firm's project.

An alternative strategy for the firm is to provide information to the agent on the basis of a soft "face-to-face" interaction pattern. The advantage of this strategy is to reduce information leakages to potential competitors. The difficulty lies however in the fact that information remaining soft, it cannot be easily verified by a third party and therefore cannot be contracted upon. Given that it is costly to the agent to undertake the appropriate actions, an hold-up problem arises where the firm may refuse to pay the agent once the right action is made, or the agent may pick up a wrong action a low cost, once being paid by the firm.

[6] See Cowan , David and Foray (2000), who argue, in a informal way, that the decision to codifiy 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

In such a case, two solutions to the opportunistic problem inside the firm can be envisioned. The first relies on repeated interactions and relational employment contracts between the firm and the agent (*à la* Baker, Gibbons and Murphy, 2002). In order to be sustainable, these relational contracts have to satisfy some incentive compatibility conditions both for the agent and the firm. The second alternative is to empower the agent by giving him ownership over parts of the production process (as studied by the incomplete contracting literature; see Grossman and Hart (1986)). Without additional costs of communication, this form of joint organizational structure helps to sustain a higher degree of softness of information between the two agents, at the cost of ex-post bargaining and sharing of the rents. Codification and the organizational mode (internal relational contract or transfer of ownership) picked up optimally by the firm are going to be affected by the intensity of external technological competition. In particular, we show that joint ownership between the firm and the agent becomes more profitable to the firm after a threshold of competitive pressures has been reached. Empowerment of workers and the intensity of competition are then positively linked.

1.2 Related Literature

This paper is related to several strands of literatures. First, our work clearly builds upon the insights of the economics of information as initiated by Arrow (1962), and in which knowledge is viewed as sharing some generic public good characteristics (non rivalry, often non excludability and costless transferability). We emphasize however the perspective of practitioners of the firm and the sociology of science which has, for long, insisted about the fact that knowledge is partially tacit and only partially transferable. Polanyi (1958) for instance is the classic reference for being the first to demonstrate the existence a component of knowledge which remains essentially tacit. He pointed out to the contextual dimension of knowledge embodied in somebody's mind, which remains inarticulate and not easily expressible to someone else. Nelson and Winter (1982) have also followed this line of thought, emphasizing the importance of information softness in skillful activities[7,8,9].

Our approach emphasizes the *two sided nature of information softness*, both as a source of contract incompleteness inside a relationship and as a source of protection against information spillover. The first point is discussed in the incomplete contracting literature. The second point is consistent with evidence gathered in the empirical literature on technology spillover and diffusion; among the stylized facts pointed out by that literature is the fact that knowledge spillover are spatially localized and that the scope of this spatial effect is negatively linked to the existence of soft information[10].

In our framework, the degree of contractual incompleteness is endogenous. This is also related to recent work by Battigalli and Maggi (2002) addressing 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)). Our paper contributes to this line of research by highlighting that this 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.

This paper also contributes to a recent emerging literature analyzing the links between the internal organization of the firm and macroeconomic growth[11]. This literature discusses how

[7]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).

[8]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 interpretating 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.

[9]See 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.

[10]For statistical evidence, see Audretsch and Feldman (1996), Keller (2002), Feldman and Lichtenberg (1997); For evidence on information spreading in the Sillicon Valley, see Saxenian (1996) ; For the role of trade networks in information spreading, see the survey by Rauch (2000).

[11]See Thesmar and Thoenig (2000), Martimort and Verdier (2004), Aghion, Acemoglu and Zilibotti (2002),

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 investigate 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 spillover generate then a feedback effect of the microstructure of the firm on macroeconomic growth. As already mentioned, this last feature aspects allows us to link also in a novel way to the literature on endogenous growth and scale effects (see the survey by Jones (2004)).

Finally, at a more general level, a significant amount of work emphasizes the importance of technological spillover in models of endogenous growth, development, international trade and economic geography. It is well known that results emanating from these models are drastically affected by the specification of spillover (local vs global). While aware that the size and scope of spillover are linked to the existence of soft information (see Krugman (1991)) most of these theories take the nature of spillover as exogenously given. Our model is a first step towards endogenizing this aspects by providing micro-foundations of some information generation activities.

The paper is organized as follows. Section 2 presents the basic framework. In section 3, the model is solved and the main results are discussed. Simple comparative statics are then performed in section 4. Section 5 provides a simple empirical discussion about the relevance of our approach. Finally, section 6 concludes.

2 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

Francois and Roberts (2003)

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:

$$x_s(i) = \frac{Y_s}{p_s(i)} \tag{1}$$

The representative consumer is endowed with the following intertemporal separable utility function: $U_t = \sum_{s=t}^{+\infty} (1+\beta)^{-(s-t)} [Y_s - e_s]$ where Y_s corresponds to date s consumption of Y and e_s to the nominal cost of effort. We assume[12] that the shadow price of effort increases at the growth rate of this economy: $e_{s+1} = (1+g_s)e_s$. 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, an entrepreneur must implement the project by creating a firm and hiring workers. When ruling a firm, an entrepreneur cannot undertake at the same time some research effort.

At each date, there is a endogenous probability θ 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 intellectual property rights by patenting their project. The very act of patenting however exogenously reveals some information on the technological know-how. Despite this feature, we assume for the moment that every firm decides to patent.

A new project enhances the productivity of the previous leading-edge project by a parameter δ with $0 < \log \delta < 1$ (see below the production function (4)). Due to limit-pricing in Bertrand competition between the new project and the previous one, the price $p_s(i)$ charged by the new firm is equal to $\delta c_s(i)$ where $c_s(i)$ is the new firm's unit cost of production at time s. Using (1),

[12] This technical assumption ensures that a steady state growth path exists. A simple story for justifying this assumption is provided in François and Roberts (2003) and is the following: An agent employed and contractually paid w_s by a given firm may shirk and in fact supply her unit of labour to another firm; in that case she gets in addition to w_s another wage $\bar{w}_s$ (ie. the reservation wage). Here "exerting effort" means that the agent accepts to supply her labour unit to the firm where she is currently employed for and thus to get only w_s. As a consequence the cost of effort e_s corresponds to an opportunity cost of not getting the reservation wage elsewhere:

$$e_s = \bar{w}_s$$

which is at steady state equal to (see condition 5): $e_s = \bar{w}_s = (1+g)^s\ \bar{w}$. All the results of the paper are valid under this alternative assumption.

this means that each project generates a cash-flow equal to :

$$\pi_s = (1 - \delta^{-1}).Y_s \tag{2}$$

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

$$\theta = f(\varepsilon_i, H) \tag{3}$$

where ε_i is a parameter standing for the *endogenous* degree of knowledge spillover within industry i and $f(.,.)$ is increasing and concave in both arguments. We discuss below how the spillover parameter ε_i can be partially manipulated by the leading edge firm in order to reduce the probability of being destroyed.

Production and Hold-up

Within each industry i, at each date t, the leading edge firm produces according to a two stage process. Firstly, in the "quality" stage, a set of strategic tasks must be done in order to adapt the production process to changing environmental conditions. Secondly, in the "quantity" stage, an amount l of workers are hired in order to produce with the leading-edge technology:

$$y_i = \delta^{n_i(t)}.l \tag{4}$$

where $n_i(t)$ is the quality index of the leading edge-firm such that $\delta^{n_i(t)}$ corresponds to the productivity of the firm. The firm's unit cost of production is equal to $c_t = \bar{w}_t/\delta^{n(t)}$ where $\bar{w}_t$ is the competitive wage prevailing on the labor market. And the quantity y_i is optimally chosen for getting the monopoly profit under limit pricing as given by (2).

The "quality" stage is done by an Agent, hired on the labor market, whose job consists in implementing a set of tasks $j \in [0, 1]$: *All tasks must be correctly implemented* otherwise the "quantity" stage cannot take place and the firm's cash-flow will be null. For each task j, correct implementation requires that the Agent undertakes[13] a time-dependent "correct" action a^*_{jt} at a cost e_t.

In the "quality" stage, there is room for opportunism because we assume: (1) that the Agent is always able to undertake, *at zero cost*, a wrong action a_j; (2) that, from the contracting point

[13] We assume that the set of *possible* actions is so wide that an Agent ignoring *ex-ante* a^*_{jt} has no chance of implementing correctly the task j. Moreover a^*_{jt} evolves in an unpredictable way such that *learning by the Agent is not possible*.

of view, firm's cash-flows[14], the quality (ie. "correct" or "wrong") and the costs (ie. e_t or 0) of actions a_j are not verifiable by an outside party. Consequently in absence of a blueprint or a contract describing ex-ante the correct actions a^*_{jt} for each date t, there is an hold-up problem: If the agent undertakes the correct action a^*_{jt} at cost e_t, the firm has an 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.

The role of codification: from soft to hard information.

Strategic information of the leading-edge firm corresponds to $\{a^*_{jt}\}$, the set of correct actions (or "best practices" as usually denoted in the management literature). Initially this set of information is appropriated by the entrepreneur only (because he is the discoverer). The purpose of the KM policy is to share this information with the Agent who needs it for implementing correctly the "quality" stage. As emphasized in the existing empirical literature, we consider two types of KM policies: (1) *"face-to-face" interaction:* for a given task j, information remains soft and at each date t ,the entrepreneur gives to the Agent only the bit of soft information a^*_{jt}. There is no direct communication cost. (2) *codification:* for a given task j, at the beginning of the relationship, the entrepreneur gives to the Agent a blueprint (or a code of procedures) specifying the correct actions $\{a^*_{jt}\}_{\forall t \in (1,2,...)}$. Hence soft information is made hard. There is no direct cost of codification.

The KM policy implemented by the entrepreneur mixes both strategies. A share γ of the continuum $[0, 1]$ of tasks j is kept under soft information and is transmitted through "face-to-face" interaction. The choice of γ is irreversible. Hereafter *we denote "degree of codification" the share* $(1 - \gamma)$ *of soft information which is processed into hard information.*

Codification benefits to internal efficiency. Indeed, by hardening information (ie. the blueprint), codification allows the writing of a formal contract describing the set of correct actions which have to be done by the Agent. This consequently solves the hold-up problem for the $(1 - \gamma)$ codified tasks only. But codification has a cost in term of information leakages: The share $(1-\gamma)$ of hard information immediately and costlessly spreads towards a share $0 < \phi < 1$ of competitors[15] such that the competitive pressure θ increases. In more technical terms, the

[14] Contracts could be made contingent on the quality of the product or the amount of sales. The hold up problem would then disappear. To restore the hold up problem, we would need then 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 total quality could not be inferred.

[15] There are several ways to justify this assumption. First, codified knowledge spreads under the form of

endogenous intensity of knowledge spillover writes as $\varepsilon = \phi.(1-\gamma)$ and the competitive pressure θ is equal to (see expression (3)):

$$\theta = \theta(\underset{(-)}{\gamma}) \text{ with } \theta' < 0 \text{ and } \theta'' < 0$$

To sum up, the endogenous degree of information softness γ stands both for the degree of contractual incompleteness and the size of spillover. *This dual aspect comes basically from the fact that codification (ie. switching from soft to hard information) enables to design more precise contracts but simultaneously promotes information leakage.*

The trade-off faced by the firm is clear: despite the underlying hold-up problem the firm may still choose to keep part of information soft (ie. $\gamma > 0$) to diminish information leakages and competitive pressure. In that case, the firm must use an alternative instrument to reduce the hold-up: either relational contracts (ie. repeated interactions between the firm and the Agent) or an optimal pattern of ownership structure (as studied by the incomplete contracting literature, Grossman and Hart (1986)).

Steady-state

We focus on steady-state symmetric growth path equilibria such that all variables grow at the same pace g:

$$Y_t = (1+g)^t.Y_0, e_t = (1+g)^t.e \text{ and } \bar{w}_t = (1+g)^t.\bar{w} \tag{5}$$

where g is the stationary growth rate prevailing in the economy and equal to[16]:

$$g = \theta(\gamma).\log\delta \tag{6}$$

As $\gamma \in (0,1)$, this equation shows that the equilibrium value of g can take value only within the range $[0,\bar{g}]$ where $\bar{g} = \theta(0).\log\delta$. Finally we assume for the sake of computational simplicity

a blueprint. It spreads costlessly to the whole market because there is a duopoly on the market of codified knowledge [indeed both the entrepreneur and the Agent have access to the blueprint of hard information]. As a blueprint is costless to produce, the equilibrium in this duopoly game is that information is sold for free to everybody. Secondly, another possible 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, the important feature is that information leakage cannot be perfectly contracted upon, in the sense that i*nformation leakage is neither completely observable nor verifiable*: The Agent is always able to transmit a piece of hard information to an outside competitor without being convicted. This view of codified knowledge as a non rival, non appropriable, public good is consistent with the standard (neoclassical) view (Arrow (1962)) .

[16] 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 $p_{it} = \bar{w}_t/\delta^{n_i(t)-1}$ where $\bar{w}_t$ 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 $\log\bar{w}_t = \int_0^1 \log\left(\delta^{n_i(t)-1}\right).di$ and the stationary rate of growth is given by $g = \theta\log\delta$

that the growth rate g, the interest rate r and the creative destruction rate θ are small enough 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.[17]

3 The basic results

This section studies the two instruments used by the firm for solving the hold up problem, namely relational contracts and ownership transfer. We provide here only the sketch of the argument: all the technical details are given in the appendix.

3.1 In-house relational contracts

Consider now relational employment contracts inside the organization. At the beginning of the relationship the firm designs a contract. This contract codifies a share $(1-\gamma)$ of the tasks and specifies a wage schedule $\{w_t\}$ which has to be paid to the agent whenever theses 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 non codified part γ of know-how, the agent will be "free" to undertake them (at a total cost γe_t) as this part of the job is not described in the contract.

The underlying opportunism problem can be solved through relational contracts. The agent is willing to undertake the non codified actions (despite the threat of hold-up) if she expects to get a compensation for her non contractual effort. This compensation takes the form of a non contractual wage ω_t (a bonus) that the firm gives ex-post[18]. As a consequence an employment relational contract implicitly specifies that the agent must undertake at each date t the correct actions 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 component paid when the agent has made the right verifiable actions on the share $(1-\gamma)$ of the codified tasks and ω_t is a promised non contractual wage

[17] 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.

[18] In all generality, there are two other instruments which can be used by the firm in order to incentivize the agent. First the contractual wage w_t could take 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 non codified part otherwise she would be fired and she would loose her future efficiency wage premium $(w_t - \bar{w}_t)$. However we show in appendix that this efficiency wage mechanism is always dominated by a simple ex-post bonus scheme ω_t. And at equilibrium the participation constraint of the agent is binding: $w + \omega - e = \bar{w}$.

Secondly the contractual schemes could have three components: w_t, ie. the contractual wage; ω_t^a, ie. a non-contractual wage which is paid ex-ante; and ω_t, ie. a non-contractual wage which is paid ex-post. However the analyzis (see appendix) should convince the reader that the role of ω_t^a 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 (a more formal proof can be available from the authors upon request). Hence we can focus only on 2-dimensional schemes (w_t, ω_t) without any loss of generality.

paid when the agent has made the part of the job on the γ remaining non codified tasks. That contract needs to be self enforcing for the two parties. It should therefore satisfy incentive compatibility constraints both for the agent and the firm and the agent's individual rationality constraint.

The agent's incentive constraint: Focusing on detrended stationary contracts along a stationary growth path, it can be shown that for small values of r, θ and g, the incentive compatibility constraint of an agent writes as:

$$\gamma e \leq \omega + \frac{w + \omega - e - \bar{w}}{r + \theta - g} \tag{MIC}$$

This has a straightforward interpretation. The one period gain from cheating[19] (saving the effort cost γe on non verifiable tasks) should be less that the value of not cheating. The latter is the sum of the bonus ω received at the end of the period and the expected discounted gains of the cooperative employment relationship in the future. Condition [MIC] clearly shows that any share γ of information softness can be sustained from the agent's point of view as soon as the bonus ω is sufficiently large: unfortunately the firm will tend to renege on large values of ω and this instrument is difficult to enforce from the firm's point of view (see below).

The firm's incentive constraint: Similarly the firm's incentive constraint can be written as:

$$\omega \leq \frac{\pi - w - \omega}{r + \theta - g} \tag{FIC}$$

The one period gain from cheating[20] on the agent and not paying the bonus ω, has to be less than the expected discounted value of the cooperative relationship to the firm (ie. the RHS). 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 ω, the more the firm wants to renege. The larger is the net surplus of the relationship the more the firm cooperates.

The agent's participation constraint: The per period value of employment $w + \omega - e$ must be equal to, or larger than, the opportunity cost of working as a production worker $\bar{w}$. But in the appendix we show that the optimal contract is such that the participation constraint is always binding:

$$w + \omega - e = \bar{w} \tag{PC}$$

[19] After cheating, the agent is fired by the firm and goes back to the labor market with a bad reputation. This reputation prevents her to be hired by other firms as a manager and thus constraints her to earn the reservation wage $\bar{w}$ (see appendix for all the details).

[20] After cheating on the agent, the firm gets a bad reputation and no agent will accept to work for the firm as a manager. The firm is thus unable to produce anymore and gets 0 cash-flow (see appendix for all the details).

For a given stationary growth rate $g \in (0, \bar{g})$, the optimal problem of the firm is to maximizes its expected discounted value with respect to information softness γ under (PC)-(MIC)-(FIC), which in detrented value is equal to:

$$V = \underset{\gamma}{Max} \frac{\pi - e - \bar{w}}{r + \theta(\gamma) - g}$$

Given that the rate of creative destruction $\theta(\gamma)$ is decreasing in γ, it is clear that the firm would like to implement the largest possible value of γ. Plunging (PC) in conditions (MIC) and (FIC), this means that the optimal γ and ω are given by the largest value of γ such that: $\gamma e \leq \omega \leq \frac{\pi - e - \bar{w}}{r + \theta - g}$. This gives:

Result 1: Under in-house relational contracts, the optimal contract is such that: the contractual wage compensates the agent for the codified share of know-how only, $w = (1 - \gamma)e + \bar{w}$*; the non contractual wage compensates for the non verifiable share of know-how,* $\omega = \gamma e$*. The optimal degree of information softness* $\gamma(g)$ *is below* 1*, is increasing with the growth rate* g *and is such that:*

$$\gamma . e = \frac{\pi - e - \bar{w}}{r + \theta(\gamma) - g} \tag{7}$$

The intuition is the following. Given that the rate of creative destruction $\theta(\gamma)$ is decreasing in the degree information softness γ, the firm would like to implement the largest possible value of γ sustainable through a relational contract (w, ω). The sustainability of γ is however restricted by the fact that the non contractual bonus ω has a limited impact: A large value of ω always provides correct incentives to the agent (see MIC), but not to the firm which may have interest to renege on ω instead of rewarding the agent. Given the absence of commitment device from the firm's point of view, the firm has to choose a value of γ strictly less than 1 (codification of information) to mitigate the internal hold up problem.

An increase in the growth rate g tends to increase the degree of information softness γ. Intuitively, the larger the growth rate g, the more valuable the future cash-flows and wages. It is then important both for the firm and the agent not to renege now in order to enjoy the gains from future cooperation. Cooperation becomes easier for both sides and, consequently a larger degree of softness is sustainable. We call *capitalization effect* this positive impact of growth on information softness[21]

[21] It is easy 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 (MIC) and (FIC). From (22), this immediately drives that $\gamma = 0$.

Note finally that in this type of employment relationship, the firm's present value writes as:

$$V^{in}(g) = \frac{\pi - e - \bar{w}}{r + \theta(\gamma) - g} \tag{8}$$

3.2 Joint ownership and Empowerment

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 empower the agent by making a transfer of ownership in his favor. 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 studied in the incomplete contracting literature[22]. Transfer of ownership affects the status quo points of the two parties compared to in-house employment contracts and therefore may have strong implications on the ex ante incentives.

As before, at the beginning of the relationship the firm decides its level of information softness γ , taking as given the rest of the economy. Under *Joint Participation,* the agent owns his production such that 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[23]. Finally joint-ownership does not increase communication costs between the firm and the agent.[24] As already said, for the firm the benefit of transferring ownership to the worker comes from the fact that the hold up problem is partially solved in a one-shot interaction. Therefore, the firm is able to sustain a higher level of information softness and can protect better its incumbent position against technological competition. The cost of joint ownership however is the fact that the firm now looses some rents (whereas in the in-house relationship it was capturing the whole surplus).

[22] Here we consider only the case of spot contracts after 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). Baker, 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.

[23] In absence of limited liability, there could be an ex-ante *license fee*, W, that the agent pays to the firm in order to get the right to produce for the firm. In that case the firm could always achieve its first best contract under joint ownership. This is so because we do not have here any communication cost. However, it is quite natural to suspect that communication costs should be larger under joint-ownership than under in-house production. A more general model would be such that the trade-off between in-house production and joint ownership balances hold-up inefficiency vs communication costs.

In our present setting, the assumption of limited liability forces W to be zero and therefore keeps the symmetry in term of hold-up inefficiencies between ownership transfer (empowerment) and relational employment contracts. This simplifies the exposition without qualitatively changing our results.

[24] 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 joint ownership are not too large.

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 π. Outside options of both agents are zero and we immediately get that:

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

The agent receives p only when the overall quality is achieved. Given that the surplus of the relationship is assumed to be large enough, ie. $\pi/2 - e > \overline{w}$, (see assumption A_3 in appendix), the agent always undertakes the full degree of effort *whatever the degree of softness of information.* As a consequence, the firm is able to sustain, under joint ownership, an extreme level of softness $\gamma = 1$ in order to reduce information leakage. From the firm's point of view, the surplus is equal to $\pi/2$ at each date. Hence the firm's intertemporal total surplus is equal to:

$$V^{out}(g) = \frac{\pi/2}{r + \theta(1) - g} \tag{9}$$

Result 2: Under joint ownership a full degree of information softness can be sustained, ie. $\gamma = 1$, *and is chosen by the firm.*[25]

3.3 KM-policy and 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 joint ownership along a stationary growth path characterized by a given growth rate g. The firm decides to share ownership whenever:

$$V^{out}(g) \geq V^{in}(g)$$

where V^{in} is given by (22) and (8); and V^{out} is given by (9). This condition can be written as:

$$\frac{r + \theta(1) - g}{r + \theta(\gamma^{in}) - g} \leq \frac{\pi/2}{\pi - e - \bar{w}} \tag{10}$$

Hereafter we denote $\tilde{g}$ the growth rate value such that the previous condition holds as an equality. In the appendix we show the following:

Result 3: For $0 \leq g \leq \tilde{g}$, *in-house production is preferred while for* $\tilde{g} \leq g \leq \bar{g}$, *joint ownership is preferred.*

[25] Clearly in the presence of communication costs under joint ownership, the previous result would be less extreme, as the firm would benefit from increasing codification in order to reduce these costs.

The intuition for this result is as follows. The relative cost of joint ownership compared to in-house production comes from a reduced flow of income in each period. The relative advantage of joint ownership comes from the increased capacity to sustain softness 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 joint ownership organizational form. When the growth rate is small, the capitalization effect is weak and in-house production tends to dominate because of the larger flows of income that the firm receives. Hence this result illustrates how *the KM-policy of a firm and its organizational structure in term of ownership are closely interrelated.*

Graphic 3 depicts the KM-curve, namely $\gamma(g)$ the firm level choice of softness with respect to g. For $g < \tilde{g}$, $\gamma(g)$ is given by condition (22); it is upward sloping because of the capitalization effect under relational contracting. For $g > \tilde{g}$, $\gamma(g) = 1$ under joint ownership. At $g = \tilde{g}$ firms are indifferent[26] between the two organizational strategies; this is represented by the vertical segment on the diagram.

3.4 Macroeconomic equilibrium

In this section we solve for the macroeconomic variables which play a key role in the previous analysis, e.g. the growth rate g and the competitive rate $\bar{w}$. The demand for labor has two components: a demand for (supervising) 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:

$$L = 1 + Y_t/\delta\bar{w}_t \tag{12}$$

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 the market clearing condition writes down: $L = 1 + Y/\delta\bar{w}$.

Moreover from limit-pricing by monopolies we know that $\delta\bar{w} = P$. But the price of the final good is the numeraire. It follows that the competitive wage is such that $\bar{w} = \delta^{-1}$. Plunging back this term in the market clearing condition, we have $Y = L - 1$. From equation (2) the detrended

[26] At $g = g$ the firm is indifferent and relies on mixed strategy: In-house strategy is chosen with a probability λ. This probability must be compatible with the aggregate growth rate $\tilde{g}$ as given by (6). This means that λ is such that:

$$\tilde{g} = \log\delta.\left[\lambda\theta(\gamma(\tilde{g})) + (1-\lambda)\theta(1)\right] \tag{11}$$

value of cash-flow can be written as $\pi = (1-\delta^{-1}).(L-1)$; the net surplus of the firm is thus equal to $S \equiv \pi - e - \bar{w} = (1-\delta^{-1})(L-1) - e - \delta^{-1}$. As a consequence the macro equilibrium is characterized by two conditions.

First, the aggregate spillover condition ties down the value of the stationary growth rate to the firms'choice of softness. It is simply given by condition (6):

$$g = \theta(\underset{(-)}{\gamma}). \log \delta \tag{AS}$$

Second, the KM-condition associates the firm level choice of γ to the aggregate rate of growth. This KM-condition has been studied in the previous section and is given by (22) and (10) which, together with labor market clearing condition, writes down as:

$$\gamma e = \frac{S}{r + \theta(\gamma) - g} \text{ for } g < \tilde{g};\ \gamma = 1 \text{ for } g \geq \tilde{g} \tag{KM}$$

where $\tilde{g}$ is given by equality in condition (10).

On graphic 3, the upward sloping curve (KM) corresponds to the KM condition while the downward sloping curve (AS) corresponds to the aggregate spillover curve. We get:

Result 4: A steady state equilibrium always exists and is unique .

Depending on the locus of the KM curve and the AS curve, three different types of equilibria may emerge: in-house relational equilibrium, joint ownership equilibrium and an equilibrium in which both types of organizational forms coexist.

4 Comparative statics and extensions

In this section we perform various comparative statics relying on graphical support. All computational details are given in the appendix.

4.1 The Bell-shaped evolution of knowledge codification

Start our comparative statics exercises with the impact of the long run evolution of Information and Communication Technologies (ICTs). The spread of ICTs has increased the speed of diffusion and transmission of information. However it is reasonable to believe that ICTs mainly deal with hard information while soft information is diffused through face to face interactions. In our framework knowledge spillover are equal to $\varepsilon = \phi(1-\gamma)$ (see equation (3)) where $(1-\gamma)$ stands for the degree of codification; clearly ϕ may be interpreted as the efficiency of ICTs.

On diagrams 4a, 4b and 4c, an increase in ϕ has a direct effect on the aggregate spillover curve (AS) which shifts upwards. For a given γ an improvement in ICTs' efficiency increases informational spillover and thus the aggregate growth rate of the economy. The effect on the KM-curve is less obvious. First, it unambiguously reduces $(0, \tilde{g})$ which corresponds to the range of the growth rate where in-house production is preferred to joint ownership by firms. The reason is that the increase in ICTs efficiency makes, for a given degree γ, the cost of information leakage more important. Firms therefore try to reduce codification. This is done by switching from in-house production to joint ownership (where $\gamma = 1$ is sustainable). Hence ICTs diffusion promotes joint ownership.

Second, within the in-house regime, there is a *creative destruction effect* that stands for the fact that an increase in ϕ directly increases competitive pressure θ at the microeconomic level; this in turn makes relational contracts less sustainable for a given g. This reduces the degree of soft information γ which can be sustained with relational contracts and corresponds to a downward shift of the KM curve within the range $(0, \tilde{g})$.

Summarizing, for low values of ϕ, an increase in ϕ maintains first the economy within the in-house regime but decreases γ (see diagram 4a). For intermediate values of ϕ, both organizations co-exist (ie. in-house relational one and joint ownership one) but an increase in ϕ promotes the joint ownership regime and increases γ (see diagram 4b). For large ϕ, the economy is in the joint ownership regime with $\gamma = 1$ and an increase in ϕ has no aggregate effect (see diagram 4c). As a result, the degree of codification is a bell-shaped curve with respect to the efficiency of ICTs (see diagram 5).

According to equations (3) and (6), the growth rate is given by $g = f(\phi(1-\gamma), H). \log \delta$. An increase in ϕ has a direct effect on g through an increase in the scope of informational spillover. But it also has an indirect effect through the endogenous shift in γ. While the direct effect is always positive, the indirect effect can be negative if γ is endogenously promoted by the diffusion of ICTs. Both effects go in the same direction as long as the economy remains in the in-house regime; hence, growth increases with ICTs efficiency (see diagram 4a). On the contrary this last feature does not hold anymore along the transition from the in-house regime to the joint ownership regime where γ increases; in this transitory regime, growth decreases with ICTs (see diagram 4b). Finally, when the whole economy has shifted toward joint ownership, information is only under a soft form ($\gamma = 1$) and consequently the increase in ϕ has no effect anymore in the growth rate, neither through the direct effect nor through the indirect effect (see diagram

4c).

All this discussion may be summarized as follows:

Result 5: When ϕ increases , the economy switches from a in-house equilibrium to a joint ownership equilibrium. There is a Bell-shaped relationship between the level of knowledge codification $(1-\gamma)$ and ϕ. Finally, there is a decrease in the aggregate growth rate during the transition phase from the in-house regime to the joint ownership regime (see diagram (5)) .

This result suggests that ICTs may not necessarily affect positively growth and the scope of informational spillover when firms adjust endogenously the nature of information flows. The diffusion of ICTs can strenghten the threat of information leakages so much that in reaction, firms reduce the degree of codification of their know-how and switch from hard to soft information. This in turn results in a decrease in aggregate knowledge spillover and a reduced growth rate.

This comparative statics is broadly consistent with the after war period of economic expansion. The Mass Production regime corresponds, in our framework, to a regime of high growth, high codification and large informational spillover whereas the Knowledge based Economy is initially characterized by a improvement of ICTs efficiency, a productivity slowdown and a switch toward more information softness. 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 vertical disintegration, joint ownership and agents' empowerment.

4.2 Growth and scale effects

Consider now an increase of the stock of skilled workers H available for innovation and R&D in the economy. It is first worth noting that within our framework, an increase in H drives qualitatively the same results[27] than an increase in ϕ. Hence the following result :

Result 6: When the stock of skilled workers H increases , the economy switches from a in-house equilibrium to a joint ownership equilibrium. There is a Bell-shaped relationship between the level of information codification $(1-\gamma)$ and H. Finally, there is a decrease in the aggregate growth rate during the transition phase from the in-house regime to the joint ownership regime.

A first implication of this result is the fact that the dramatic rise in skilled workforce experienced since the 1970s in many developed countries economies (see Acemoglu (2002) for a discussion) could help to explain the switch form Mass production to Knowledge based Economy and the observed transformations in the pattern of firms' organizations.

[27] All technical details are available from the authors upon request.

More interestingly, the non monotonic comparative statics on the growth rate can be related to the literature on scale effects in endogenous growth models. The first generation of endogenous growth models (Romer (1990), Aghion and Howit (1992), Grossman and Helpman (1991)) was characterized by the existence of strong scale effects, namely the fact that the growth rate of an economy is an increasing function of its size or positively related to the stock of resources available for innovation and R&D. While the very long run history of economic growth appears consistent with the existence of strong scale effects (see Kremer, 1993), they are inconsistent with the relative stability of growth rates in the United States in the 20th century (though the stock of researchers has steadily increased during the same period). Nor do they match stylized recent cross country evidence on growth patterns. Models getting rid of strong scale effects[28] have been developed in the literature. However, either these models are semi endogenous growth models with policy invariant growth rates, either these models maintain the potency of policy to alter long run growth but at the cost of several knife-edge assumptions (see the survey by Jones, 2004).

Our present setting starts with a work-horse model of endogenous growth model generating strong scale effects (putting therefore ourselves in the worst possible situation to reduce them). Still, adding endogenous information flows (soft versus hard) and their implications for the structure of knowledge spillover in the economy, triggers ambiguous scale effects in growth. In particular, our approach suggests that the *strength of scale effects in idea-based growth models can be mitigated by the changing nature of information flows and knowledge spillover*. Moreover, in our context, this aspect is most likely to occur when we have high diffusion of ICTs technologies and/or an already large stock of research personnel in the economy. These last facts seem to fit relatively well the evolution of OECD countries in the last 50 years, period for which strong scale effects on growth seem to be the least relevant.

Finally, it is worth noting that an additional feature of our current approach is the fact that long run growth (even with ambiguous strong scale effects) can still be affected by policy variables. Indeed, in this setting, growth depends on the nature of information flows which in turn is a function of institutional and policy variables affecting the environment of the firm (patent laws, ownership structures, labor contracts laws). Therefore, there still remains scope for policy impacts on long run growth in a context somewhat more generic than other scale free

[28] As opposed to "weak scale effects", namely the fact that the size of the economy affects the *level* of per capita income (see Jones (2004)).

endogenous growth models. [29]

4.3 Social embeddedness

In a celebrated book, Saxenian (1996) analyzes the relative performance of Silicon Valley and Route 128 during the 80s. The cornerstone of her analysis is that different cultures and social embededdness within these areas are key variables to explain the observed patterns of organizations (within and between firms) and the observed scope of informational spillover which ultimately explain global performance of each area.

The broad picture is the following. On the one hand, Silicon Valley during the 80s was characterized by a culture[30] of sharing technical informations which resulted in: i/ a rapid diffusion of knowledge through face-to-face interactions and high labor turnover, ii/ a network of small firms with informal internal organization and close links with their outside suppliers[31]. On the other hand, Route 128 was characterized by a East-coast type of puritan culture where loyalty to the firm and reputation was enforced by a strict social control which resulted in: i/ life long employment and internal labor market ii/ big vertically integrated firms with iii/ high degree of internal codification and hierarchization[32].

In this section, we show how our framework can simply be extended to capture this link between social embeddedness, knowledge spillover and firms internal organization. The literature on social networks has highlighted two channels through which social networks affect individual behavior: norms and information. The information channel emphasizes how a person's knowledge depends on the network she belongs to; the social norm channel emphasizes how a person's behavior is affected by social and peer pressure within the network. Hereafter we look at both channels.

The first function of social network is to speed the spread of information, either hard or soft, through face-to-face interactions or social gathering. Analytically, this issue is very much

[29] See in particular Jones (2004) p. 47 for an insighful discussion of these models.

[30] In chapter 2, Saxenian describes the Silicon Valley as a technical community where "informal conversations were pervasive and served as an important source of up-to-date information about competitors, customers markets, and technologies [...]. The velocity of information is very high".

[31] In the chapter entitled "Route 128: independence and hierarchy", Saxenian says "Route 128s technology enterprises imitated the structure of the traditional mass production corporation. While Silicon's Valley entrepreneurs rejected the corporate practices of the large, established East Coast producers [...]

Saxenian, chapter 6: "Silicon Valley computer firms redefined relations with their most important suppliers [...] they began treating them as partners in a joint process of designing, developing and manufacturing innovative systems".

[32] In chapter 3, Saxenian argues that "the managers of Route 128 technology companies [...] created organizations characterized by formal decisionmaking procedures and management styles, loyal long-term employees and conservative workplace procedures, dress and work styles."

the same as the one discussed above on the impact of ICTs diffusion. Similar results apply and consequently, a culture of information sharing promotes joint ownership and has a Bell-shaped impact on knowledge codification.

What is new to the analysis is the role of social networks in terms of social pressure and norms'enforcement. Indeed, within our framework, the absence of anonymity and the existence of social reputation, by triggering collective retaliation in case of defection, plays a key role in sustaining cooperation within relational contracts. Hence, the strength and persistence of reputation is in some ways similar to the existence of social pressure. In order to capture this, we add a simple feature to our model by assuming now that an agent's reputation (either entrepreneur or agent) is not perfect and spreads from one period to the other only with a exogenous probability $\beta \leq 1$. Hence, in case of cheating under a relational contract, the agent's bad reputation persists with probability β. In the previous benchmark framework, we assumed $\beta = 1$. Clearly β can be interpreted as a proxy for the importance of social pressure.

Social pressure obviously affects positively the sustainability of cooperation under relational contracts between the entrepreneur and the agent. The larger it is, the more stringent is retaliation by society in case of cheating. However, β plays no role under joint ownership. In that case, the hold-up inefficiency due to information softness is solved through an increase in the worker spot bargaining power due to a partial transfer of ownership.

In the appendix we show that the equilibrium is described by equations similar to (AS) and (KM) except that the KM-curve is now given by:

$$\gamma e = \beta . \frac{S}{r + \theta(\gamma) - g} \text{ for } g < \tilde{g}(\underset{(+)}{\beta}); \; \gamma = 1 \text{ for } g \geq \tilde{g}(\underset{(+)}{\beta})$$

What is the aggregate impact of a larger β (see diagram 6)? This induces an upward shift of the KM-curve. Indeed, a larger value of β makes cooperation easier within relational contracts and improves the degree of information softness which can be sustained. As a consequence, the larger β, the larger the range $(0, \tilde{g})$ of growth rates for which in-house production is preferred to joint ownership. The overall effect is to switch the economy from a "low codification/joint ownership" equilibrium (point E_0 on diagram 6) to a "high codification/in-house production" equilibrium (point E_1 on diagram 6).

Result 7: An increase in the degree of social pressure, β, promotes in-house production and codification.

4.4 Patent vs secrecy

In the basic framework, the only source of information leakage is the codification of internal know-how. However another empirically relevant source of leakage is the patenting policy. Indeed it is well known that the benefit from patenting is related to the protection of intellectual property rights against imitation but at a cost in term of information leakages. Hence, we expect the firm's patenting policy to interact with its KM policy of codification.

In this section we allow firms to patent or not their innovation . In order to deal with this issue, we simplify the model in the following way. We assume that at each date the leading edge firm can be imitated , with a probability I, or can be leapfrogged by a more advanced innovation, with a probability θ. Both processes are independent and driven by the pool of entrepreneurs who are not on the leading edge. To make the analysis simple, we assume that these processes are characterized by the following linear functions $I = I.\varepsilon$ and $\theta = \theta.\varepsilon$ where ε is the endogenous intensity of knowledge spillover given by:

$$\varepsilon = \phi.(\gamma.1_{patent}\tau + (1-\gamma))$$

where γ, as before, is the degree of information softness chosen by the leading edge firm and 1_{patent} is an index equal to 1 if the leading edge firm decides to patent, and equal to 0 otherwise. The intuition for this formulation of spillover is that patenting reveals a share $\tau < 1$ of soft information while hard information $(1-\gamma)$ is revealed independently from the patenting policy.

At the microeconomic level the firm takes as given the macroeconomic growth rate g and chooses simultaneously: (i) to patent or not (ii) the degree of information softness γ (iii) relational contracts or joint ownership .

Let us first look at a firm which decides to patent. With respect to the benchmark framework, nothing is changed except that the firm faces now a rate of creative destruction equal to $\theta\phi.[\gamma\tau + (1-\gamma)]$. Using equation (7) the degree of soft information γ which can be sustained through relational contracts is characterized by:

$$\gamma^{pat} e = \frac{\pi - e - \bar{w}}{r + \theta\phi.[\gamma^{pat}\tau + (1-\gamma^{pat})] - g} \tag{13}$$

Denote $P(\gamma^{pat}, g)$ the RHS of this condition.

If the firm decides not to patent and prefers to keep his discovery secret, it faces the threat of imitation with probability I and the threat of leapfrogging with probability θ . Therefore the total rate of attrition due to technological competitive pressure is given by $(\theta + I).\phi.(1-\gamma)$.

Hence the sustainable γ under relational contracts and trade secret is such that:

$$\gamma^{\text{sec}} e = \frac{\pi - e - \bar{w}}{r + (\theta + I).\phi(1 - \gamma^{\text{sec}}) - g} \tag{14}$$

Denote $TS(\gamma^{sec}, g)$ the RHS of this condition.

The firm chooses the patenting policy giving the larger value, ie. $\max(P(\gamma^{pat}, g), TS(\gamma^{\text{sec}}, g))$. Graphically, this choice is depicted on diagram 7. Note that the curve $P(\gamma, g)$ is above the curve $TS(\gamma, g)$ for $\gamma \leq \hat{\gamma}$ where $\hat{\gamma} = 1 - \tau/(I/\theta + \tau)$ which does not depend on g. Note also that under joint participation, the firm chooses $\gamma = 1$ and thus never patents[33]. In the appendix, we derive the full discussion of the equilibrium. The analysis is close to the one of the benchmark case (except that the pricing policy of firms is changed when imitation occurs, having therefore an impact on the labor market clearing condition).

Result 8: Patenting and knowledge codification are complementary policies. When codification is large, ie. $\gamma < \hat{\gamma}$*, patenting is optimal; when codification is low, ie.* $\gamma > \hat{\gamma}$*, trade secret is optimal.*

The intuition for this result is the following. Codification increases internal efficiency but at the cost of information leakages. Hence the marginal cost of patenting in term of information leakage is smaller when codification is extensive than when it is not. On the other hand, the benefits of patenting in term of protection against imitation are constant whatever degree of codification chosen by the firm. As a consequence, patenting is optimal when codification is extensive.

This result links the external KM-policy of a firm (in term of patenting or trade secret) to its internal KM-policy (in term of codification). The main interest of this is observational and empirical. Indeed, the nature of information flows (soft vs hard) within firms is not easily observable for an outside observer while the patent policy is. In other words, the Patenting Policy constitutes an empirical proxy for the nature of internal information flows.

[33] Under joint participation and patenting the firm chooses $\gamma = 1$ and thus gets:

$$\frac{\pi/2}{r + \theta\phi.\gamma\tau - g}$$

Under joint participation and non patenting the firm chooses $\gamma = 1$ and gets:

$$\frac{\pi/2}{r - g}$$

Clearly the second value is larger than the first one. Hence under joint participation, the firm prefers to keep secret its innovation.

Associated with the results emphasized in previous sections, this model thus predicts that the increase in skill supply and the spread of ICTs during the 80s and 90s should have triggered a move toward less codification and more information softness, relying on a decrease in firms'size and empowerment of agents. If it is so, we should also observe a downward trend in the propensity to patent in high-tech industries.

A recent paper by Cohen, Nelson and Walsh (2000) tends to confirm this view. Using the Carnegie Mellon Survey (CMS) on Industrial R&D in the US manufacturing sector in 1994, this piece of work considers the effectiveness of appropriability mechanisms by firms. They find that firms typically protect the profits due to innovations through a variety of strategies, including patents, secrecy, lead time advantages, complementary marketing and manufacturing capabilities. They find secrecy to be the dominant mechanism for process innovations and to be second (after "lead time") as the most effective protective strategy for product innovations. Further, they compare their 1994 CMS findings with results from a similar survey (the Yale Survey) conducted in 1983 by Levin, Klevorick, Nelson and Winter (1987). For product innovations, they find that in most industries in the US manufacturing sector, secrecy went from being judged by firms as the least effective major mechanism to being judged as the most effective one along with lead time. For protection of process innovations, they also found that secrecy ranked higher in the 1994 CMS survey than in the 1983 Yale survey. This tendency for firms to use increasingly secrecy as a strategy to protect their innovations is consistent with other more limited results from a 1995 National Science Foundation pilot survey of 236 firms inquiring about the relative importance of patents, design registration, secrecy, lead time and complexity, and finding secrecy just to be ranked second to lead time as a way to protect rents for product innovations.

5 Further discussion on knowledge codification.

In a recent paper Autor, Murnane and Levy (2003) provide direct[34] evidence that there has been a rise in non procedural activities since the 70s. The main point of their paper is that this rise is pervasive at all educational levels and is accounted by the rapid diffusion of computers at the industry level. This evidence is consistent with our theory which predicts that the spread of IT, by triggering competition and imitation at the industry level, forces firms to relax the degree of codification through joint participation and agents'empowerment. While Autor and al. have

[34] Using samples of the CPS matched with representative data on job tasks requirements from the Dictionnary of Occupational Titles (DOT), they show that "by 1998, non routine analytic task input averaged 6.8 centiles above its 1970 level and nonroutine interactive input averaged 11.5 centiles above its 1970 level".

an alternative interpretation -they argue that computers directly substitute to procedural tasks at the firm level- both mechanisms may in fact be at work. Indeed, their empirical analysis is driven at the industry level. It cannot therefore discriminate between their theory (firm level substitution effect) and ours (industry level increase in competition). Moreover, Askenazy et al. (2004) provide empirical evidence that the effect of IT diffusion on organizational change is mainly channelized by industry wide competition effects and not by firm level "adoption" effects.

Our main theoretical prediction has been established in section (4.1): all along the development process, due to a constant improvement in communication technologies and a permanent increase in skilled labor supply, we should observe a Bell-shaped evolution of knowledge codification. The Mass Production regime should be characterized by a increasing degree of codification and large informational spillover whereas the Knowledge based Economy, which emerged in the late 70s, should be characterized by a switch toward more information softness.

Finding a direct empirical counterpart for the degree of information softness/codification seems at first sight a difficult challenge: by definition information softness is non observable. However, a reasonable premise underlying our theoretical analysis is that information softness and labor contract incompleteness are positively related. More soft information implies less proceduralization of a given related activity and therefore a larger degree of contractual incompleteness in working relationships. In turn, tackling contractual incompleteness empirically may be somewhat easier. Indeed, everything else being equal, we should expect a higher frequency of labor conflicts when the degree of contractual incompleteness increases. As a consequence, a plausible proxy for information softness can be a measure of the intensity of internal labour conflicts, which may be to some extent observable through the number of labor litigation cases brought to legal court.

In the following, we start a very first tentative exploration along this line of reasoning. We use a data set collected by Ioanna Marinescu (2002) which provides information on the number of labor conflicts in industrial tribunals in France since 1850. If labor litigation cases are positively associated to the degree of information softness inside organizations, then a structural Bell-shaped change in terms of knowledge codification should translate into a U-shaped relationship for labor litigation cases.

Historically in France, nearly all labor litigations cases are related to a breach of labor contract and dismissals (see Marinescu 2002). Such dismissals arise for disciplinary purposes (ie. a cheating party) or for economic reasons. As we said, contractual incompleteness means that there are dimensions of the labor relationship which are non verifiable by a third party (the judge). Hence, the larger the extent of that incompleteness, the harder it is for a judge to identify ex-post who is the cheater among the parties when there is a breach of contract. As a consequence, the cheating party may be willing to refuse a private settlement and to prefer a legal settlement[35]. This implies that the frequency of labor disputes and degree of incompleteness are positively correlated.

Three elements have to be noticed at the outset. First, the costs of legal pursuits in France have remained historically constant and relatively low[36]. Hence, the empirical variations in the frequency of labor conflicts do not depend significantly on variations in costs. Second, it is well known that the frequency of labor conflicts is sensitive to business cycles fluctuations. The reason is that dismissals for economic reasons still leave room for disputes even under verifiable labor contract[37]. Finally, we need to keep in mind that the decision for a worker or a firm to cheat is itself endogenous and clearly *depends positively* on the degree of contract incompleteness (the more incomplete the contract is, the more both parties will cheat). All in all, we get that the frequency of labor conflicts may increase for two reasons: either the number of economic dismissals increases (business cycles effects) or the degree of contractual incompleteness increases. In the following we provide two attempts for controlling for the first effect: i/ by looking at the trends on very long period and ii/ by controlling for the number of economic dismissals within the economy.

The first industrial tribunal ("tribunal des prud'hommes") to be created was settled in 1806 in the city of Lyon. Since then the number kept on increasing until reaching its maximal coverage[38] in 1979. Marinescu (2002) builds two measures: On figure 8, the scattered plots

[35] Note that in France (and in many other countries) the decision to trigger legal pursuit is at the discretion of the employee whereas the employer can only use internal sanctions or dismissal to retaliate an employee.

[36] For example the assistance by an advocate is not mandatory. Note that this free of charge aspect is specific to labor conflicts (other conflicts or penal procedures are not).

[37] A straightforward reason is that, in case of dismissals for economic reasons, the size of severance payment may be subject to conflicts. Another reason is specific to Europe where employment protection legislation requires firms firing workers for economic reasons to compensate them with a severance payment, while they do not have to pay firing costs if this is for disciplinary reasons. Hence, whenever there is a dismissal, a double moral hazard problem arises. Firms have incentives to claim it is a disciplinary issue to avoid paying firing costs whereas workers have incentives to claim for unfair dismissals in order to get the severance payment.

This double hazard problem is analyzed by Galdon-Sanchez and Guell (2003). One of their results is that for small enough degree of non verifiablity of efforts by third party (the judge), this double hazard problem cancels out. Hence contractual completness reduces the frequency of labor conflicts.

[38] This exogenous long run spread in the coverage of industrial tribunals is innocuous with respect to the evidence we discuss here; indeed at each date we compute herefater the frequency of labor conflicts *within the share of the workforce covered by industrial tribunals only.*

depict the frequency of labor conflicts, computed as the number of trials divided by the working population covered by the industrial tribunals jurisdiction; the smooth line correspond to a 10 year moving average. It points to a U-shaped relationship where the reversal point is in the 70s corresponding to the transition period from the mass-production to the knowledge based economy. Given that we consider a very long run time span, this reasonably suggests that this trend reflects more than business cycles effects. Figure 9 provides an alternative and more direct way to control for the business cycle effect. It gives the frequency of labor conflict per dismissal (measured as the ratio between the number of conflicts divided by population and the number of economic dismissals). Due to data restrictions[39], the period is smaller. But there is again a clear downward trend of labor disputes cases within the 1947-1979 subperiod, followed by a clear upward trend within the 1980-1998 subperiod.

Of course, we are keen to insist that this evidence is definitively not a formal test for our theory and its Bell-shaped prediction. Clearly, alternative historical evolutions and mechanisms may also explain part of this long run pattern. First, the dynamics of the structural unemployment rate, which has exploded in France in the last two decades, could explain the 1980-1999 evolution of labor conflicts. However, it cannot explain the 1900-1974 period where structural unemployment rate was low (except in the 30s) and labor conflicts steadily decrease. Second, the evolution of trade union density is another competitive factor. Indeed in presence of a trade union, most labor disputes are solved directly at the firm level, through a direct settlement between the firms and the unions, without triggering a legal procedure. This substitution effect, between resolution by trade unions and resolution by industrial tribunals, may explain a potential negative correlation between union density and the frequency of labor conflicts. As density in France has constantly declined since 1980, this could possibly explain the parallel increase in labor disputes; But over the 1945-1980 period, the union density remained globally stable while labor conflicts steadily decreased[40].

Finally, we should also note that the rise in labor conflicts in the last two decades has been documented for other countries with different labor market institutions (Bertola et al. (2000) provide evidence for Germany and for the UK, Burgess et al. (2001) even show that most of this increase cannot be related to the increase in the unemployment rate). Though again only

[39] In fact the number of economic dismissals is known only on the 1980-1998 subperiod; on the 1947-1979 subperiod, Marinescu (2002) uses the number of bankruptcies.

[40] In France, union participation rate was equal to 25,5% in 1953; 19,5% in 1958; 20,9% in 1963; 21,3% in 1968; 23,1% in 1973; 21,5% in 1978; 16,9% in 1983; 12,3% in 1988; 10,9% in 1993; 9,1% in 1995.

suggestive, these pieces of evidence are consistent with our framework if we consider that the last two decades or so have been characterized by diffusions of ICTs and a shift from long term implicit working relationships towards labor empowerment and short term labor contracts.

6 Conclusions

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

In order to illustrate these mechanisms in the simplest way, we abstracted from many other facets of the problem of soft information and its diffusion into society. First, we abstracted from technological constraints related to costs of communication, articulation and codification of soft information. Introducing them will add another margin the firm needs 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 soft information. Indeed, to some extent, soft information is also associated to processes through which one may informally learn how to do things with some degree of "subsidiary" awareness. [41] Through such a process, an agent exposed to the practice\transmission of soft information, may also get that knowledge embodied in himself as a new form of soft information. This capacity of learning generates interesting issues. In particular, the possibility of appropriation of soft information may imply new forms of opportunism and competition between two parties sharing that piece of knowledge. This in turn will have some implications for the design of information flows and the organizational structure in which these flows have to 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 to investigate more

[41] This process of letting something become subsidiary to one's awareness refers to what Polanyi (1958), describes as "indwelling". With this respect, tacit knowledge is like letting something become a tool for our usage and allow it to become an extension of us.

systematically the role of social networks and communities to stabilize the problems of opportunism based on soft information. 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 information flows spreading between them.

Finally, our setting endogenizes knowledge spillover in a very simple way. It would be useful to describe more precisely the process through which hard information gets diffused in the society. This could be due to labor market turnover, migration, industrial spying, information leakages from enforcing or regulating parties,.etc.. Investigating 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 improve our understanding of the nature of knowledge spillover and their implications in various economic areas like international trade, FDI, economic geography or development.

REFERENCES

Acemoglu D., (2002), "Technical Change, Inequality, and The Labor Market", *Journal of Economic Literature*, volume 40, pp. 7-72.

Acemoglu D., Aghion P. and F. Zilibotti, "Vertical Integration and Distance to Frontier", *Journal of the European Economic Association, forthcoming.*

Aghion, Philippe, Howitt, Peter (1992) "A Model of Growth Through Creative Destruction", *Econometrica,* Vol. 60(2), pp.323-351.

Arrow Kenneth, (1962), "Economic Welfare and The Allocation of Resources for Inventions" in *The Rate and Direction of Inventive Activity*, R. Nelson, ed. Princeton, N.J., Princeton University Press.

Askhenazy P., Thesmar D. and Thoenig M., (2004), "On the Relation between Organizational Practices and New Technologies: The Role of Time based Competition", *mimeo CERAS.*

Audretsch David and Maryann Feldman, (1996), "R&D Spillover and the geography of Innovation and Production", *American Economic Review*, 86(4), 253-273.

Autor D., F. Levy and R. J. Murname, 2003, "The Skill Content of Recent Technological Change: An Empirical Exploration", *Quarterly Journal of Economics*, 118(4).

Baker, Gibbons and Murphy,(2002), "Relational contracts and the theory of the firm", *Quarterly Journal of Economics*, 117, 39-83.

Battigalli P. and Maggi G., (2002), "Rigidity, Discretion and the Costs of Writing Contracts," *American Economic Review*, vol. 92(4), pp. 798-817

Baumard P., (1999), *Tacit Knowledge in Organizations*, Sage, London.

Bertola G., Boeri T. and Cazes S., (2000), "Employment protection and labour market adjustment in OECD countries", *International Labour Review.*

Burgess S., Propper C. and Wilson D., (2001), "Explaining the Growth in the Number of Applications to Industrial Tribunals, 1972-1997", mimeo Department of Trade and University of Bristol.

Castells Manuel, (1996), *The Rise of the Network Society, Information Age, I.* Blackwell Publishers, Oxford.

Cohen Wesley, M., Richard R. Nelson and John P. Walsh, (2000), "Protecting their intellectual assets: appropriability conditions and why U.S. Manufacturing firms patent (or not)", NBER Working Paper 7552.

Collins, H. (1974), "The TEA Set, Tacit Knowledge in Scientific Networks", *Science Studies*,4, 165-186.

Davenport T., (1994), "Saving IT's Soul: Human-Centered Information Management", *Harvard Business Review*, March.

Dinopoulos E. and P. Thompson, (1998), "Schumpeterian Growth without Scale Effects", *Journal of Economic Growth*, 3(4), pp. 313-335.

Drucker Peter F., *Post-Capitalistic Society*, Harper Collins, New York.

Feldman Maryann and Lichtenberg Frank, (1997), "The Impact and Organization of Publicly-funded Research and Development in the European Community", Working Paper 6040.

Foray D. and Gault F, (2003), "Measurement of Knowledge Management Practices", , in *Measuring Knowledge Management in the Business Sector*, chapter 1, ed. by OECD.

Francois Patrick and Joanne Roberts, (2003), "Contracting Productivity Growth," *Review of Economic Studies*, Vol. 70 (1) pp. 59-85.

Grossman Gene and Elhanan Helpman, (1991), *Innovation and Growth in the Global Economy*, MIT Press.

Grossman, Sanford, and Hart, O. (1986), "The Costs and Benefits of Ownership : A Theory of Vertical and Lateral Integration", *Journal of Political Economy*, Vol 94:4, pp 691 - 714

Hansen MT., Norhia N. and Th. Tierney, (1999), "What's your strategy for managing knowledge", *Harvard Business Review*, pp.106-116.

Howitt P. (1999), "Steady Endogenous Grwoth with Population and R&D Inputs Growing", Journal of Political Economy, 107(4), pp. 715-730.

Jones C. (1995), "R&D- Based Models of Economic Growth", Journal of Political Economy, 103 (4), pp. 759-784.

Jones C. (2004), "Growth and Ideas", Draft Chapter for the *Handbook of Economic Growth.*

Keller Wolfgang,(2002), "Geographic Localization of International Technology Diffusion", *American Economic Review.*

Kremer M. (1993), "Population Growth and Technological Change: One Million B.C. to 1990", *Quarterly Journal of Economics*, 108 (4), pp. 681-716.

Kremp E. and Mairesse J, (2003), "Knowledge Management , Innovation and Productivity: a firm level exploration based on french manufacturing CIS3 Data", in *Measuring Knowledge Management in the Business Sector*, ed. by OECD.

Krugman, Paul, (1991), *Geography and Trade*, MIT Press.

Levin R.C., A.K. Klevorick, R.R. Nelson, and S.G. Winter, (1987), "Appropriating the Returns from Industrial Research and Development", *Brookings Papers on Economic Activity*, 3.

Levin J., (2003), "Relational Incentive Contracts", *American Economic Review*, June.

Mac Kenzie, D. and Spinardi, G.(1995), "Tacit knowledge, weapons design and the uninvention of nuclear weapons", *American Journal of Sociology* , vol.101, n°1, 44-99.

Marinescu I, 2002, "Les prud'hommes sont-ils efficaces?", mimeo Delta.

Martimort D. and Verdier T., (2004), "The Agency cost of internal collusion and Schumpeterian Growth", *Review of Economic Studies, forthcoming.*

Mokyr Joel, (2002), *The Gifts of Athena: Historical Origins of the Knowledge Economy*, Princeton University Press.

Nelson Richard and Winter Sidney (1982), *An Evolutionary Theory of Economic Change*, Cambridge, MA , Harvard University Press.

Nickerson Jack, and Zender Todd, (2002), " A Knowledge-based Theory of Governance Choice: A Problem Solving Approach", Mimeo Washington University.

OECD, 2003, *Measuring Knowledge Management in the Business Sector*, OECD, Paris.

Polanyi Michael (1958), *Personnel Knowledge: Towards a Post-Critical Philosophy*, London, Routledge.

Quintas P., (2003), "Managing Knowledge in Practice", in *Measuring Knowledge Management in the Business Sector*, chapter 2, OECD ed., Paris.

Reich Robert B. (1991), *The Work of Nations: Preparing Ourselves for 21th Century Capitalism*, Simon and Schuster, London.

Romer P. (1990), "Endogenous Technological Change", Journal of Political Economy, 98(5), pp. S71-S102.

Saxenian A, (1996), *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Harvard University Press.

Segerstrom P. (1998), "Endogenous Growth Without Scale Effects", American Economic Review, 88(5), pp. 1290-1310.

Thesmar, David and Thoenig, Mathias, (2000) "Creative Destruction and organisation Change", *Quarterly Journal of Economics,* Vol.115(4), pp.1201-1237.

Von Hippel Eric, (1994), "Sticky Information and the Locus of Problem Solving: Implications for Innovation", *Management Science*, vol.40, n°4.

Young A. (1998), "Growth without Scale Effects", *Journal of Political Economy*, 106(1), pp. 41-63.

Appendix

A Equilibrium Analysis

In order to simplify the computations, some assumptions related to the value of parameters are useful.

$$A_0: \ \log \delta < 1$$

$$A_1: \ \forall \gamma \in [0,1], \theta(\gamma) < 1, \theta'(\gamma) < 0, \theta''(\gamma) < 0,$$

$$A_2: \ \tfrac{(1-\delta^{-1})(L-1)-e-\delta^{-1}}{r+\theta(1)-\theta(0)\log \delta} < e/3$$

$$A_3: \ (\delta - 1)(L-1) > 2(\delta e + 1)$$

Assumptions A_0 and A_1 are standard. Assumption A_2 guaranties that a full degree of information softness (ie.$\gamma = 1$) cannot be sustained under relational contracts. Assumption A_3 ensures that the joint ownership regime is sustainable.

A.1 In-house relational employment contracts

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 into 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 project-specific.

At each date, a worker knows all his history of wage payments ω_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 ω_t. At each date, each firm knows the history of past wage payments ω_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.

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, ω_t) where w_t is the formal component paid when the agent has made the right verifiable actions on the share $(1-\gamma)$ of the hard tasks and ω_t is a promised non contractual wage paid when the agent has made the part of the job on the γ remaining non codified tasks. That contract needs to be self enforcing for the two parties. It should therefore satisfy incentive compatibility constraints both for the agent and the firm and the agent's individual rationality constraint.

The 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:

$$\begin{aligned} & w_{t+s} - (1-\gamma)e_{t+s} + \sum_{\tau=1}^{\infty} \frac{(1-\theta)^{\tau}}{(1+r)^{\tau}} \bar{w}_{t+s+\tau} \\ \leq \ & w_{t+s} + \omega_{t+s} - e_{t+s} + \sum_{\tau=1}^{\infty} \frac{(1-\theta)^{\tau}}{(1+r)^{\tau}} \left[w_{t+s+\tau} + \omega_{t+s+\tau} - e_{t+s+\tau} \right] \end{aligned}$$

Assuming that the firm pays the relational contract in each period, when the agent does not shirk, he will earn $w_{t+s+\tau}+\omega_{t+s+\tau}-e_{t+s+\tau}$ 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 hard share of tasks, faces a cost $(1-\gamma)e_{t+s}$ 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.[42] 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:

$$\gamma e_{t+s}\leq\omega_{t+s}+\sum_{\tau=1}^{\infty}\frac{(1-\theta)^{\tau}}{(1+r)^{\tau}}\left\{w_{t+s+\tau}+\omega_{t+s+\tau}-e_{t+s+\tau}-\bar{w}_{t+s+\tau}\right\} \tag{15}$$

From Levin (2003) we know that in this environment, the detrended optimal contract is a stationary contract such that $w_s=(1+g)^{s-t}w_t$ and $\omega_s=(1+g)^{s-t}\omega_t$. The previous constraint takes then a simpler form:

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

This incentive constraint must be true at any date $t+s$ after the hiring. Together with the steady state condition (5), the agent's incentive constraint becomes then (in detrented value):

$$\gamma e\leq\omega+\frac{(1-\theta)(1+g)}{(1+r)}\left(\frac{w+\omega-e-\bar{w}}{1-\frac{(1-\theta)(1+g)}{(1+r)}}\right) \tag{16}$$

Note that when (16) holds, (15) 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, θ and g ((16)) becomes:

$$\gamma e\leq\omega+\frac{w+\omega-e-\bar{w}}{r+\theta-g} \tag{17}$$

The 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:

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

At any further date $t+s$, a cooperative firm receives π_{t+s} and compensates the agent by giving her the contractual wage w_{t+s} and the non-contractual wage ω_{t+s}. In that case cooperation between

[42] 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.

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 π_{t+s}, gives the contractual wage w_{t+s} to the agent but reneges on the noncontractual wage ω_{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 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:

$$\omega \leq \frac{\pi - w}{1 + r + \theta - g} \tag{18}$$

The agent's participation constraint:

Finally the contract has to satisfy the agent participation constraint. When hired by a firm, the agent undertakes an effort e_t 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 θ, the agent goes back to the labor market. Hence the agent's participation constraint writes as:

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

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

$$w + \omega - e \geq \bar{w} \tag{19}$$

The set of contracts sustaining a given degree of softness γ

Consider a given degree of softness γ and let us call $\Gamma(\gamma)$, the set of relational contracts (w, ω) which can sustain cooperation between the agent and the firm for this degree of softness. $\Gamma(\gamma)$ is described in the space (w, ω) by the constraints (17)-(18)-(19); $\Gamma(\gamma)$ is depicted on diagram 1. 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:

$$\gamma e \leq \frac{\pi - e - \bar{w}}{r + \theta(\gamma) - g} \tag{20}$$

For a given γ 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[43]. Hence as soon γ as is sustainable (ie. condition (20) is satisfied) the participation constraint is binding, $w+\omega = e+\bar{w}$, 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 γ, the firm always prefers to incite the agent through ω rather than through the efficiency wage $(w-e-\bar{w})$. 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

[43] 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:

$$\frac{\gamma e[r + \theta - g] + e + \bar{w}}{1 + r + \theta - g} \geq e + \bar{w}$$

incentive constraint (see condition MIC) and in the firm's incentive constraint (see condition FIC)][44].

The optimal degree of softness for a given growth rate $g \in (0, \bar{g})$

For a given contractual schemes $\{w_s, \omega_s\}_{s \geq t}$ the firm's intertemporal value is given by

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

where the competitive pressure $\theta(\gamma)$ is given by $\theta(\gamma) = f(\phi.(1-\gamma), H)$. Firm maximizes this value with respect to softness γ under the constraints (17)-(18)-(19) which ensure that cooperation can be sustained through a well designed labor contracts. In detrented value this means that the firm's objective function writes as:

$$\begin{cases} V = \underset{w,\omega,\gamma}{Max} \frac{\pi - w - \omega}{r+\theta(\gamma)-g} \\ s.t. \ \{w, \omega\} \in \Gamma(\gamma) \end{cases} \tag{21}$$

Let us characterize this optimal γ^{in}. From the previous analysis of $\Gamma(\gamma)$, we know that the participation constraint is necessarily binding. If either the agent's or the firm's incentive constraint is not binding,.this means the dimension of $\Gamma(\gamma^{in})$ is 2 (see diagram 1). Unambiguously this implies that condition (20) cannot be an equality. This last point means that it is possible to find a marginally larger degree of softness, $\gamma^{in} + \Delta$, which can be sustained by a relational contract (ie. satisfying the condition (20)). As a consequence, γ^{in} could not be the optimal contract. Hence at the optimal γ^{in}, all constraints are binding. Using equations (PC)-(MIC)-(FIC), this means that the optimal degree of softness is the largest γ such that:

$$\gamma.e \leq \frac{\pi - e - \bar{w}}{r + \theta(\gamma) - g} \tag{22}$$

At the optimal degree γ, all constraints are binding. Hence we get immediately $\gamma e = \omega$ and $w = (1-\gamma)e + \bar{w}$.

Finally from equation (22), we may find out $\gamma(g)$ for $g \in (0, \bar{g})$, ie. the optimal degree of information softness with respect to the growth rate. The degree of softness chosen under in-house production is given by equation (22):

$$\gamma.e = \frac{\pi - e - \bar{w}}{r + \theta(\gamma) - g} \tag{23}$$

Let denote $RHS(\gamma, g)$ the right-hand-side of (23). Clearly $\frac{\partial RHS}{\partial g} > 0$. And $\forall g \in [0, \bar{g}], RHS(0, g) \geq \frac{(1-\delta^{-1})(L-1)-e-\delta^{-1}}{r+\theta(0)(1-\log\delta)}$ which is positive according to assumption A_0. >From A_1 we get $\frac{\partial RHS}{\partial \gamma} > 0$ and $\frac{\partial^2 RHS}{\partial^2 \gamma} > 0$. Hence $RHS(\gamma, g)$ is increasing and convex in γ. For a given g, equation (23) is depicted in figure 2. Two cases may happen. First: $RHS(1, g) < e$; this means that there is one and only one $\gamma < 1$ such that $\gamma e = RHS(\gamma, g)$; this corresponds to the degree of information softness chosen by the firm. Second: $RHS(1, g) > e$; this would mean that a full degree of softness could be sustained; however assumption A_2 implies that $RHS(1, \bar{g}) < e/3 < e$; RHS being increasing in g, this means that $\forall g \in [0, \bar{g}], RHS(1, g) < e$ and so this case is impossible.

[44] 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.

Differentiating (23) we get:

$$(\frac{d\gamma}{dg})/\gamma = [\gamma\theta'(\gamma) + r + \theta(\gamma) - g]^{-1} \tag{24}$$

A look at figure 2,case 1, should convince the reader that at the intercept γ between the two curves, the slope of γe is larger than the slope of $RHS(\gamma, g)$; hence $\partial RHS/\partial\gamma < e$; this implies that $\theta'(\gamma) + \gamma^{-1}.(r + \theta(\gamma) - g) > 0$ and so we get $\frac{d\gamma}{dg} > 0$.

To sum up this section, we have shown that the implicit γ in equation (22) is such that $\forall g \in [0, \bar{g}]$, $\gamma'(g) > 0$ and $\gamma(g) \in [0, \bar{\gamma}]$ where $\bar{\gamma} < 1$.

A.2 In-House vs Joint Ownership

In the main text we show that joint-ownership is preferred to in-house production when:

$$\frac{r + \theta(\gamma) - g}{r + \theta(1) - g} \geq \frac{\pi - e - \bar{w}}{\pi/2} \tag{25}$$

where γ is given by equation (23). Let $W(g)$ and Ω be respectively the left-hand-side and the right-hand-side of condition (25). Assumption A_3 means that $\Omega > 1$.

Consider now a point of "indifference" $\tilde{g} \in [0, \bar{g}]$ where condition (25) is an equality: $W(\tilde{g}) = \Omega$. An obvious differentiation gives:

$$Sg(W'(\tilde{g})) = Sg\left(\theta(\tilde{\gamma}) - \theta(1) + \theta'(\tilde{\gamma}).\frac{d\gamma}{dg}.(r + \theta(1) - \tilde{g})\right) \tag{26}$$

The sign of the right-hand-side of (26) is ambiguous as $\forall\tilde{\gamma} \in [0, 1], \theta(\tilde{\gamma}) > \theta(1)$ but $\theta'(\tilde{\gamma}) < 0$ and $\frac{d\gamma}{dg}.(r + \theta(1) - \tilde{g}) > 0$. However using the definition of $\tilde{g}$ and equation (24), we have: $Sg(W'(\tilde{g})) = Sg(\theta(\tilde{\gamma}) - \theta(1) + \theta'(\tilde{\gamma}).(\Omega.\tilde{\gamma}^{-1} + \theta'(\tilde{\gamma}).\tilde{\gamma}.2e/\pi)^{-1})$ where $\tilde{\gamma} \in [0, \bar{\gamma}]$. From assumptions A_1, A_2 and A_3 we get: $Sg(W'(\tilde{g})) \geq Sg(\theta(\bar{\gamma}) - \theta(1) + \theta'(\bar{\gamma}).(\bar{\gamma}^{-1} + \theta'(\bar{\gamma}).\bar{\gamma})^{-1})$.

But $\theta(.)$ being convex, the theorem of intermediate values guaranties that: $\forall\bar{\gamma} \in [0, 1], (\theta(\bar{\gamma}) - \theta(1)).(\bar{\gamma} - 1)^{-1} \leq \theta'(\bar{\gamma})$. Consequently we have: $Sg(W'(\tilde{g})) \geq Sg(\theta'(\bar{\gamma}).(2 - \bar{\gamma}^{-1} + \bar{\gamma}(\theta(\bar{\gamma}) - \theta(1)))$. By definition, $\bar{\gamma}$ is given by condition (23) with $g = \bar{g} \equiv \theta(0)\log\delta$; hence from assumption A_2 we get that $\bar{\gamma} \leq 1/3$ which implies that: $Sg(W'(\tilde{g})) \geq 0$.

This last inequality means that at the point $\tilde{g}$ where $W(\tilde{g}) = \Omega$, the function $W(.)$ is upward sloping and $W'(\tilde{g}) \geq 0$; but $W(.)$ is continuous and differentiable on $[0, \bar{g}]$; consequently we know that there is at most one point $\tilde{g} \in [0, \bar{g}]$ such that $W(\tilde{g}) = \Omega$. In that case $\forall g \in [0, \tilde{g}], W(\tilde{g}) \leq \Omega$ and $\forall g \in [\tilde{g}, \bar{g}], W(\tilde{g}) \geq \Omega$. From condition (25) this means that $V^{IN}(g) \geq V^{OUT}(g)$ if $g \leq \tilde{g}$; and $V^{OUT}(g) \geq V^{IN}(g)$ if $g \geq \tilde{g}$ where $\tilde{g}$ is the only point on $[0, \bar{g}]$ where condition (25) is an equality.

B Comparative Statics

B.1 ICTs

The variable ϕ impacts the economy through $\theta(.)$ which is equal to: $\theta(\gamma) = f(\phi(1-\gamma), H)$. The equilibrium is characterized by equations (6), (KM) and (10) and is depicted on figure 3. For $g \leq \tilde{g}$, the equilibrium writes down as $\gamma e = RHS(\gamma, g, \phi)$ where $g = f(\phi(1-\gamma), H).\log\delta$ and the definition of $RHS(.,.)$ is given above in the appendix. A straightforward differentiation gives:

$$\frac{d\gamma}{d\phi} = \frac{\partial RHS/\partial\phi}{e - \partial RHS/\partial\gamma} < 0$$

This expression is negative; indeed from the definition of RHS it is obvious that $\partial RHS/\partial\phi < 0$; and we show above that $e > \partial RHS/\partial\gamma$.

For $g \geq \tilde{g}$ the joint ownership regime prevails and the equilibrium is characterized by $\gamma = 1$ and $g = f(0, H).\log\delta$. Hence it is obvious that ϕ does not impact the equilibrium within this regime.

Finally the threshold value $\tilde{g}$ is such that condition (25) is an equality: $W(\tilde{g}) = \Omega$. A straightforward differentiation gives:

$$\frac{d\tilde{g}}{d\phi} = \frac{-\partial W/\partial\phi}{\partial W/\partial\tilde{g}} \leq 0$$

This term is negative because we show above that $\partial W/\partial g$ is positive for the value $g = \tilde{g}$ and from the definition of $W(.)$ it is clear that $\partial W/\partial\phi \geq 0$.

B.2 Social pressure

As discussed in the main text the social pressure parameter affects the aggregate equilibrium only in the in-house regime. Let β be the probability that reputation does not disappear from one period to the other (ie. $1-\beta$ is correspondingly the probability that the agent goes back to anonymity). For a agent; let denote U_t the market present value of bad reputation, $\bar{U}_t$ the value of anonymity and U^{coop} the value of cooperating with the entrepreneur. Agent's incentive constraint writes down

$$\begin{aligned} & w_t - (1-\gamma)e_t + \frac{1}{1+r}\left[(1-\beta)\bar{U}_{t+1} + \beta(1-\theta)U_{t+1} + \beta\theta\bar{U}_{t+1}\right] \\ \leq\ & w_t + \omega_t - e_t + \frac{1}{1+r}\left[(1-\theta)U^{coop}_{t+1} + \theta\bar{U}_{t+1}\right] \end{aligned}$$

Using the fact that $U^{coop}_t = \sum_{\tau=1}^{\infty} \frac{(1-\theta)^\tau(1+g)^\tau}{(1+r)^\tau}\left\{w_t + \omega_t - e_t - \bar{w}_t\right\}$, straightforward computations show that the incentive constraint writes down in detrented terms as:

$$\omega[1+r+\theta-g] + w \geq e\gamma[r+\theta-g] + e + \bar{w} + (1-\beta)(\bar{u}-u) \tag{27}$$

For an entrepreneur, let denote V_t the market present value of not being on the leading edge, $\bar{V}_t$ the value of being on the leading edge with a good reputation (0 is clearly the value of being on the leading edge with a bad reputation, as in the benchmark model) and V^{coop}_t the value of cooperating with the agent. Entrepreneur's incentive constraint writes down

$$\begin{aligned} & \pi_t - w_t + \frac{1}{1+r}\left[(1-\beta)(1-\theta)\bar{V}_{t+1} + (1-\beta)\theta V_{t+1} + \beta(1-\theta).0 + \beta\theta V_{t+1}\right] \\ \leq\ & \pi_t - w_t - \omega_t + \frac{1}{1+r}\left[(1-\theta)V^{coop}_{t+1} + \theta V_{t+1}\right] \end{aligned}$$

Using the fact that in detrented value, we have $V^{coop} = (r+\theta-g)^{-1}.\left\{\pi - w - \omega - \bar{w}\right\}$, $\bar{V} = (r+\theta-g)^{-1}.\bar{v}$, some computations show that the incentive constraint writes down in detrented terms as:

$$\omega[1+r+\theta-g] + w \leq \pi - (1-\beta)\bar{v} \tag{28}$$

The agent's participation constraint is not changed and is equal to:

$$w + \omega \geq e + \bar{w} \tag{29}$$

As in the benchmark case, the optimal contract for sustaining a given degree of softness is such that the three constraints (27)-(28)-(29) are binding. Hence workers are always paid at their reservation wage and consequently we get $\bar{u} - u = 0$ in (27). As a consequence γ is given by $\gamma\psi_0 e = (\pi - e - \bar{w} - (1-\beta)\bar{v})/(r + \theta(\gamma) - g)$. But $\bar{v} = \pi - e - \bar{w}$. Hence: $\gamma\psi_0 e = \beta(\pi - e - \bar{w})/(r + \theta(\gamma) - g)$. This last equation is the one emphasized in the main text.

The growth rate $\tilde{g}$ corresponding to indifference between in-house production and joint ownership is still given by condition (25) which writes down as: $W(\tilde{g}) = \beta\Omega$. Differentiating gives $d\tilde{g}/d\beta = \Omega.W'(\tilde{g})$ which is positive as we show previously that $W'(\tilde{g}) \geq 0$. Hence we get that $\tilde{g}(\beta)$ is an increasing function.

B.3 Endogenous Patenting

As discussed in the main text, the pricing policy of firms is changed when imitation occurs, having therefore an impact on the labor market clearing condition. Hence we explicitly derive here the macroeconomic equilibrium. When firms patent (ie. $\gamma < \hat{\gamma}$), the pricing policy and the labor market equilibrium are similar to the ones in the benchmark model. In that case the competitive wage is such that: $\bar{w} = w^* = \delta^{-1}$.

When firms decide not to patent (ie. $\gamma > \hat{\gamma}$) imitation is possible. When it occurs the leading edge firm and the imitator compete à la Bertrand such that the duopoly price is equal to the cost of production $\bar{w}$. When it does not occur, the limit pricing policy is similar to the one in the benchmark model and the price is equal to $\delta\bar{w}$.

In the economy, at the steady state, the share of industries where imitation occurs (resp. does not occur) is $I/\theta + I$ (resp. $\theta/\theta + I$). These shares impact the labor market clearing condition such that the competitive wage is now equal to:

$$w^{**} = \left[\frac{\theta}{\theta + I}\delta + \frac{I}{I + \theta}\right]^{-1}$$

We can remark that the competitive wage is now larger than $w^* \equiv \delta^{-1}$, the one in the benchmark model. The reason is that imitation lowers the market power of leading edge firms and thus decreases monopoly distortions. Using conditions (13), (14) and the expression of $\bar{w}$, the KM-curve in the (g, γ) space corresponds to:

$$\begin{cases} \gamma\psi_0 e = \left((1-\delta^{-1})(L-1) - e - w^{**}\right) / \left(r + \theta\phi(1-\gamma) - g\right) \text{ for } g < g^* \\ \gamma\psi_0 e = \left((1-\delta^{-1})(L-1) - e - w^{*}\right) / \left(r + \theta\phi(1-\gamma) - g\right) \text{ for } g > g^{**} \\ \gamma = \hat{\gamma} \text{ for } g^* \leq g \leq g^{**} \end{cases}$$

where $(g^* g^{**})$ are such that:

$$\frac{(1-\delta^{-1})(L-1) - e - w^*}{r + \theta\phi(\tau\gamma + 1 - \gamma) - g^*} = \frac{(1-\delta^{-1})(L-1) - e - w^{**}}{r + \theta\phi(\tau\gamma + 1 - \gamma) - g^{**}}$$

Finally the aggregate spillover curve is such that:

$$\begin{cases} g = \theta\phi(1-\gamma)\log\delta \text{ for } \gamma > \hat{\gamma} \\ g = \theta\phi[\tau\gamma + (1-\gamma)\log\delta] \text{ for } \gamma < \hat{\gamma} \end{cases}$$

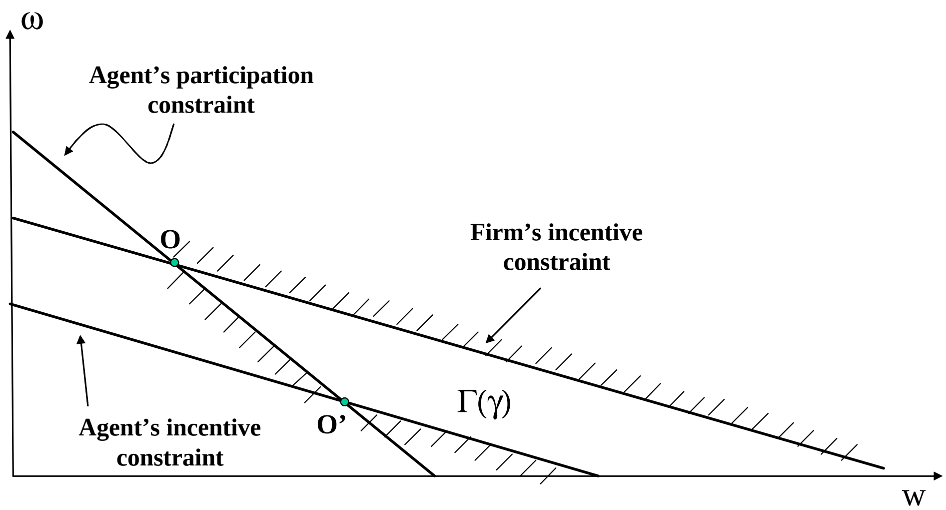
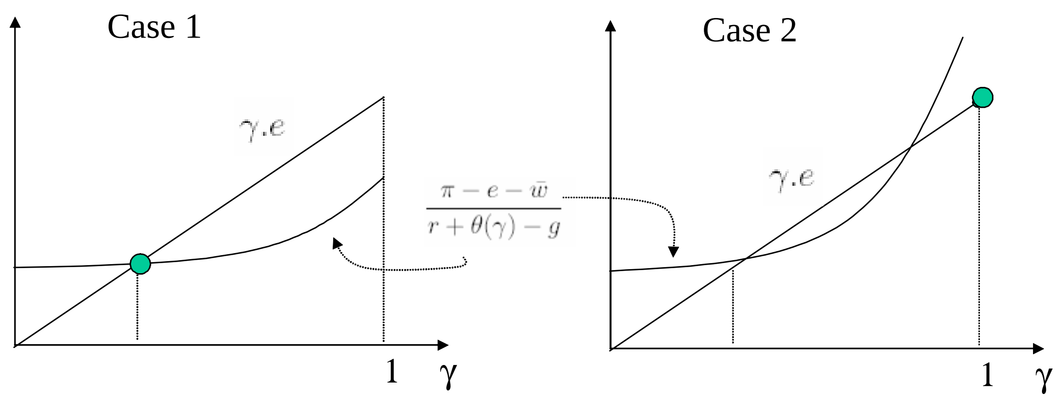

ω
Agent's participation constraint
O
Firm's incentive constraint
Γ(γ)
O'
Agent's incentive constraint
w

Figure 1



Optimal γ under relational contracts:

$$\gamma.e \leq \frac{\pi - e - \bar{w}}{r + \theta(\gamma) - g}$$

Figure 2

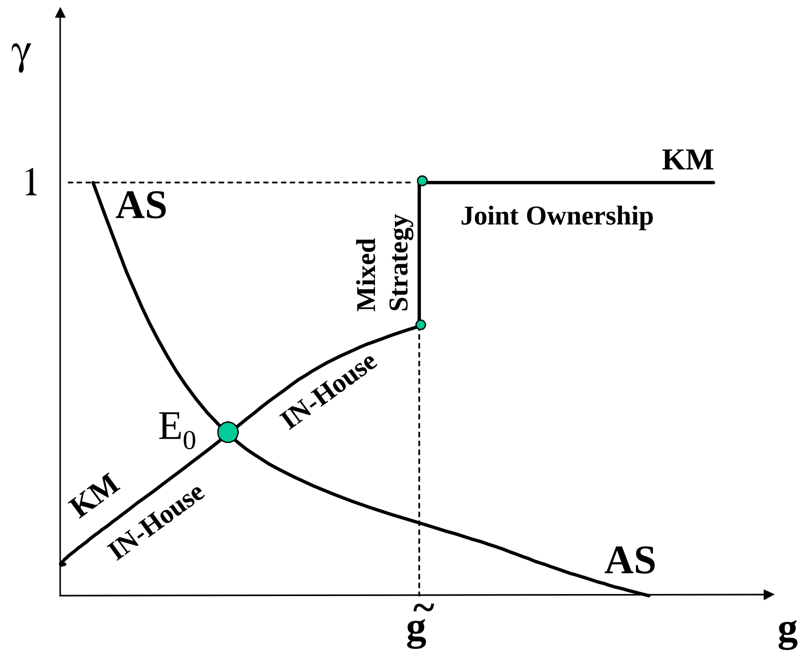


Figure 3

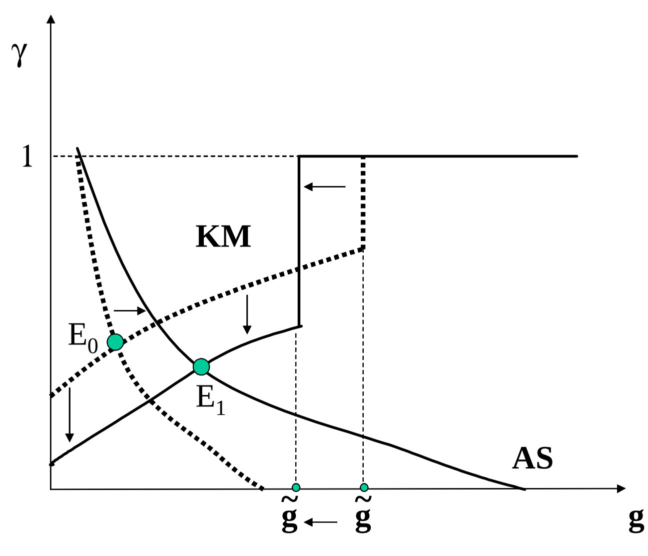
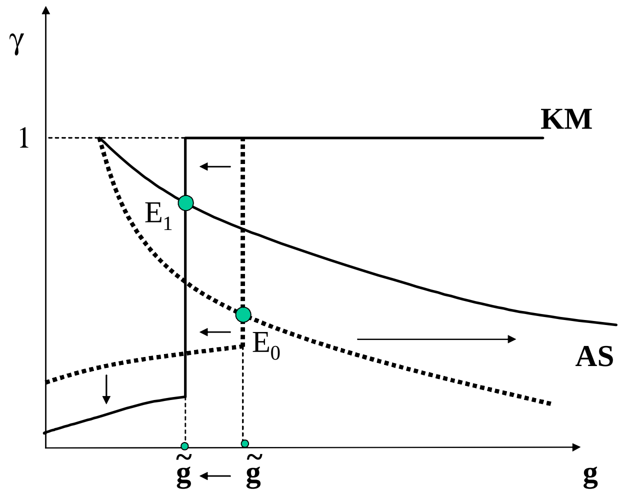
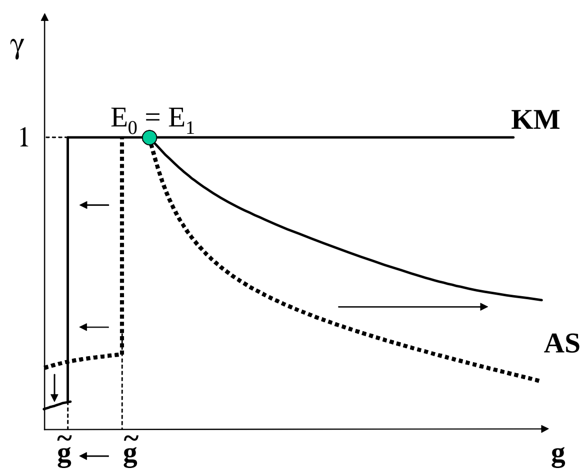


Figure 4a



Static comparative in ϕ for intermediate values of ϕ
Mixed Regime

Figure 4b



Static comparative in ϕ for large values of ϕ
Join Ownership Regime

Figure 4c

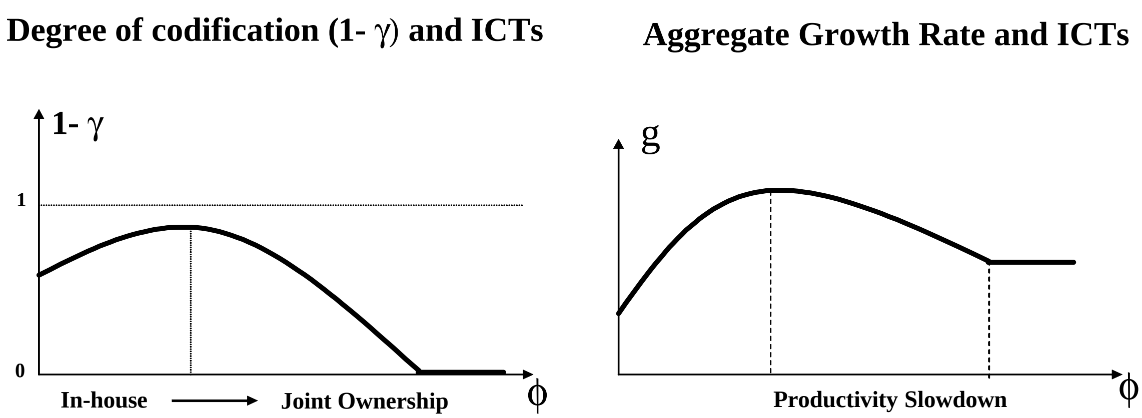


Figure 5

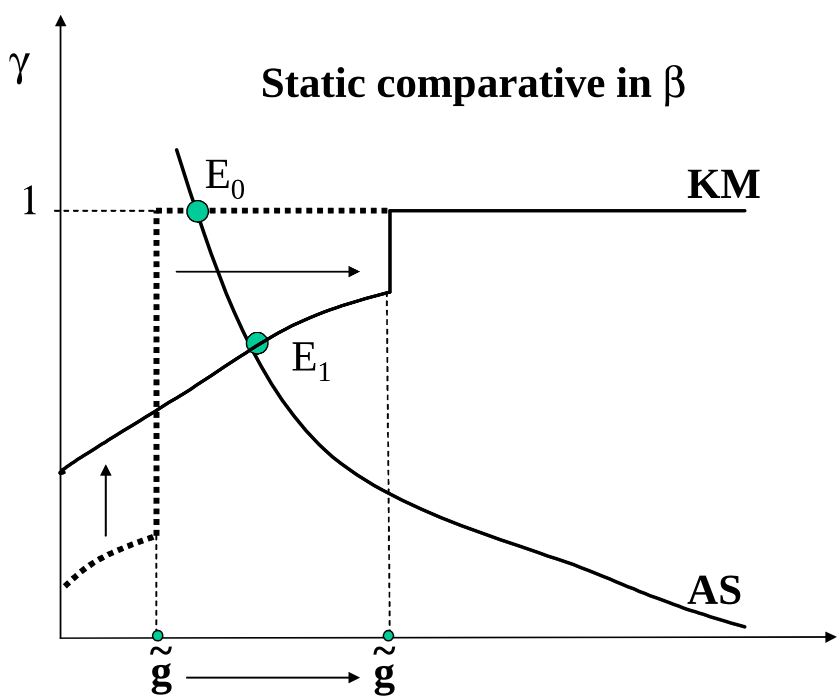
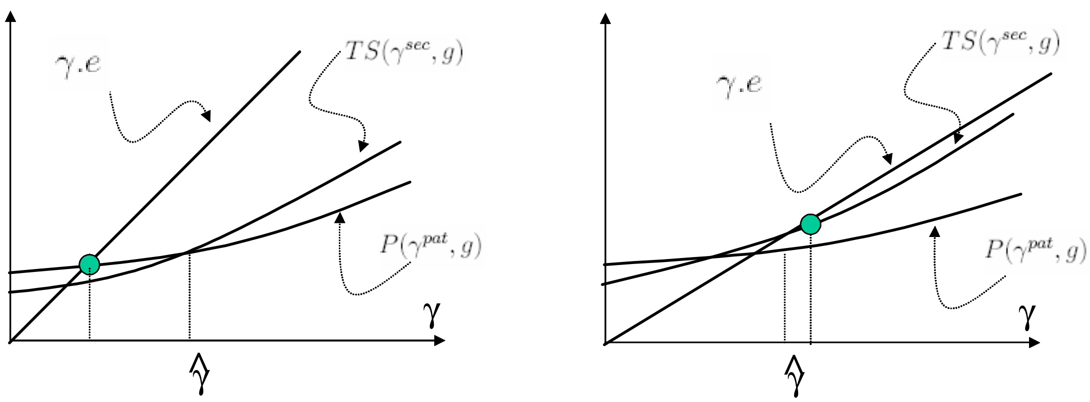


Figure 6

Case 1: Patent > Secret

Case 2: Patent < Secret

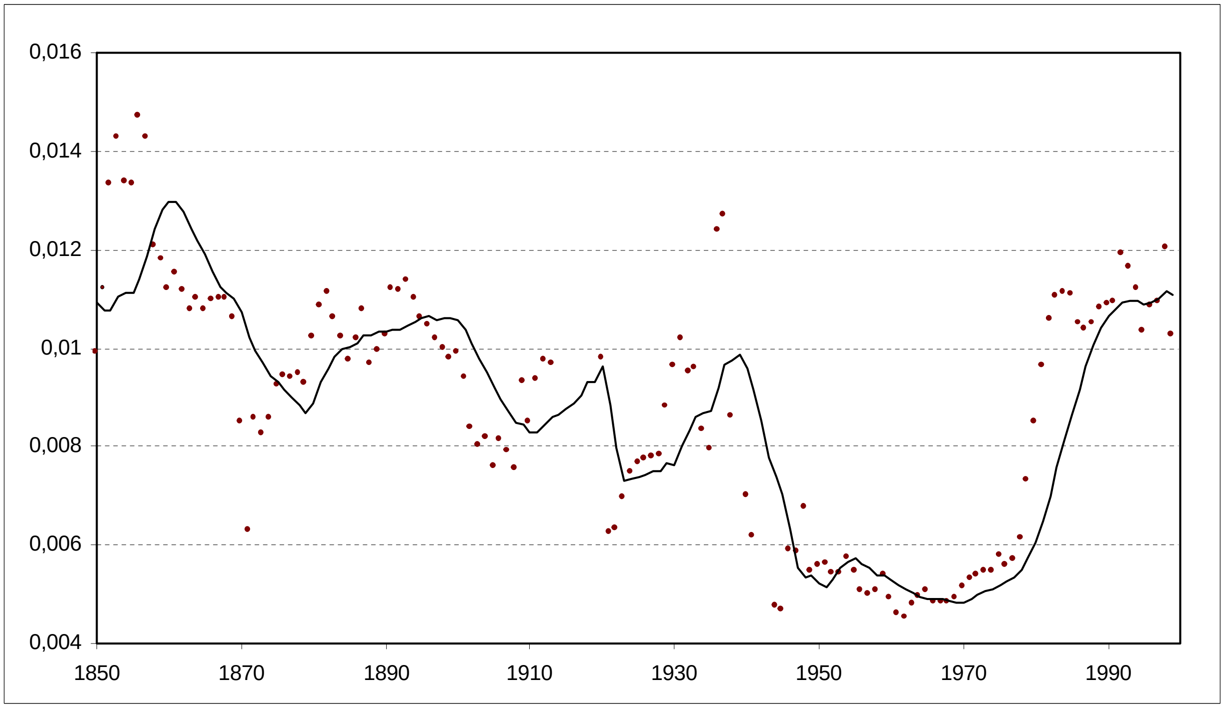


Secret vs Patenting under relational contracts:

$$\gamma.e \leq \max(T(\gamma^{pat}, g), TS(\gamma^{sec}, g))$$

Figure 7

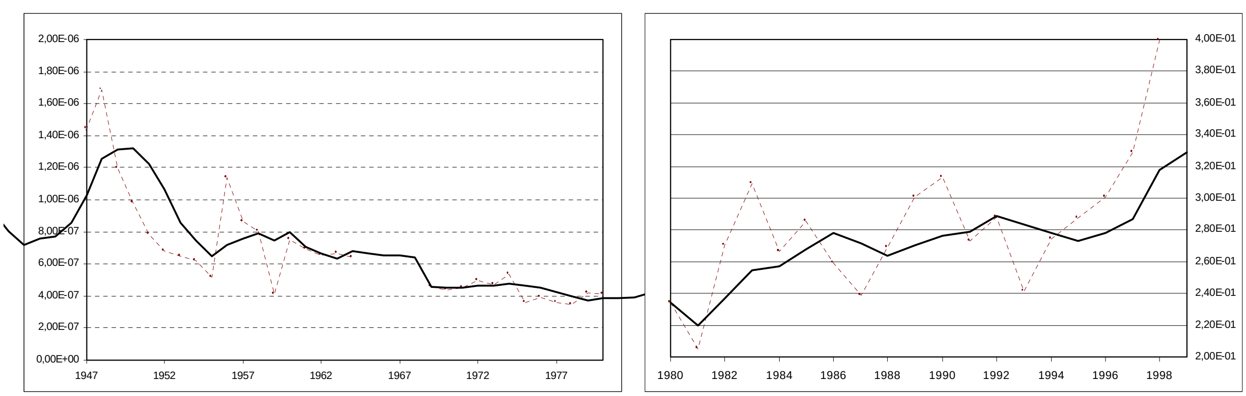
Frequency of Labor Disputes for France: 1850- 1999



Source:Marinescu (2002). Scattered plots depict the frequency of labor disputes, computed as the number of labor disputes divided by the size of the workforce covered by the industrial tribunals jurisdiction. The smooth line depicts a 10 year moving average.

Figure 8

Frequency of labor disputes per dismissal: 1947 -1999 period



Source:Marinescu (2002). The dashed line depicts the ratio of the number of labor disputes divided by the number of dismissals within the workforce covered by the industrial tribunals jurisdiction. On the 1947-1980 subperiod, dismissals are proxied by bankruptcies. The smooth line depicts a 5 year moving average.

Figure 9