The Internal Organization of the Firm, Transaction Costs and Macroeconomic Growth[+]

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ABSTRACT: This paper analyzes the links between the internal organization of the firm and macroeconomic growth. We present a Schumpeterian growth model in which firms face agency costs due to the existence of asymmetries of information and the formation of vertical collusions inside those firms. To respond to the threat of collusion, optimal collusion-proof incentive contracts depend on the efficiency of collusive side contracting within organizations. Collusion affects therefore the firms' profitability, the incentives to innovate and, finally, the stationary equilibrium growth rate of the economy. On the other hand, when the growth rate is small, the prospects of long term relationships within firms increase the agents' incentives to invest in a better collusive technology. We then discuss the two-ways relationships between the structure of internal transaction costs, organizational technologies and macroeconomic growth.

Keywords : Bureaucratization, Schumpeterian Growth, Dynamic Collusion, Internal Organization of the Firm.

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1 Introduction

What are the relationships between the internal organization of firms and macroeconomic growth? What are the links between the structure of agency costs within firms and the macroeconomic environment where these firms evolve? Does technological progress provide efficient pressures on organizational slacks? Are social relationships within firms dependent in any sense on their environment? These questions are obviously central to have a better understanding of the role of organizations and, more broadly of institutions, in the growth process. They always have attracted the attention of social scientists studying the determinants of economic development, whether in economic history[1] or economic sociology.[2] Still, little effort has been devoted to give formal answers to these questions in modern growth theory.

This paper contributes at filling that gap. Our main motivation is to understand the links between macroeconomic growth and the kind of social relationships which establish within organizations. In particular, we want to understand how the optimal incentive schemes designed within organizations and the macroeconomic performances of an economy are linked.

Our paper lies at the intersection of two different traditions in the economic literature. The first one takes a macroeconomic perspective and is best exemplified by Olson's book The Rise and Decline of Nations (1982). Olson pushes strongly the argument that "Stable societies with unchanged boundaries tend to accumulate more collusions and organizations for collective action over time". Starting from this observation, Olson concludes that collusion inside institutions and organizations has detrimental consequences for the growth rate of the economy. However, his argument remains informal and clearly lacks theoretical microfoundations.

The second pillar of our analysis comes from the more recent formal microeconomic literature on collusion in organizations initiated by Tirole (1986, 1992). This literature rationalizes the emergence of bureaucratic rules as optimal responses to the threat of collusions inside the firm. However, the analysis remains partial equilibrium and no consequences for the behavior of the economy as a whole are derived from these studies.

In this paper, we integrate altogether the insights of these two literatures. We start from a Schumpeterian model of economic growth à la Aghion and Howitt (1992, 1998) and Grossman and Helpman (1992) in which we embedd a simple collusion model as in Tirole (1986, 1992). This model provides a tractable framework to analyze the links between macroeconomic growth and the structure of incentives inside firms.

More precisely, we consider an economy with a final competitive sector using intermediate goods produced by monopolies. The perspective of monopoly profits in these

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[1] See Schumpeter (1942), North (1990) and Mockyr (1990).

[2] See Weber (1922) and Granovetter and Swedberg (1992).

intermediate sectors generates the incentives of the R&D sectors to innovate. The profitability of those monopolies coupled with the positive externality among innovating firms due to the public good nature of social knowledge is thus the fundamental engine of growth.

Departing however from standard growth models, the firm is not viewed as a simple production function but the black box of its internal organization is explicitly opened. Monopolies are viewed as three-tier hierarchies involving owners, supervisors and managers and facing the double-edged separation between, one one side, ownership and control of productive assets, and, on the other side, ownership and supervision.[3] More specifically, the monopolies' owners allocate resources within the firm subject to the incentive constraints which arise when managers have a better knowledge of the firm's market demand and may enjoy informational rent from this knowledge. Owners may nevertheless use monitoring structures (supervisors) to reduce the informational gap between them and the managers. Following the industrial sociology literature,[4] supervisors and managers have access to some information which is not available to the firms' owners. Hence, they may use strategically this common information to promote their own objectives and collude against the interests of owners.[5] Using Dalton's terminology, supervisors and managers form active vertical cliques affecting the allocation of resources within the firm. As a response to the possibility of those collective manipulations of information, owners tilt incentive schemes towards bureaucratic rules which are less sensitive to information and leave few discretion to supervisors.

Our first contribution is to show how the internal organization and contracts within firms are related to macroeconomic growth. In particular, we analyze how the degree of informational asymmetries and the opportunities for the formation of vertical cliques inside firms affect the aggregate performance of the economy. More precisely, as shown by most of the literature on collusion in organizations,[6] the firms' optimal incentive contracts and thus their profits depend critically on the quality of the collusive side-contracts between supervisors and managers. The efficiency of side-contracting affects in turn the profitability of firms and the incentives to innovate. Therefore, there exists a direct link between the nature of the social relationships within organizations and the growth rate of the economy.

Interestingly, three different effects with conflicting implications may be at work simultaneously. Of course, there is a first intuitive partial equilibrium effect. Easier collusion reduces the profitability of the firms and consequently the return to innovations, hence

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[3] See Jensen and Meckling (1976).

[4] See the most noticeable contributions of Dalton (1959) and Crozier (1962).

[5] Supervisors may manipulate or delay the audit they perform to assess the managers' performances. In exchange, the latter may provide bribes or in-kind transfers to the former. These collusive activities are costly to the organization.

[6] See Tirole (1986, 1992), Kofman and Lawarrée (1993), Laffont and Tirole (1993, Chapter 11) and Laffont and Martimort (1999) among others.

dampening growth. However, there are also two general equilibrium effects which come from an increase in the possibilities of collusion in a manufacturing sector of the economy. First, higher agency costs within a given sector reduce the output of this sector. On the one hand, this reduces the sector's demand for primary resources and more of these resources become then available for the R&D sector. This effect has, in itself, a positive impact on innovation and growth. On the other hand, however, if the R&D sector also uses as intermediate inputs some of the goods produced by sectors subject to collusion, inefficiencies then spill-over from the intermediate sectors to the R&D sector. This reduces growth in the economy. We show, however, that, as long as R&D sectors use intermediate inputs as well as labor, the negative effects of collusion on growth outweights the positive effects. This rationalizes Olson's informal claim that collusion within organizations tend to reduce the growth rate of an economy.[7]

An important corollary of this analysis is that parameters affecting the internal organization of the firm (like control mechanisms and information processing technologies) have important implications for the aggregate growth rate of the economy as a whole. In particular, any change in information and monitoring technologies which reduces (increases) opportunities for collusion has a positive (negative) impact on macroeconomic growth.

The model also suggests a potential channel through which differences in cultural environments might be translated into differences in growth rates. Indeed, the quality of informal side-contracting within organizations may depend on cultural characteristics naturally shared by individuals in society. An obvious one which comes to mind is trust. In a celebrated book, Fukuyama (1995) argued that the amount of trust embedded in social relationships should be positively correlated with macroeconomic growth. Our analysis suggests that this assertion actually may depend on the nature of the transaction costs reduced by the existence of trust. While trust can certainly have positive allocative effects in reducing transaction costs between trading partners in an economy plagued with opportunistic behavior, on the other hand, it may also facilitate implicit collusive agreements inside organizations with potentially important negative effects on growth and innovation.[8]

Our second contribution is to show a reverse causality between growth and, more specifically, the process of creative destruction and the quality of internal social relationships, affecting thereby the incentive schemes within firms. Indeed, the competitive environment in which firms evolve, certainly influences their organizational structures. The

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[7] In the Appendix, we show that the same result holds in a model with capital accumulation in which physical capital is complementary to R&D and is produced out of intermediate sectors subject to collusion.

[8] Wintrobe and Breton (1986) distinguishes vertical trust between principals and their agents from horizontal trust between agents. They informally argue that the former form of trust increases the performances of the organization while the latter has a negative impact on these performances. LaPorta and al. (1997) link the role of trust to cultural patterns of society like religion. Knack and Keefer (1997) provides a cross country study showing that trust may be detrimental to growth.

quality of informal side-contracting between two individuals is expected to depend on the resources invested by these individuals to enforce their collusive relationships. Clearly, the incentives to do such investments depend, in turn, on the beliefs that the collusive partners have on the stability of their relationships. This stability is itself negatively correlated with turnover rates and creative destruction. One may thus expect that the quality of side-contracting is negatively correlated with the rate of creative destruction in the economy. Indeed, as noticed by Crozier (1962), the stability of the environment is a fundamental glue of collusion. When the process of creative destruction in society does not exert its clumpsering effect, vertical cliques within the firm may form more easily.

Allowing for the fact that individuals inside organization may devote resources to improve the quality of side-contracting, we discuss the implications of the reverse causality from growth to organizational collusive behavior. Interestingly, the two-way complementarity between growth and the internal structure of the firm may generate multiple long run growth equilibria. In the high growth equilibrium, there is a high degree of creative destruction, reducing the agents' incentives for improving side-contracting. This, in turn, increases the profitability of firms, triggering further growth and creative destruction. In a slow growth equilibrium, on the contrary, creative destruction and inter-firms turnover are weak. This makes it easier to build efficient informal side-contracting relationships, reducing further the incentives to innovate. Economies with similar structural parameters may therefore end up in very different long run growth paths with quite distinct organizational and social structures.

This paper is related to a small emerging literature trying to link agency considerations, the internal organization of the firm and the growth process. In a model with horizontally differentiated products, Acemoglu and Zilibotti (1999) investigate the macroeconomic informational externality through which the performances of competitors may provide useful information to improve incentives within a given firm. Aghion, Dewatripont and Rey (1999) analyze a model where the threat of bankruptcy forces conservative managers to speed up the adoption of new technologies to remain competitive on the product market. Thesmar and Thoenig (1998) endogenize the choice of firms' organizational structures in a Schumpeterian growth model. However they abstract from an explicit discussion of agency costs and rather emphasize how different internal structures affect the tradeoff between productivity and delay in adopting new technologies.

Section 2 describes both the macroeconomic and the microeconomic sides of the economy. Section 3 discusses how the stationary equilibrium growth is affected by informational asymmetries, the quality of side-contracting and monitoring in firms. Section 4 goes further in considering endogenous transaction costs and in exhibiting the possibility for multiple stationary growth paths. Section 5 concludes. Proofs are relegated to an Appendix. This Appendix also provides a specification of the model with capital accumulation generating the same type of results as the model in the main text.

2 The Model

Our framework has two building blocks. The first one is a standard Schumpeterian model along the lines of Aghion and Howitt (1992, 1998) and Grossman and Helpman (1992). It represents the macroeconomic side of the economy. The second building block is microeconomic and discusses the internal organization of the monopolistic firms evolving in this macroeconomic environment.

2.1 The Schumpeterian Model

We abstract completely from capital accumulation.[9] Time is continuous and indexed by $t \in \{0; +\infty\}$.

2.1.1 Preferences

The economy is populated by a continuous mass L of individuals with linear intertemporal preferences over consumption paths $y = \{y_t\}_{t \geq 0}$:

$$u(y) = \int_0^{\infty} y_t e^{-\rho t} dt. \tag{1}$$

ρ is the psychological discount rate. Because of the linearity of preferences, $\rho = r$ where r is the interest rate in this economy. Each of these individuals is endowed with one unit flow of skilled labor.

2.1.2 Technologies

- Final Sector: There is only one final consumption good which is produced from a continuum of intermediate goods indexed on the unit interval. More precisely, date t output in the final good sector writes as:

$$y_t = \int_0^1 y_{it} di$$

where

$$y_{it} = A_{it} \beta_{it} x_{it}^{\alpha} \quad (\alpha \in [0; 1[) \tag{2}$$

is the flow of final good which can be produced using a quantity x_{it} of intermediate good i at date t.

The parameter A_{it} is the “fundamental” productivity of the latest generation of intermediate good i. However the overall productivity of this sector is also affected by the realization of some random shock β_{it}. These shocks are independently distributed over time and sectors according to the same common knowledge distribution on $\{\underline{\beta}; \bar{\beta}\}$ with respective probabilities $1 - \gamma$ and γ (we denote thereafter by $\Delta\beta = \bar{\beta} - \underline{\beta} > 0$ the spread

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[9] See the Appendix for a simple extension with physical accumulation.

of the uncertainty). β_{it} captures the intrinsic uncertainty on the quality of the match between the intermediate sector i and the final good technology.[10]

- The final sector has perfect knowledge of the realizations of β_{it}. This sector is perfectly competitive and its demand for each intermediate good writes as:

$$p_{it} = \alpha A_{it}\beta_{it}x_{it}^{\alpha-1} \tag{3}$$

where p_{it} is the price of good i at date t.

- **Intermediate Sectors:** Each intermediate good is produced by a monopolistic sector i. The monopolistic firm M_i holds a patent of the latest generation of good i. To produce one unit of intermediate good i requires one unit of skilled labor.

  Since the productivity of the final sector is random, this monopolist faces, at each date t, an uncertain demand for its good. This demand depends on the realization of β_{it}.[11]

- **Research Sectors:** There are as many research sectors as intermediate goods. R&D firms in each sector compete to discover the next generation of good i.[12] The arrival of innovations in a given sector follows a Poisson process with an arrival rate $\lambda(E_{it}) \in [0;1]$ where E_{it} is the intensity of R&D effort devoted to research in this sector (to be specified below). For technical reasons, we assume that $\lambda(0) = 0$, $\lambda'(E) > 0$ (with the Inada conditions $\lambda'(0) = \infty$ and $\lambda'(\infty) = 0$) and $\lambda''(E) \leq 0$ for all $E \geq 0$.

By innovating in sector i, a R&D firm acquires the leading-edge technology whose productivity parameter is given by $A_t^{max} = \max_i A_{it}$. Hence, though arrival rates in different sectors are independent, the innovations themselves are all drawn from the same pool of shared knowledge. Therefore, there exist innovation spillovers accross sectors. Each time an innovation is made, the leading-edge technology jumps upwards by an increment q where $q > 1$. The leading edge technology parameter A_t^{max} grows gradually, at a rate which depends on the aggregate flow of innovations. Because the profitability of R&D will be the same in all sectors, the same equilibrium R&D effort E_t will also be applied in each sector at each date t. Along such a symmetric path, the leading-edge technology growths according to:

$$\frac{\dot{A}_t^{max}}{A_t^{max}} = \lambda(E_t)\ln q. \tag{4}$$

Equation (4) captures the evolution of social knowledge in the economy. Each discovery is implementable only in the innovator's sector. However its discovery allows the next

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[10] More generally, β_{it} can be viewed as a technological shock as those considered in the real business cycle literature.

[11] We consider that the monopolistic firm does not have to undertake limit pricing to capture its market's demand. This occurs when the increment of quality between two successive innovations (q) is large enough.

[12] Alternatively we may consider that there is a continuum of entrepreneurs who can be potential owners of firms in the intermediate sectors and who, before setting up a business in the intermediate good sectors, have to do themselves R&D to discover blueprints of better quality intermediate goods. In that interpretation, R&D sectors will be merged with the intermediate good sectors.

innovator to discover also a better technology in another sector. The evolution of the leading-edge technology stresses a macroeconomic positive externality due the public good nature of society knowledge. Note nevertheless that the fundamental productivity parameter in any given sector i, A_{it}, may move discontinuously at the time of innovation if it jumps ahead several steps to reach the new leading-edge technology. The quality of a new generation of product benefits from this technological spillover across sectors.

The R&D activity requires two inputs: skilled labor and some final good. The R&D effort E_{it} in sector i at time t writes thus as

$$E_{it} = \gamma^{-\gamma}(1-\gamma)^{-(1-\gamma)} m_{it}^{\gamma} l_{it}^{1-\gamma} \tag{5}$$

where l_{it} is the amount of skilled labor and $m_{it} = \frac{M_{it}}{A_t^{max}}$. M_{it} is the amount of final goods used in the R&D process of sector i. m_{it} is then the “productivity adjusted” level of final good used in this sector. Such a formulation captures the fact that, as technology advances, it becomes more complex. An ever increasing amount of final good inputs is required to keep constant the rate of innovation. $\gamma^{-\gamma}(1-\gamma)^{-(1-\gamma)}$ is just a convenient constant for normalization.

2.2 Transaction Costs and the Internal Organization of the Monopolies

We now open the black box of the internal organization of the monopolies in the intermediate sectors.

2.2.1 Internal Organization of the Monopolies

- As said above, producing one unit of intermediate good i requires one unit of skilled labor used in a production department. However, it requires also to establish a sales department. There is separation between ownership and control of some productive assets within each monopoly. The manager of the sales department is privately informed on β_{it} the quality of the match between the intermediate i and the final good. Owners remain uninformed. A supervisor may thus be used to fill the informational gap between the manager and owners. There is also separation between ownership and supervision. This double-separation creates scope for agency costs. A monopoly can thus be viewed as a large firm having a hierarchical structure including a principal (owners), a supervisor, a production and a sales departments.
- The manager receives the sales proceeds and gives back some transfers T_{it} to the owners. The manager’s intertemporal utility writes as:

$$U_{it}^{M} = \int_t^{\infty} e^{-[\Phi(\tau)-\Phi(t)]}(\alpha A_{i\tau}\beta_{i\tau}x_{i\tau}^{\alpha} - T_{i\tau})d\tau \tag{6}$$

with $\dot{\Phi}(t) = r + \phi(E_{it})$:

- The supervisor may learn an informative signal $\sigma_{i\tau}$ on the realization of $\beta_{i\tau}$. More precisely, the monitoring technology is such that $\bar{\beta}$ is learned with a conditional probability ν. Otherwise, nothing is learned. This gives the following unconditional probabilities:

$$\sigma_{i\tau} = \begin{cases} \bar{\beta} & \text{with probability } \nu^2 \\ \emptyset & \text{with probability } 1-\nu^2. \end{cases}$$

Following Tirole (1986), $\sigma_{i\tau}$ is a hard information signal. The knowledge of $\bar{\beta}$ can be concealed to the principal but can never be manipulated by the supervisor.

The supervisor receives wages S_{it} from the owners of the firm. His intertemporal utility from date t on becomes:

$$U^S_{it} = \int_t^{\infty} e^{-[\Phi(\tau)-\Phi(t)]} S_{i\tau}\, d\tau. \tag{7}$$

- Owners of a patent for good i starting at date t (sometimes called “the principal" thereafter) maximize their intertemporal discounted profits from that date on taking into account the probability that there is no new innovation, i.e., the probability that their firm goes on as a valuable venture:

$$V_{it} = \int_t^{\infty} e^{-[\Phi(\tau)-\Phi(t)]}\, \Pi_{i\tau}\, d\tau \tag{8}$$

where $\Pi_{i\tau} = T_{i\tau} - S_{i\tau} - w_\tau x_{i\tau}$ is date τ profit and w_τ is date τ wage of skilled labor.

- There is a unit mass of supervisors (resp. sales department managers) available in this economy. Upon arrival of an innovation, there are as many supervisors and managers “dying” in old obsolete firms than new supervisors and managers hired in newly created monopolies. The arrival rate of innovations can thus be also viewed as a rough index for inter-firm managerial turnover.
- Supervisors and managers have an exogenously given reservation wage fixed to zero.[13]

2.2.2 Contracts

Because monitoring is imperfect, owners rely on incentive schemes to induce information revelation from the manager and the supervisor. From the Revelation Principle, there is no loss of generality in considering direct revelation mechanisms. An incentive scheme in firm i from date t on is a sequence of triplets $\{x_{i\tau}(\hat{\sigma}_{i\tau}, \hat{\beta}_{i\tau}); T_{i\tau}(\hat{\sigma}_{i\tau}, \hat{\beta}_{i\tau}); S_{i\tau}(\hat{\sigma}_{i\tau}, \hat{\beta}_{i\tau})\}$

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[13] This assumption implicitly requires that supervisors are not part of the skilled labor force. For instance, becoming a manager or a supervisor requires to incur some specific investment ex ante and this invesment creates a segmented labor market. Otherwise, we would have to introduce a non-zero reservation wage for the supervisor. Doing so would not change the main results of our analysis. Indeed, since this non-zero reservation wage is fixed and does not depend on the knowledge of β_{it}, it would not have any impact on allocative distortions imposed by the incentive problem within the firm. Only the profit of the owners would be translated downward by a constant term. This certainly affects the incentives to innovate of the R& D sector. However, the stream of profits would exhibit the same intertemporal path as with a zero reservation wage. This effect is thus orthogonal to our main focus which is to analyze the impact of dynamic agency costs within the monopolies (and thus their intertemporal path of productions) on their profitability and therefore on the growth rate.

for all dates ¿ ¸ t. $\hat{¾}_{i¿}$ (resp. $\hat{\ }_{i¿}$) is the supervisor's (resp. the manager's) report on the signal he has observed at date ¿. To make notation simpler, we denote by $\mathbf{n}$ $\bar{x}_{i¿};\bar{T}_{i¿}); (\underline{x}_{i¿};\underline{T}_{i¿}); (\bar{x}^{¤}_{i¿};\bar{T}^{¤}_{i¿})$ $\mathbf{o}$ the output and transfer targets respectively in the states of nature ($¾_{i¿}$ = ;; $¯_{i¿}$ = ±), ($¾_{i¿}$ = ;; $¯_{i¿}$ = $\underline{¯}$) and ($¾_{i¿}$ = ±; $¯_{i¿}$ = ±). Note that these states arise with respective probabilities º(1 ¡ ²); 1 ¡ º and º².

² Contracts: Two important features of the contracts should be stressed.

First, the agent's report is only used following an uninformative report from the supervisor $\hat{¾}_{i¿}$ = ;. Indeed, when $\hat{¾}_{i¿}$ = ± has been reported (and has also been observed since information is hard), there is no reason to use the manager's report since the state of nature is perfectly known by owners.

Second, to simplify the analysis, the contracts are not history dependent. Wages and output targets are contingent on the whole past history of reports. Only calendar time and current reports are used in date t contract.

² Incentive Compatibility and Participation Constraints: We can now easily write the incentive compatibility constraint preventing a manager having observed a high realization of demand ± to pretend having observed a low realization $\underline{¯}$:

$$\bar{u}_{i¿} ´ A_{i¿}{}^{±}\bar{x}^{®}_{i¿} ¡ \bar{T}_{i¿} ¸ ®A_{i¿}{}^{±}\underline{x}^{®}_{i¿} ¡ \underline{T}_{i¿} ´ \underline{u}_{i¿} + ®A_{i¿} ¢ ¯ \underline{x}^{®}_{i¿} \quad (9)$$

where $\bar{u}_{i¿}$ (resp. $\underline{u}_{i¿}$) denotes the manager's informational rent at date ¿ when he has observed $¯_{i¿}$ = ± (resp. $¯_{i¿}$ = $\underline{¯}$).[14] Similarly, the manager cannot be forced to a negative utility in any single period, so that the limited liability constraint[15]

$$\underline{u}_{i¿} ¸ 0 \quad (10)$$

is always satisfied.[16]

When $\hat{¾}_{i¿}$ = ±, the manager has a high demand for his intermediate good. The owners of the firm can extract all his informational rent so that he only gets his reservation value. Denoting by $\bar{u}^{¤}_{i¿}$ the manager's informational rent in this state of nature, we have:

$$\bar{u}^{¤}_{i¿} ´ A_{i¿}{}^{±}\bar{x}^{¤®}_{i¿} ¡ \bar{T}^{¤}_{i¿} = 0: \quad (11)$$

2.2.3 Collusion

We complete the description of incentive problems within the firm by recognizing the bureaucratic limits that large organizations face.[17] The supervisor has some discretionary

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[14] It is standard to show that this incentive constraint is the only binding one at the optimum. The incentive constraint of a low demand manager is automatically satisfied.

[15] An alternative assumption is that the manager is infinitely risk-averse below zero wealth.

[16] When (10) and (9) are binding, it is easy to show that $\bar{u}_{i¿}$ ¸ 0 so that the limited liability constraint of a ± manager is automatically satisfied.

[17] See Williamson (1985, Chapter 6).

power coming from his ability to reveal or not the manager's information when he has received an informative signal ¾i¿ = ±. By hiding this information to owners, the supervisor let the manager benefit from some informational rent. By instead revealing this information, the supervisor ensures that this informational rent can be fully captured by owners. The supervisor acts opportunistically to maximize the benefits he may draw from using this discretionary power to promote his own goals rather than those of the firm.

Since they share some commonly known information, there is scope for a collusion between the supervisor and the manager. By concealing the hard evidence ¾i¿ = ± to the owners, the supervisor lets the manager benefit from some informational rent. In exchange, he receives some bribes. These bribes may take the form of explicit monetary transfers but may also be viewed as a reduced form for the good social relationships which may establish on the work place, for the enforcement of a norm of reciprocity of favors, or other in-kinds transfers.[18]

Following Tirole (1986), all bargaining power in the side-contract is given to the supervisor. A priori, the full gain from collusion should thus accrue to the supervisor. This gain is the difference in informational rents ūi¿ ¡ ū¤i¿ that can be pocketed by the manager when the supervisor hides an informative signal to the owners. However, as it has been suggested by Tirole (1992) and Laffont and Tirole (1993), the collusive activity suffers from some deadweight loss due to transaction costs of exchanging favors within the firm. When a side-transfer is made between the supervisor and the agent, a fraction 1 ¡ K of this transfer is lost. The true supervisor's benefit from colluding with the manager writes therefore as K(ūi¿ ¡ ū¤i¿) where K < 1 is the efficiency of side-contracting. For the time being, we assume that K is exogenously given.[19] Firms may then differ with respect to the size of this parameter. For instance, when K gets large, collusion is very efficient and is quite harmful to the organization.

To prevent collusion, the supervisor is given a wage large enough so that he prefers revealing an informative signal ¾i¿ = ± to the principal rather than concealing evidence and sharing the corresponding informational rent with the manager. An incentive mechanism therefore prevents collusion between the supervisor and the manager when the following static collusion-proofness constraint is satisfied:

S¤i¿ ¡ S;i¿ ¸ K(ūi¿ ¡ ū¤i¿): (12)

S¤i¿ (resp. S;i¿) is the supervisor's wage when he reports an informative signal ¾i¿ = ± to the owners, (resp. an uninformative signal ¾i¿ = ;). Moreover, the supervisor is also

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[18] See Gouldner (1961) for the sociological analysis of these reciprocal exchanges on the work places. Martimort (1997, 1999) proposes some formal modellings explaining how those norms of reciprocity may be enforced between either symmetric or asymmetric agents.

[19] This is the assumption generally made in the collusion literature. A noticeable exception is Faure-Grimaud, Laffont and Martimort (2000) who endogenize these frictions in a model with a risk averse supervisor.

protected by limited liability:[20]

$$S^{\emptyset}_{i\tau} \geq 0. \tag{13}$$

2.3 Optimal Collusion-Proof Contract

We can now characterize the optimal collusion-proof contract implemented by the owners of monopoly i when they get a patent from date t on. Since incentive, collusion-proofness and participation constraints are not linked from one period to the other, the optimal collusion-proof contract is obtained by adding altogether the solutions to the following static problems for all dates $\tau \geq t$ (where we have used the definitions of the informational rents to express transfers $T_{i\tau}$ as a functions of $u_{i\tau}$ into the owners' objective function):

$$\max_{\{x_{i\tau};u_{i\tau};S_{i\tau}\}} \nu(1-\varepsilon)(\alpha A_{it}\bar{\beta}\bar{x}^{\alpha}_{i\tau} - w_{\tau}\bar{x}_{i\tau}) + \nu\varepsilon(\alpha A_{it}\bar{\beta}\bar{x}^{*\alpha}_{i\tau} - w_{\tau}\bar{x}^{*}_{i\tau}) + (1-\nu)(\alpha A_{it}\underline{\beta}\underline{x}^{\alpha}_{i\tau} - w_{t+\tau}\underline{x}_{i\tau})$$

$$-(\nu\varepsilon\bar{u}^{*}_{i\tau} + \nu(1-\varepsilon)\bar{u}_{i\tau} + (1-\nu)\underline{u}_{i\tau} + \nu\varepsilon S^{*}_{i\tau} + (1-\nu\varepsilon)S^{\emptyset}_{i\tau})$$

subject to (9) - (10) - (11) - (12) and (13).

The following proposition describes the standard structure of the optimal collusion-proof contract.[21] In the sequel, we assume that $\underline{\beta} - \frac{\nu}{1-\nu}\Delta\beta > 0$ to insure always positive outputs in all states of nature even under asymmetric information.

Proposition 1 : The optimal collusion-proof contract implemented at each date in a monopoly M_i starting life at date t entails:

1. No distortion with respect to the complete information monopoly output in states $\{\sigma_{i\tau} = \bar{\beta}\}$ and $\{\sigma_{i\tau} = \bar{\beta}; \beta_{i\tau} = \bar{\beta}\}$;

$$\bar{x}_{i\tau} = \bar{x}^{*}_{i\tau} = \left(\frac{w_{\tau}}{\alpha^2\bar{\beta}A_{it}}\right)^{\frac{1}{\alpha-1}} \quad \text{for all } \tau \geq t.$$

2. A downward distortion with respect to the complete information monopoly output in state $\{\sigma_{i\tau} = \emptyset; \beta_{i\tau} = \underline{\beta}\}$;

$$\underline{x}_{i\tau} = \left(\frac{w_{\tau}}{\alpha^2\underline{\beta}(K;\varepsilon;\Delta\beta)A_{it}}\right)^{\frac{1}{\alpha-1}} \quad \text{for all } \tau \geq t$$

where

$$\underline{\beta}(K;\varepsilon;\Delta\beta) = \underline{\beta} - \frac{\nu}{1-\nu}\Delta\beta(1-\varepsilon+\varepsilon K).$$

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[20] Alternatively, the supervisor can also be infinitely risk averse below zero wealth.

[21] See for instance Tirole (1992), Laffont and Tirole (1993, Chapter 11), Martimort (1999) and Laffont and Martimort (1999) for similar derivations of the optimal collusion-proof contract in static contexts.

3. Average output at date τ in sector i is given by:

$$X_{i\tau} = \left(\frac{w_\tau}{\alpha^2\bar{\beta}A_{it}}\right)^{\frac{1}{\alpha-1}}\left(\nu + (1-\nu)\left(\frac{\underline{\beta}(K;\varepsilon;\Delta\beta)}{\bar{\beta}}\right)^{\frac{1}{1-\alpha}}\right).$$

4. Average profit at date τ in sector i is given by:

$$\Pi_{i\tau} = \left(\frac{1-\alpha}{\alpha}\right)w_\tau X_{i\tau}.$$

Asymmetric information makes costly the implementation of the complete information monopoly output. To make the allocation of a low-demand manager less attractive to a high-demand manager, owners reduce output in state $(\sigma_{i\tau} = \emptyset; \beta_{i\tau} = \underline{\beta})$. This reduces the costly informational rent of a high demand manager and the incentive compatibility constraint (9) becomes less costly to satisfy.

Moreover, reducing informational rent also diminishes the prospects for collusion between the supervisor and the manager once the former has observed an informative signal. Indeed, the collusion-proofness constraint (12) is also relaxed. The benefits of reducing the size of activity increases when K gets larger. More efficient side-contracting calls for more output distortions, less powerful incentives and therefore less informational rents for a high demand manager. The supervisor is given less discretion as K increases. The optimal contract looks more like a bureaucratic rule leaving few discretion to the supervisor.

As a result of these two forces justifying an output reduction in state $(\sigma_{i\tau} = \emptyset; \beta_{i\tau} = \underline{\beta})$, everything happens as if the true demand faced by the monopolist had been replaced by a lower virtual demand $\underline{\beta}$.[22] This virtual demand decreases when K gets larger. In the sequel, it will be useful to express average output and profit as functions of the following parameter:

$$Q(K;\varepsilon;\Delta\beta) = \nu + (1-\nu)\left(\frac{\underline{\beta}(K;\varepsilon;\Delta\beta)}{\bar{\beta}}\right)^{\frac{1}{1-\alpha}}$$

with $Q(K;\varepsilon;\Delta\beta)$ being decreasing in K and $\Delta\beta$, and increasing in ε.

3 Transaction Costs and Growth

We now bring back this theory of internal collusion within firms into the framework of Schumpeterian growth. We consider a stationary equilibrium path with a constant growth rate and we denote by E^* the size of R&D effort in each R&D sector along this balanced and symmetric growth path. It is first convenient to express the cost function $C(E_i; w_t; A_t^{max})$ of having an effort E_i in any R&D sector i at any date t:

$$C(E_i; w_t; A_t^{max}) = \text{Min}\, M_{it} + w_t l_{it}$$

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[22] Myerson (1979) coined this term.

subject to

$$E_i = \gamma^{-\gamma}(1-\gamma)^{-(1-\gamma)}\left(\frac{M_{it}}{A_t^{max}}\right)^{\gamma} l_{it}^{1-\gamma}.$$

After computations, we get $C(E_i; w_t; A_t^{max}) = (A_t^{max})^{\gamma} w_t^{1-\gamma} E$.

Because of stationarity and symmetry of the model, any given monopolistic firm i has the same probability of survival in any interval $[\tau; \tau + d\tau]$. Given that innovations follow a Poisson process with arrival rate of $\phi(E^*)$, the intertemporal profit from being a monopolist from date t on in any sector i writes thus as:

$$V_{it} = \int_t^{\infty} e^{-[r+\phi(E^*)](\tau-t)}\pi_{i\tau}d\tau = \int_0^{\infty} e^{-[r+\phi(E^*)]u}\left(\frac{w_{t+u}}{\alpha^{2}A_{it}}\right)^{\frac{1}{\alpha-1}}\left(\frac{1-\alpha}{\alpha}\right) w_{t+u}Q(K;\varepsilon;\Delta\beta)du.$$

We now introduce the wage-productivity adjusted parameter $\omega_t = \frac{w_t}{A_t^{max}}$ which, along a balanced growth path, is also constant and denoted by ω^*. The wage rate w_t grows at the same constant growth rate g^* than the leading edge A_t^{max}, i.e., $g^* = \phi(E^*)\ln q$. Hence, one can easily compute V_{it} in each sector as:

$$\begin{aligned} V_{it} &= Q(K;\varepsilon;\Delta\beta)\int_0^{\infty} e^{-[r+\phi(E^*)]u}\left(\frac{\omega^* e^{g^*u}}{\alpha^{2}}\right)^{\frac{1}{\alpha-1}} A_t^{max}\omega^* e^{gu}du \\ &= \frac{1-\alpha}{\alpha}Q(K;\varepsilon;\Delta\beta)A_t^{max}\left(\frac{\omega^*}{\alpha^{2}}\right)^{\frac{1}{\alpha-1}}\frac{\omega^*}{r+\phi(E^*)\left(1+\frac{\alpha}{1-\alpha}\right)\ln q} \end{aligned}$$

Since, V_{it} is independent of i, we denote thereafter $V_{it} = V_t$.

The innovative effort performed in each R&D sector is such that the expected marginal benefit of innovating and being a monopoly from date t on equals the marginal cost of this effort. Therefore, E^* satisfies the following equation:

$$\phi'(E^*)V_t = \frac{\partial C}{\partial E}(E^*; w_t; A_t^{max}) = (A_t^{max})^{\gamma} w_t^{1-\gamma} = A_t^{max}(\omega^*)^{1-\gamma}$$

which finally yields the research arbitrage condition:

$$\left(\frac{1-\alpha}{\alpha}\right)Q(K;\varepsilon;\Delta\beta)\left(\frac{1}{\alpha^{2}}\right)^{\frac{1}{\alpha-1}}\frac{\phi'(E^*)}{r+\phi(E^*)\left(1+\frac{\alpha}{1-\alpha}\ln q\right)} = (\omega^*)^{\frac{1}{1-\alpha}-\gamma} \tag{14}$$

To close our general equilibrium model, we derive the skilled labor market clearing equation. As observed by Aghion and Howitt (1998), in a stationary equilibrium growth path, there will be a stationary distribution of relative fundamental productivity parameters $a = \frac{A_{it}}{A_t^{max}}$ given by the following cumulative:

$$H(a) = a^{\frac{1}{\ln q}} \quad \text{for} \quad a \in (0;1].^{23}$$

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[23] See Aghion and Howitt (1998, Appendix p.115).

The average output produced by the intermediate sectors in a stationary equilibrium is thus:

$$\int_0^1 \left(\frac{\omega^*}{a\alpha\epsilon\delta}\right)^{\frac{1}{\alpha-1}} Q(K,\epsilon,\Delta\beta)\,dH(a) = Q(K,\epsilon,\Delta\beta)\left(\frac{\omega^*}{\alpha\epsilon\delta}\right)^{\frac{1}{\alpha-1}} \frac{1}{1+\frac{\ln q}{1-\alpha}}. \tag{15}$$

Using Sheppard's lemma, the R&D demand for skilled labor is given by:

$$\frac{\partial C_w^0}{\partial w}(E,w_t,A_t^{\max}) = (1-\gamma)(A_t^{\max})^{\gamma} w_t^{-\gamma} E = (1-\gamma)\,\omega_t^{-\gamma} E. \tag{16}$$

From (15) and (16), we can derive the skilled labor market clearing condition in a stationary equilibrium as:

$$L = (1-\gamma)(\omega^*)^{-\gamma}E^* + Q(K,\epsilon,\Delta\beta)\left(\frac{\omega^*}{\alpha\epsilon\delta}\right)^{\frac{1}{\alpha-1}} \frac{1}{1+\frac{\ln q}{1-\alpha}}. \tag{17}$$

The stationary equilibrium R&D effort E^* and adjusted wage ω^* are simultaneously obtained from (14) and (17). One deduces immediately the stationary growth rate as $\phi(E^*)\ln q$. It is easy to see that (14) defines a negative relationship (R) between the adjusted wage ω^* and the R&D effort E^* since $1 > \gamma(1-\alpha)$. A higher productivity adjusted wage ω increases the cost of doing R&D and reduces therefore the R&D effort E. (17) defines instead a positive relationship (L) between ω^* and E^*. Indeed, as a larger R&D effort E increases the demand for skilled labor, leading to a higher productivity adjusted wage ω to clear the skilled labor market. These curves (R) and (L) are both shown on Figure 1. The stationary equilibrium path is obtained when these two curves intersect.

Proposition 2 : When the efficiency of side-contracting K is exogenous, there exists a unique grow rate in the economy $g^*(K,\epsilon,\Delta\beta)$.

3.1 Agency Costs, Transaction Costs, Monitoring Technologies and Growth

From the research arbitrage and the labor market clearing equations, we see immediately that all the parameters affecting the internal organization of the firm, i.e., $\Delta\beta$, K, and ϵ, have an impact on the average growth rate of the economy. $\Delta\beta$ reflects the importance of informational asymmetries between the owners of the firms and the internal hierarchy. It summarizes the size of potential agency costs. K captures a crucial aspect of social relationships between agents working in the same firms. Finally, ϵ is determined by the nature of the monitoring technology available to the firms. These monitoring devices are likely to be positively affected by the degree of centralization of informational processing technologies and the interlinking between informational networks inside the firms. In this respect, one may expect computerization and diffusion of sophisticated information technologies to increase ϵ.

These three organizational parameters above affect both the research arbitrage equation (through a profitability effect on firms) and the labor market equation (through a labor demand effect from the intermediate sectors) since they all impact on $Q(K;\epsilon;\Delta\beta)$. $Q(.)$ summarizes the importance of collusion for macroeconomic growth. Any shift in one variable which makes vertical collusion opportunities more costly (respectively less costly) for the firms' owners produces a downward (respectively upward) shift in $Q(.)$. It is thus useful to first discuss the impact of a shift in $Q(.)$ on aggregate macroeconomic growth.

Consider for instance a downward shift in $Q(.)$. Three effects are at work. First, a lower $Q(.)$ means a reduced profitability of monopolistic firms and therefore a decrease in the return to innovation. This can be seen on Figure 1 when (R) is shifted downward to (R'). Slightly abusing language, it is a partial equilibrium effect which has a negative impact on growth. However, a downward shift in $Q(.)$ also means that firms in the intermediate sector are less efficient. The overall average output of these sectors contracts. Two general equilibrium implications going in opposite direction result. First, the labor-market clearing curve (L) is also shifted downward to (L'). Less productive intermediate sectors reject more skilled labor into the research sector. The latter becomes therefore more innovative, increasing thereby the rate of creative destruction. On the other hand, as intermediate good sectors produce less intermediate inputs and thus less final goods, the cost of R&D increases. This last effect finally reduces the amount of R&D effort E^*.[24]

The final impact of a downward shift in $Q(.)$ on growth appears as ambiguous. We are able to show however that, overall, there is a positive relationship between $Q(.)$ and the growth rate. The consequences for the effects of the parameters $\Delta\beta, K,$ and ϵ can then be immediately deduced from their impact on $Q(.)$. This is summarized in the following proposition.

Proposition 3 :

- For $\gamma > 0$, i) A larger informational spread $\Delta\beta$ reduces the stationary equilibrium growth rate (i.e., $\frac{\partial g^*}{\partial \Delta\beta} < 0$). ii) Higher opportunities for side-contracting reduce the stationary equilibrium growth rate (i.e., $\frac{\partial g^*}{\partial K} < 0$). iii) A more efficient monitoring technology increases the stationary equilibrium growth rate (i.e., $\frac{\partial g^*}{\partial \epsilon} > 0$).
- For $\gamma = 0$, the stationary equilibrium growth rate is independent from any organizational parameters (i.e., $\frac{\partial g^*}{\partial \Delta\beta} = \frac{\partial g^*}{\partial K} = \frac{\partial g^*}{\partial \epsilon} = 0$).

A larger spread of uncertainty $\Delta\beta$ increases informational asymmetries between ownership and management. This increases agency costs and shifts down $Q(.)$. The final effect is a

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[24] This effect is illustrated by the fact that, everything else being equal, a decrease in $Q(.)$, results in a less than proportional decrease in the "adjusted productivity wage" ω in (R) (this is reflected by the exposant $\gamma < 1$ in equation (14)).

lower growth rate. Incidentally, it also shows that the growth rate under asymmetry of information is smaller than under perfect information (i.e., when $\Delta\beta = 0$).

Similarly, an increase in K is associated with easier side-contracting opportunities. This facilitates collusion and pushes downwards the parameter $Q(.)$. Again, the impact on macroeconomic growth is negative. Clearly K summarizes specific features of social relationships within firms and society. Indeed, it captures how informal agreements can be enforced between collusive parties. In this respect, it can be affected by various actions and investments undertaken by individuals to improve the quality of side-contracting. It might also be dependent on the social and cultural environment in which individuals evolve. A typical example is the level of trust that is shared in a given society. Social scientists have sometimes argued that the actual amount of trust embedded in social relationships should be positively related to the macroeconomic performances of that society. The general problem with such informal assertions is that the meaning of trust remains unclear. Our analysis suggests that the impact of trust on economic growth actually may depend on what sort of transaction costs are reduced by its existence. While it is hard to deny the fact that cooperative cultural beliefs and practices have positive allocative effects in many trading relationships between principal and agents, our analysis points out that trust can also be a two-edge sword. It can also facilitate implicit collusive agreements inside organizations with potentially important negative effects on growth and innovation.

The model shows also the potentially important role of changes in organizational and monitoring technologies on macroeconomic growth. Indeed, a better monitoring technology reflected by a larger probability of monitoring, ε, reduces the problem of internal agency and therefore shifts up $Q(.)$: A better monitoring technology stimulates innovation and improves the productive efficiency of the intermediate good sectors. Overall, this stimulates creative destruction and growth.

By providing an explicit link from internal informational processing technologies to macroeconomic growth, our analysis puts also into perspective the recent “New Economy" debate and the fact that the introduction and diffusion of computerization may have a positive and permanent impact on growth and productivity. It suggests that, an important channel through which this may occur is the major reorganization of monitoring functions inside firms and the consequences for agency costs and collusion. Sectors potentially very much vulnerable to agency costs (like services and customized good sectors) will first have their profitability increased, spilling over then to other sectors and stimultating further innovations in the economy.

4 Endogenous Transaction Costs and Growth

So far, we have assumed that the quality of side-contracting within organizations, as captured by the parameter K, was exogenous. However, the structure of the transaction costs of side-contracting internal to the firms is certainly affected by various actions undertaken by individuals within these organizations. Exchanges of informal favors and reciprocity between individuals may forster horizontal trust between agents. These actions may also be investments in particular assets (material or immaterial)[25] which facilitate the opportunities for informal trading relationships and reduce therefore the transactions costs of side-contracting. Obviously, whether this is through repeated actions or through specific investments, the agents' incentives to reduce theses transacions costs will depend on their beliefs about the future profitability of the informal relationships they may sustain within the organization. As this future profitability is itself strongly positively related to the expected life time of the firm, we certainly expect that the parameter K characterizing the structure of informal social relationships within organizations is not exogenous but actually depends positively on the expected life time of the firm. There exists a key feedback from creative destruction and growth on the pattern of transactions costs within organizations. Beliefs about the life time of an organization affects investments in collusive relationships. In turn, these investments affect the firm's profitability and, thus, the economy rate of growth. This provides a two-way causality between the internal structure of firms and macroeconomic growth.

4.1 Investing in the Quality of Side-Contracting

We investigate now how the quality of side-contracting can be endogenized in a general equilibrium framework. To improve the quality of side-contracting, the supervisor allocates part of the ressources available to the firm away from production towards activities improving social relationships between agents and supervisors. In our simple model, those resources are summarized by the amount of skilled labor used in the production process. At the beginning of the relationship, the supervisor uses those resources to reduce the transation costs of side-contracting. More precisely, we assume that a specific investment in skilled labor takes place just after the owner of an innovating firm has designed the contours of the firm and hired a manager and a supervisor. Investing l units of skilled labor pushes the efficiency of side-contracting to $K(l)$.[26]. For technical reasons, we assume

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[25] Material assets may be various types of mechanisms (hidden banking accounts, payments procedures, private enforcement mechanisms and the like) which facilitate implicit side-transfers between individuals. Immaterial assets may be goodwill and reputation building which enhance the capacity to make informal trading.

[26] An alternative would be to allow for a recurrent effort made in each period of time during the repeated relationship between the supervisor and the manager. While this assumption would give similar qualitative results, it turns out to be much less tractable than the one in the text.

that collusion fails when no investment is made ($K(0)=0$) and that collusion is perfect when a maximal amount L of skilled labor is used ($K(L)=1$). Moreover, using l units of skilled labor to improve collusion has an opportunity cost $w_t l$ for the supervisor. Finally, we assume that $K'(l)>0$ (with the Inada conditions $K'(0)=+\infty$ and $K'(L)=0$) and $K''(l)\leq 0$ for all $l\geq 0$.

The design of the collusion-proof contract by the firm's owners follows the the choice of the side-contracting technology by the supervisor. When making this choice, the supervisor anticipates thus the whole sequence of collusion-proof wages $(S^{\emptyset}_{i\tau}(l);S^{*}_{i\tau}(l))=(0;K(l)\alpha A_{it}\Delta\underline{\beta}(x_{i\tau}(l))^{\alpha})$ where we make explicit the dependence of contracts and ouputs on the investment l. Given these wages, the expected present value of the supervisor's utility along a stationary growth path with investment in R&D E^* writes as:

$$U^S_{it}(l)=\int_t^{\infty}e^{-[r+\phi(E^*)](\tau-t)}\nu\varepsilon S^*_{i\tau}(l)d\tau$$

when l has been invested in the collusive technology. It is useful in the sequel to define

$$\Gamma(l)=K(l)\left(\underline{\beta}(K(l);\varepsilon;\Delta\beta)\right)^{\frac{1}{1-\alpha}};$$

so that we can write

$$U^S_{it}(l)=\alpha\nu\varepsilon\Delta\beta A_{it}\left(\frac{\alpha^2}{\omega}\right)^{\frac{1}{1-\alpha}}\frac{\Gamma(l)}{r+\phi(E^*)\left(1+\frac{1}{1-\alpha}\ln q\right)}.$$

Differentiation of $\Gamma(l)$ provides immediately the following result.

Lemma 1 : When $\underline{\beta}>\frac{\gamma}{1-\gamma}\Delta\beta\left(1+\frac{1-\varepsilon}{1-\alpha}\right)$, $\Gamma(l)$ is strictly increasing (with Inada conditions $\Gamma'(0)=+\infty$ and $\Gamma'(L)=0$) and strictly concave on $[0;L]$.

An increase in K (i.e., a reduction of transaction costs of side-contracting), through an increase in l, has a priori two conflicting effects. First lower transaction costs of side-contracting allows the supervisor to capture a larger share of the collusion gain with the manager. This forces the principal to offer him a larger wage $S^*_{i\tau}$ in order to prevent effective collusion. On the other hand, as it becomes easier to sustain collusion between the supervisor and the manager, the optimal contract should also become less high-powered and biased towards more bureaucratization. This second effect reduces the informational rents left to the manager and the wage rate paid to the supervisor. However, as shown in Lemma 1, the first effect dominates when the size of informational asymmetry is not too large.

The supervisor's objective being strictly concave in l, his investment into reducing the transaction costs of side-contracting satisfies the collusive investment equation which equals the marginal gain of collusive investment to its marginal cost:

$$\alpha\nu\varepsilon\Delta\beta\left(\frac{\alpha^2}{\omega}\right)^{\frac{1}{1-\alpha}}\frac{\Gamma'(l^*)}{r+\phi(E^*)\left(1+\frac{1}{1-\alpha}\ln q\right)}=\frac{w_t}{A_{it}}=\omega^*. \tag{18}$$

As can be seen, the supervisor's incentives to improve the quality of side-contracting depends negatively on the macroeconomic effort of innovation E^* and the productivity adjusted wage ω^*. Indeed, the supervisor's profitability of collusive side-contracting depends on the prospects for colluding agents to remain entrenched within the firm for a longer time horizon. When the external pressure of creative destruction in the economy diminishes, the monopoly's expected life is longer and investments in collusive relationships become more valuable. The negative relationship between I^* and E^* captures many casual observations and case studies by management scholars, emphasizing how the competitive external environment has strong implications for the structure of power and cliques inside organizations.[27] In economic terms, the macroeconomic environment affects the internal efficiency of the firm. Also a higher wage rate ω^* reduces the level of monopoly output. This, in turn, lowers the informational rents which might be captured through collusion, reducing again the supervisor's incentives to improve the quality of side-contracting within the firm.

4.2 The Macroeconomic Equilibrium

It remains now to close the model on the macroeconomic side. As before we will be looking for a symmetric stationary equilibrium in which supervisors in each sector adopt the same investment strategy in the collusion technology.

As we already know from Section 3, the rate of innovation depends on the firms' profitability which itself is a function of the level of bureaucratization emerging as a response to side-contracting. In formal terms, the stationary equilibrium rate of R&D $E^*(I^*)$ and the productivity adjusted wage $\omega^*(I^*)$ are both decreasing functions the supervisor's investment I^*. The internal organization of the firm had an impact on the aggregate rate of creative destruction in the economy

Putting altogether the research arbitrage condition, the skilled labor market clearing equation and the investment in collusive technology equation, we obtain a system of three equations defining implicitly the steady state stationary path of the economy in terms of internal transaction costs and macroeconomic growth. More precisely, comparing with Section 3, the R&D arbitrage condition (R) still writes as (14). However, the skilled labor market clearing equation (L) takes now into account that some skilled labor is used in improving collusion. It writes as:

$$L = (1-\gamma)(\omega^*)^{-\gamma}E^* + Q(K_0;\varepsilon;\Delta\beta)\left(\frac{\omega^*}{\alpha^2\delta}\right)^{\frac{1}{\alpha-1}}\frac{1}{1+\frac{\ln q}{1-\alpha}} + I^*. \tag{19}$$

A stationary growth equilibrium can now be defined as a triplet $(I_e^*; E_e^*; \omega_e^*)$ which satisfies conditions (14), (18) and (19). Existence of the macroeconomic equilibrium is however still guaranteed.

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[27] See most noticeably Pfeffer (1981), Pfeffer and Leblebici (1973) and Bluedorn (1982).

Proposition 4 : When the efficiency of side-contracting K is endogenous, there still exists at least one stationary equilibrium with a positive growth rate. Any such stationary equilibrium has a growth rate $g_e^*(\varepsilon; \Delta\beta)$ such that:

$$g_e^*(\varepsilon; \Delta\beta) < g^*(0; \varepsilon; \Delta\beta):$$

4.3 Multiple Equilibria

In Section 3, we have seen that, for a given quality of side-contracting, the equilibrium innovation effort E^* and the productivity adjusted wage ω^* are decreasing functions of the quality of side contracting K. At the same time, according to (18), the supervisor's incentives to improve side-contracting K decrease also with the level of R&D effort E^* and the wage rate ω^*. These monotonicities generate a strategic complementarity between creative destruction and opportunities for side-contracting inside firms. Indeed, less innovation in the R&D sectors makes monopolies in the intermediate sectors enjoy a relatively quiet life. As their expected life time gets longer, the supervisor has more incentives to invest into making the collusive relationships easier (i.e., K is increased). This, in turn, decreases the profitability of the intermediate sectors and thus reduces the incentives to innovate in R&D sectors. Depressed incentives in the R&D sectors reduce further the rate of creative destruction in the economy, ensuring an even quieter life to monopolies.

Thanks to this strategic complementarity between the micro and the macro sides of the model, multiple stationary equilibria may therefore arise. Economies sharing the same fundamental characteristics may end up in very different long run situations in terms of their internal organization and aggregate macroeconomic performances. On Figures 2a) and 2b), we represent the labor market clearing equation and the collusive investment equation once w^* has been replaced by its expression taken from the research arbitrage equation. These two curves are both decreasing, leaving the possibility of a multiplicity of equilibria (Figure 2b).

In an equilibrium which is characterized by a high positive growth rate and high creative destruction, the firms' life time in the intermediate sector is relatively short and there is a high turnover of managers and supervisors across firms. These short term relationships on the work field, in turn, reduces the supervisors' incentives to invest into side-contracting. Agency costs associated to vertical collusion remain at a relatively low level. Incentives within firms are high powered and the return to innovation is high, sustaining high macroeconomic growth.

Conversely, in an equilibrium where creative destruction is weak, the firms' average lifetime of intermediate sector is relatively long. This induces supervisors to invest into side-contracting. This in turn reduces the firms' profitability and the return to innovation in these sectors. The macroeconomic growth rate is accordingly further depressed.

Finally, note that, the Inada assumptions made on $K(\cdot)$ and $\phi(\cdot)$ ensure that there always exists an equilibrium with zero growth were all resources are devoted to improving collusive technology instead of innovating. This equilibrium is nevertheless unstable.

5 Conclusion

In the present paper, we have started to investigate how the internal organization of firms can be related to the macroeconomic performances of the economy. We have built a Schumpeterian growth model in which the internal structure of firms is explicitely affected by the existence of agency costs and opportunities for internal vertical collusion. Doing this allowed us to discuss how the macroeconomic environment and the microeconomic conditions strongly interact to define the equilibrium growth rate. Clearly, many aspects of the interactions between the quality of social relationship within organizations and economic development have been left aside in our analysis. Let us mention here two areas which might be fruitful for future research.

First, we have considered that a better technology for side-contracting had a positive impact on agency costs inside firms. This may not always be the case. As a matter of fact, side-contracting may also induce beneficial cooperation between individuals,[28] increasing thereby the profitability of firms and consequently the growth rate of the economy. Including such features into the analysis would be a desirable extension of our analysis. It could actually provide a nonmonotonic relationship between transaction costs and macroeconomic growth.

Also our analysis has only considered external R&D. Therefore, the threat of creative destruction and inter firms turnover came only from external potential competitors. An interesting extension would be to allow for internal R&D and make the rate of turnover of teams on a given project partially under the control of the firm's owners. Obviously, in such a case, it could be in the interest of the firm to undertake internally some creative destruction as a way to increase the transactions costs of informal side-contracting between individuals in the same working team.

More generally, the framework developed in this paper provides a mapping between transaction costs of side-contracting within the firm and the equilibrium growth rate of the economy. Within such a setting, it is natural to think that, at the margin, private incentives to create organizational innovations mitigating the opportunities for collusions would arise. One could then interestingly consider the consequences of such endogenous organizational and institutional changes on the equilibrium growth rate. In this respect,

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[28] On this point see Tirole (1992).

our framework may then be viewed a useful building block towards a theory of endogenous institutional changes and growth that, for instance, North (1990) has called for.

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Appendix

Proof of Proposition 1: It is standard to show that all constraints (9) to (13) are in fact binding at the optimum. Inserting the corresponding value $\bar{u}^*_{i\tau} = 0$, $\bar{u}_{i\tau} = \alpha A_{it}\Delta\beta \underline{x}^{\alpha}_{i\tau}$, $\underline{u}_{it} = 0$, $S^{\varphi}_{it} = 0$, $S^*_{i\tau} = K(\tau)\alpha A_{it}\Delta\beta \underline{x}^{\alpha}_{i\tau}$ into the owners' objective function and optimizing with respect to $\bar{x}_{i\tau}, \underline{x}_{i\tau}$ and $\bar{x}^*_{i\tau}$, we obtain the values expressed in the text of the proposition ■

Proofs of Proposition 2 and 3: The R&D equation and the labor market clearing condition can be combined to get the following equation independent from $Q(K, \varepsilon, \Delta\beta)$:

$$L(\omega^*)^{\gamma} = (1-\gamma)E^* + \frac{r + \varphi(E^*)\left(1 + \frac{\alpha}{1-\alpha}\ln q\right)}{\varphi'(E^*)\left(1 + \frac{\ln q}{1-\alpha}\right)}\left(\frac{\alpha}{1-\alpha}\right). \tag{20}$$

(20) defines ω^* as a strictly increasing function of E^* for $\gamma > 0$, namely $\omega^*_1(E^*)$. The R&D arbitrage equation writes as:

$$\left(\frac{1-\alpha}{\alpha}\right) Q(K, \varepsilon, \Delta\beta)\left(\frac{1}{\alpha^{2-\varepsilon}}\right)^{\frac{1}{\alpha-1}} \frac{\varphi'(E^*)}{r + \varphi(E^*)\left(1 + \frac{\alpha}{1-\alpha}\ln q\right)} = (\omega^*)^{\frac{1}{1-\alpha}-\gamma}. \tag{21}$$

Since $1 > \gamma(1-\alpha)$, (21) defines ω^* as a strictly decreasing function of E^*, namely $\omega^*_2(E^*)$.

First, note that a stationary equilibrium (ω^*, E^*) is obtained when $\omega^*_1(E^*)$ and $\omega^*_2(E^*)$ intersect. Since $\omega^*_1(E^*)$ is increasing and $\omega^*_2(E^*)$ is decreasing this intersection, if it exists, is unique. Moreover, since $\varphi'(0) = +\infty$ (resp. $\varphi'(L) = 0$) $\omega^*_1(0) = 0$ (resp. $\omega^*_1(L) = +\infty$) and this intersection always exists.

Second, it is then clear that a shift in $Q(K, \varepsilon, \Delta\beta)$ shifts the curve defined by (21) but does not affect the one defined by (20). From this and the fact that, for $\gamma > 0$, the curve associated to (20) has a positively slope, it follows immediately that a upward shift in $Q(K, \varepsilon, \Delta\beta)$ generates an increase in ω^* and E^*.

$$\frac{\partial\omega^*}{\partial Q} > 0 \quad \text{and} \quad \frac{\partial E^*}{\partial Q} > 0.$$

The impact of the parameters $\Delta\beta, K$ and ε on aggregate growth are easily obtained from the effect of these parameters on $Q(.)$. Finally, when $\gamma = 0$, the R&D only uses skilled labor, (20) defines the equilibrium level of effort and the subsequent macroeconomic growth rate independently of $Q(.)$ ■

Proof of lemma 1: Let us define $\lambda(k) = k(\underline{\beta}(k, \varepsilon, \Delta\beta))^{\frac{1}{1-\alpha}}$. We have:

$$\lambda'(k) = (\underline{\beta}(k, \varepsilon, \Delta\beta))^{\frac{1}{1-\alpha}-1}\left(\underline{\beta} - \frac{\nu}{1-\nu}\Delta\beta\left(1 + \frac{1-\varepsilon}{1-\alpha}\right)\right) > 0$$

when $\underline{\beta} > \frac{\nu}{1-\nu}\Delta\beta\left(1+\frac{1-\varepsilon}{1-\alpha}\right)$, and

$$\lambda'''(k) = -\frac{2\nu\Delta\beta(1-\varepsilon)}{(1-\nu)(1-\alpha)}(\underline{\beta}(k;\varepsilon;\Delta\beta))^{\frac{1}{1-\alpha}-2}\left(\underline{\beta}-\frac{\nu}{1-\nu}\Delta\beta\left(1+\frac{\alpha(1-\varepsilon)}{2(1-\alpha)}\right)\right) < 0$$

when $\underline{\beta} > \frac{\nu}{1-\nu}\Delta\beta\left(1+\frac{1-\varepsilon}{1-\alpha}\right)$.

Finally, we deduce from that $\Gamma'(l) = \lambda'(k)K'(l) > 0$ (with $\Gamma'(0) = +\infty$ and $\Gamma'(L) = 0$) and $\Gamma''(l) = \lambda''(k)(K'(l))^2 + \lambda'(k)K''(l) \leq 0$ ■

Proofs of Proposition 4: First, using (14) and (19) to eliminate w^*, we get:

$$(L - l^*)\left(\frac{1-\alpha}{\alpha}\right)^{\frac{\gamma(1-\alpha)}{1-\gamma(1-\alpha)}}\left(\frac{1}{\alpha^{\varepsilon-1}}\right)^{\frac{\gamma(1-\alpha)}{1-\gamma(1-\alpha)}}(Q(K(l^*);\varepsilon;\Delta\beta))^{\frac{\gamma(1-\alpha)}{1-\gamma(1-\alpha)}} = \tag{22}$$

$$\left(\frac{r+\phi(E^*)\left(1+\frac{\alpha}{1-\alpha}\ln q\right)}{\phi'(E^*)}\right)^{\frac{\gamma(1-\alpha)}{1-\gamma(1-\alpha)}}\left((1-\gamma)E^* + \frac{r+\phi(E^*)\left(1+\frac{\alpha}{1-\alpha}\ln q\right)}{\phi'(E^*)\left(1+\frac{\ln q}{1-\alpha}\right)}\left(\frac{\alpha}{1-\alpha}\right)\right).$$

The left-hand-side of (22) being decreasing with l^* and the right-hand-side being increasing with E^*, this latter equation defines a strictly decreasing and positive function $l_1^*(E^*)$. The domain of definition of this function is the set of values of E^* such that l^* remains positive. For $l^* = 0$, $K(l^*) = 0$ and E^* takes its maximal value which is the equilibrium effort in a model with an exogenous efficiency of side-contracting given by $K = 0$, denoted by $E^*(0;\varepsilon;\Delta\beta)$.

Second, using (18) and (19) to eliminate w^*, we get:

$$\alpha\nu\varepsilon\Delta\beta\left(\frac{\alpha^{\varepsilon}}{\omega}\right)^{\frac{1}{1-\alpha}}\Gamma'(l^*)(L-l^*)^{\gamma\left(1+\frac{1}{1-\alpha}\right)} = \tag{23}$$

$$\left(r+\phi(E^*)\left(1+\frac{1}{1-\alpha}\ln q\right)\right)\left((1-\gamma)E^* + \frac{r+\phi(E^*)\left(1+\frac{\alpha}{1-\alpha}\ln q\right)}{\phi'(E^*)\left(1+\frac{\ln q}{1-\alpha}\right)}\left(\frac{\alpha}{1-\alpha}\right)\right)^{1+\frac{1}{1-\alpha}}.$$

The left-hand-side of (23) being again decreasing with l^* and the right-hand-side being increasing with E^*, this latter equation defines also a strictly decreasing and positive function $l_2^*(E^*)$. The domain of definition of this function is $[0; L]$. Since $\Gamma'(L) = 0$ and the right-hand-side is zero for $E^* = 0$, we have $l_2^*(0) = L$. Since $\Gamma'(0) = +\infty$ and the right-hand-side is ∞ for $E^* = L$, we have also $l_2^*(L) = 0$.

Since $l_1^*(0) = l_2^*(0) = L$, we have a first equilibrium with zero effort in R&D, and zero growth. Moreover, $l_1^{*\prime}(0)$ is finite and $l_2^{*\prime}(0)$ is infinite, hence, $l_2^*(E^*)$ is below $l_1^*(E^*)$ for E^* small enough. Finally, $l_1^*(E^*)$ being undefined for $E^* > E^*(0;\varepsilon;\Delta\beta)$, we have necessarily at least one equilibrium effort E_e^* such that $E_e^* < E^*(0;\varepsilon;\Delta\beta)$. This corresponds to a strictly positive growth rate ■

A Model with Collusion, Growth and Physical Capital

Suppose that there is a stock of capital K_t, embodied in durable machines. Consider for simplicity that capital, along with consumption and research are produced by labor and intermediate goods in the same proportion, according to the following production technology;

$$C_t + I_t + N_t = L^{1-\alpha}\int_0^1 A_{it}\beta_{it}x_{it}^{\alpha}di$$

where C_t , I_t and N_t denote respectively gross investment in capital, aggregate consumption and resources put into R&D. The only input into the production of intermediate goods is capital. Following Aghion and Howitt (1998, p. 95), suppose that, in order to produce in sector i an output x_{it}, a firm needs $A_{it}x_{it}$ units of capital. Hence, newer tecnologies associated to larger fundamental productivity parameters are also more capital intensive. Also we consider, as before, that R&D becomes more complex as technology advances. Hence, the R&D effort E_t is simply related to N_t by the relationship $E_t = N_t/A_t^{\max}$ where $A_t^{\max}$ is the leading edge technology.

Denote by χ_t the rental rate at time t, at which a monopolist can rent its capital from households through a perfect competitive capital market. The demand for each intermediate good writes now as:

$$p_{it} = \alpha A_{it}\beta_{it}x_{it}^{\alpha-1}L^{1-\alpha}.$$

The average cost of a firm with an intermediate sector's technology discovered at t, in each period of its production $\tau \geq t$ is now $A_{it}\chi_{\tau}$. The analysis of Section 2 can be redone in a way similar to the one in the main text. This finally gives a level of expected output in sector i given by:

$$X_{i\tau} = \left(\frac{\chi_{\tau}}{\alpha^{2}\bar{\beta}}\right)^{\frac{1}{\alpha-1}} LQ(K, \varepsilon, \Delta\beta).$$

Expected profits are obtained as:

$$\Pi_{i\tau} = A_{it}\left(\frac{1-\alpha}{\alpha}\right)\chi_{\tau}X_{i\tau}.$$

In a steady state, we have $\chi_{\tau} = \chi$ and $E_t = E$. The value of an innovation at time t in any sector i writes as:

$$V_{it} = \int_t^{\infty} e^{-[r+\phi(E^{*})](\tau-t)}\Pi_{i\tau}d\tau = A_{it}\int_0^{\infty} e^{-[r+\phi(E^{*})]u}\left(\frac{\chi_u}{\alpha^{2}\bar{\beta}}\right)^{\frac{1}{\alpha-1}}\chi_u LQ(K, \varepsilon, \Delta\beta)\left(\frac{1-\alpha}{\alpha}\right)du$$

or

$$V_{it} = A_{it}\frac{\left(\frac{\chi}{\alpha^{2}\bar{\beta}}\right)^{\frac{1}{\alpha-1}}\chi LQ(K, \varepsilon, \Delta\beta)\frac{1-\alpha}{\alpha}}{r+\phi(E)}.$$

The steady state arbitrage condition is written as:

$$A_{it}\frac{Á^{0}(E)}{r + Á(E)} \text{Ã} \frac{Â}{®^{2} =} \text{!}^{\frac{1}{® ¡ 1}} ÂLQ(K; ²; ¢¯)\frac{1 ¡ ®}{®} = A_{it}$$

since, at time t, the resource cost of doing a R&D effort E is $A_t^{max}E$ and $A_t^{max} = A_{it}$. Finally, the research arbitrage equation writes as:

$$\frac{Á^{0}(E)}{r + Á(E)} \text{Ã} \frac{1}{®^{2} ±} \text{!}^{\frac{1}{® ¡ 1}} LQ(K; ²; ¢¯) \text{µ}\frac{1 ¡ ®}{®}\text{¶} = Â^{\frac{®}{1 ¡ ®}}: \tag{24}$$

(24) defines a decreasing relationship between E and Â.

The model is closed by noting that the rental rate Â has just to cover the owner for the interest rate $r = ½$ (recall the linear preferences) and the depreciation rate of cpaital ±.

$$Â = ½ + ±$$

Substituting this into (24) gives the steady state research effort $E^{¤}$ and the aggregate growth rate $g^{¤} = Á(E^{¤}) \ln q$. It is then straighforward to see that

$$\frac{@E^{¤}}{@Q(:)} > 0:$$

All parameters affecting the internal organization of the firm affect the growth rate of the economy as in the main text. Moreover, as emphasized by Aghion and Howitt (1998),

$$\frac{@E^{¤}}{@½} < 0:$$

Capital accumulation and R&D are thus complementary. This last effect is interesting to discuss if we bring back into the picture the fact that transaction costs of side contracting may be actually endogenous and negatively related to innovation efforts E as discussed in Section 4 of the text. In that case, capital accumulation provides another channel through which the nature of side-contracting within organizations may be affected by macroeconomic variables. Indeed, any change affecting directly the functioning of the capital market (like for instance an increase in ½ which may capture the idea of more frictions in the capital market) affects the rate of innovation of the economy and therefore the opportunities for collusion. These in turn will reduce the profitability of undertaking R&D and further dampen growth.

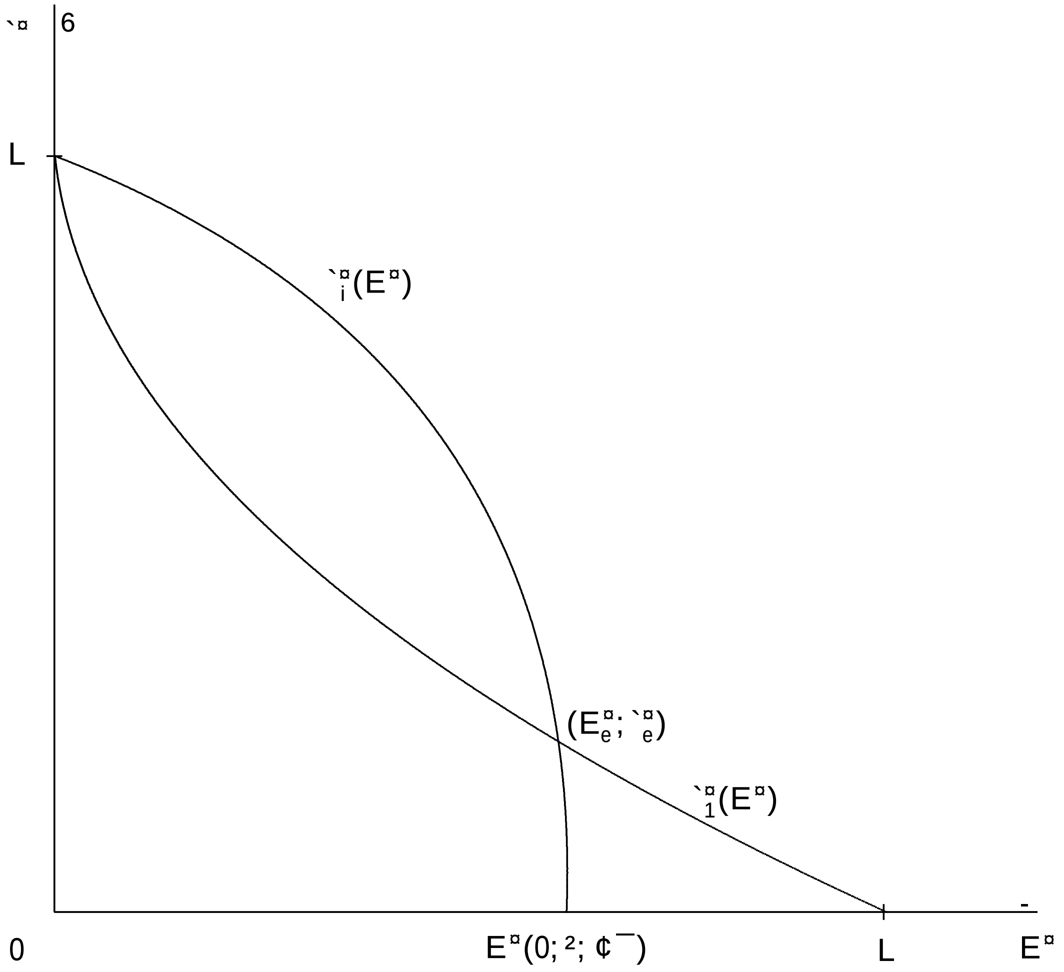

Figure 2a: Endogenous Transactions Costs : Unique Positive Growth Rate

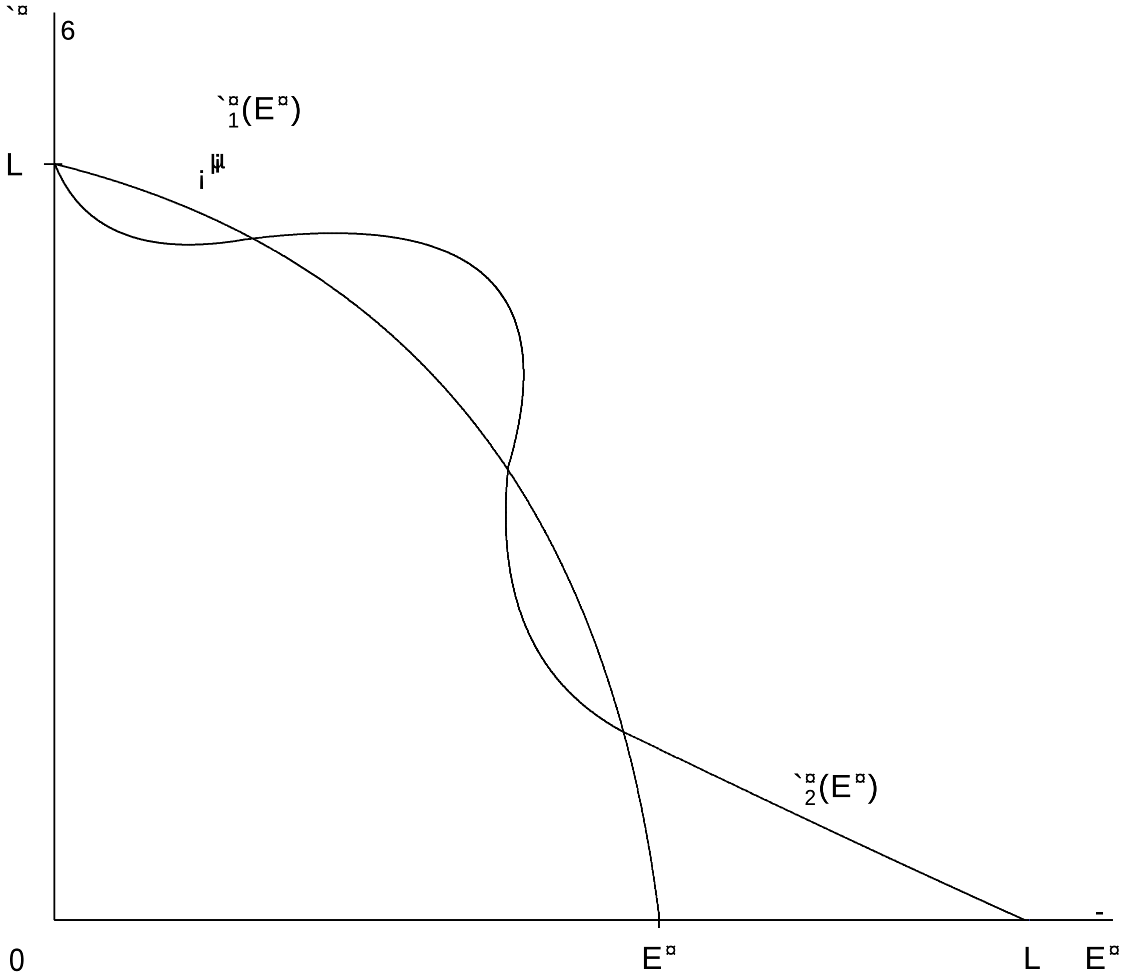

Figure 2b : Endogenous Transaction Costs : Multiple Equilibria