Does the "New Economy" Change the Frontiers of the Large Corporation ?

Bruno Amable
University of Paris X, MODEM and CEPREMAP

Régis Breton
University of Paris X, FORUM

Xavier Ragot
CEPREMAP

1 Introduction

A recent literature has stressed that the relationship between scientific discovery, innovation, technical progress and growth has changed in the 1990s. These changes are usually refered to as the "new economy".[1] From a macroeconomic perspective, three types of changes seem particularly noteworthy.

First, innovation seems to be more rapid and more crucial for firms' competitiveness. It has therefore become one of the most strategic activities of large corporations. However, the costs and risks related to innovation seem to have risen and firms have tended to become more specialised. This has several consequences for the organisation of research within industrial corporations. Even large firms cannot have the whole scientific knowledge it needs to develop marketable innovations organised around its in-house scientific laboratories. Researchers are leaving large corporations in order to found their own technology-intensive firms with the idea of developing and marketing one product or a limited range of products around an invention of their own. Therefore, the 'new economy' involves a larger role for small innovative firms.

The 'new economy' is also associated with an increasing role of financial markets in firms' financing and monitoring and a decreasing role for traditional banking, as well as the development of new, specialised intermediaries for the financing of small technology firms. These specialised intermediaries, venture capitalists, are willing to take more risks than tra-

[1] See OECD (2000), Brynjolfsson and Kahin (2000).

ditional intermediaries such as banks, and they monitor the firm until it is able to get direct finance from financial markets.

A third type of transformations associated to the 'new economy' is a rise in income inequality. Indeed, the rise in wage inequality in the US over the past two decades is well documented.[2] It is correlated with the growth of computer use,[3] but it predates the appearance of the 'new economy'. This hints at the fact that there is probably no simple causal link between the two phenomena, but they are not totally separate either.

The usual explanation of these facts relies on technology, more precisely the innovation in and the diffusion of information and communication technologies. The 'new economy' is associated with an increasing digitalisation of economic activities. This technology-based explanation goes roughly as follows. The 'digital economy' seems to be more favourable to small companies : larger companies are often less responsive to customer needs, and these needs change fast in the 'new economy''s activities. The financing of new technology-based firms requires a new type of intermediaries, venture capitalists, possessing a specific competence in the management of innovative projects.[4] Lastly, technology-based firms need to provide sufficient incentives to their managers. These incentives may take the form of benefits-related bonuses, stock options,etc. The practical consequence of these new pay schemes is that income inequality should rise, a consequence of the 'winner takes all' characteristics of this "new economy". More generally, the existence of a skill-biased technological progress favours those who master the new technologies, with consequences in the dispersion of individual incomes.[5]

The aim of this paper is to provide an alternative explanation to the three transformations referred to above, based on the interaction of technological and institutional changes. More specifically, a decrease in the cost of finance brings new opportunities for skilled personnel to found their own ventures.[6] This has consequences for the scope of activities that large firms will keep. Changes in the industrial structure will have consequences for the pattern of income inequality.

We present a model where production is based on skilled workers' research effort. Research activities can be made in-house, i.e. within a large corporation, or by small technology firms set up around the development of one particular "innovation" and managed by the "innovator". The paper can

[2] For a recent assessment, see Katz (2000).

[3] The so-called 'digital divide'.

[4] Berlin (1998), Lerner (1995), (2000).

[5] Acemoglu (1998).

[6] This question is usually addressed in the literature from the point of view of information asymmetry (Aghion and Tirole (1994), Ambec and Poitevin (1998), Bergemann and Hege (1997).). The argument is for instance that in-house R&D reduces problems associated with information asymmetry. On the other hand, the incentives associated with research conducted in independent firms may warrant a higher level of effort and thus a higher probability of success. The point of view taken in this paper abstracts from problems associated with information asymmetry and is more directly focused on the technological consequences of the different types of R&D organisation.

therefore address the consequences of a more or less easy access to finance for researchers eager to launch their own innovative ventures for two issues. (i) the boundaries of the firm, i.e. the number of researchers that will stay in the large corporation, and thus the size of the large firm. The team organisation within a large firm allows to exploit economies of scale associated with the fixed costs of research. Besides, within a team or a research division, each researcher benefits from the externalities stemming from innovative activity. Research is a human capital intensive activity and externalities of various types can be expected to flow between individual researchers of varying ability working on the same project. These external effects are absent in the case of isolated research carried on in small ventures. (ii) the wage dispersion for researchers within the large firm. The development of independent technological firms has consequences for the researchers that leave the large corporations as well as for those who stay. Innovators will leave the large firm or stay with it according to the opportunities they have, the availability of finance for founding their own ventures, etc. Their stay or exit decision will affect the productivity of other researchers within the large firm because of the interpersonal externalities involved in team research. Following this, wage dispersion among researchers within the large firm will depend on the outside opportunities available to some researchers.

The paper is organised as follows. Section 2 presents the basic model, with heterogeneous agents characterised by different innovative abilities and the different technologies of innovation, either within a large firm or in individual ventures. The equilibrium is derived, giving the allocation of researchers. Section 3 looks at the consequences of better financing conditions for innovators in terms of the allocation of researchers and the wages paid to those who stay with the large firm. A brief conclusion is drawn in Section 4.

2 The Model

2.1 Agents and technology

We consider a one-period model of an economy with two sectors, one producing a final good which can be used for consumption and investment purposes, the other producing intermediate goods which enter into the production of the final good. The price of the consumption good will be normalised to one in what follows so that all prices are expressed in consumption units. Intermediate goods are produced either by a large firm or by small individual firms. Let J denote the set of intermediate goods produced by individual firms. J is a continuum, and intermediate goods may differ in their quality levels. Large firm variables are capitalised. The production function is the following:

$$U = Q^{1-a} \cdot X^a + \int_J q_j^{1-a} \cdot x_j^a dj \tag{1}$$

with U the quantity of the final good. $a < 1$. X is the output of the large firm and Q its quality level, and x_j and q_j are the output and quality level of firm j.

There is perfect competition in the final good sector, but each intermediate good is produced by a monopolist. Production of intermediates requires a specific blueprint and η units of final good per unit of intermediate good. Blueprints are produced as a result of innovation.

The economy is populated with heterogeneous agents distributed over a continuum of mass 1. Agents are heterogeneous with respect to their "innovative" abilities and they are characterized by their type s. For simplification purposes, we assume that s is uniformly distributed over a given interval, $[s_L, s_H]$. Agents' types are public knowledge. Types are related to innovation capabilities in the following way: all agents are able to produce a blueprint for the production of an intermediate good of a certain quality, but the quality of these innovations – or more precisely the quality of the intermediate good which can be produced according to the blueprint – varies markedly across agents. Agents are risk-neutral and maximize their end-of-period individual consumption (date 1). They are endowed with Ω units of consumption good at the beginning of the period (date 0).

Agents are confronted at the beginning of the period with a choice of activity. Three possibilities are offered to them. First, every agent may always take on a "subsistence" activity which yields a fixed reward equal to $\overline{w}$ units of consumption good at date 1 ($\overline{w} > 0$). The other two possibilities imply that agents have an "innovative" activity.

Innovation produces blueprints which allow for the production of an intermediate good of a certain quality. This activity may be organised in two different ways. The first way is for an individual innovator to set up his own individual innovative venture. Self employed, an innovator of type s finds with probability p a blueprint for producing an intermediate good with quality $q(s)$. With probability $1-p$ he finds nothing. Thus, the quality of the good produced by a type s worker follows a binomial law

$$\tilde{q} = \begin{cases} q(s) & \text{with probability } p \\ 0 & \text{with probability } 1-p \end{cases} \tag{2}$$

$q(s)$ is an increasing function. The greater the signal s, the greater the expected quality $E[\tilde{q}|s] = p \cdot q(s)$. In what follows, in order to simplify computations and obtain explicit solutions, we will consider the simple linear function $q(s) = q \cdot s$, $q > 0$.

In order to start his own venture, an agent must incur a fixed cost M, with $M > \Omega$. Lack of funds compels the individual researcher willing to found his own venture to seek external financing. Unlike established firms, an individual venture lacks the necessary references to have an easy access to market finance. Empirical evidence clearly shows that small technological start-ups cannot be financed by the market, they have to obtain finance through intermediaries, and particularly through these special financial intermediaries : the venture capitalists. Many empirical and theoretical papers have emphasised the role played by venture capitalists. Some theoretical motivations for the existence of such intermediaries point to the existence of a specific asymmetric information problem related to small technological firms. Such a problem does not arise in our setting since there is no information asymmetry. The absence of information asymmetry does not however imply that starting a small firm does not involve specific costs. Indeed, one role played by venture capitalists[7] is to provide funds for start-ups and give advice on how to set up a business. There are specific costs related to starting a venture, and these costs may be all the higher that specific expertise in the field is lacking. By putting his expertise to work on the start-up project, the venture capitalist can significantly reduce the setting-up costs. We will therefore consider that besides the starting cost M, there exists expertise costs c borne by the financial intermediary in the process of channeling funds to the small technological start-up.

The second way of doing innovation takes place within a large firm which hires a certain number of agents and organises their research on the discovery of a new blueprint. Innovation within the large firm differs from individual innovation since the former implies a collective process of discovery involving individuals with different innovative abilities. The outcome of such an innovation process is a blueprint for an intermediate good with a quality level that results from the joint efforts of all the individual researchers hired by the firm.

The collective process of innovation involves two different types of externalities. The first type is a positive externality. By working together, innovators exchange ideas and each agent's creative ability is positively influenced by the ideas put forward by its colleagues. The exchange of ideas may prevent the duplication of research efforts, a faster investigation of the research possibilities and a more precise focussing of the innovation efforts on the most promising alternatives. Basically, the advantages of the innovation process within the large firm concern the benefits obtained from a collective organisation of research. The second externality concerns the more negative aspects regarding collective work. As mentioned above, researchers differ in their innovative abilities. Therefore, organising research inside the large firm means putting together heterogeneous individuals. Since part of the research time of each researcher involves exchanging ideas with other researchers, heterogeneity among individuals implies that the more able researchers will spend time and effort with lesser able researchers, so that the latter may exert a negative externality on the former's individual productivity. More able researchers will have to explain other researchers things that

[7] Berlin (1998).

they have understood right away, delaying thus their own research activity. More generally, since all researchers work collectively on a single project, completion of this project demands that a 'reasonable' degree of homogeneity be achieved regarding the diffusion of new knowledge generated by the project. Without being informed of and having understood what the more able individuals do, the contribution of the lesser able researchers would be negligible. Symmetrically, if the more able individuals do not allow the lesser able to catch up with them, they cannot benefit from their contributions. All of this would mean a diminished efficiency of the collective research effort. Therefore, this homogenising attempt will be made at the expense of individual productivity, the cost of homogenisation being mostly borne by the more able researchers. What a 'reasonable' degree of homogeneity of new knowledge diffusion actually is depends on the way collective research is organised, or in other words on the process of division of labour inside the firm. This depends both on the technology concerned – what type of good is discovered, involving what type of knowledge, etc. – as well as on the way the firm is organised.

Taking account of both the positive and negative externalities pertaining to the collective process of innovation, one can express a researcher's contribution to the quality of the firm's innovation as follows : a researcher who would, if left on his own, make an innovation which would give a blueprint for a new intermediate product of quality $q(s)$, contributes to the quality of the firm's innovation by an amount $h(s,S) \cdot q(s)$. $h(s,S)$ gathers the two external effects described above, it depends on the researcher's own type s as well as S the set of all workers employed by the firm. Research within the large firm gives a blueprint for an intermediate of quality $\overline{Q}$ and one has :

$$E\left[\overline{Q}\right] = \int_{s_L}^{s_H} h(s,S) \cdot E\left[\tilde{q}(s)|s\right] \cdot x(s) \cdot f(s)ds \tag{3}$$

where $x(s) \in [0,1]$ is the proportion of type s workers hired by the firm. If the firm does not hire any type s workers, $x(s) = 0$. $f(s)$ is the density function of the type s, and is constant by assumption.

In the following, in order to carry on computations in a tractable way, we will take a specific functional form for the externality term $h(s,S)$:

$$h(s,S) = h(s,S_m,N) = \alpha\left(1 + \frac{S_m - s}{N}\right) \tag{4}$$

with $S = [\underline{s},\overline{s}]$, $S_m = \frac{\overline{s}+\underline{s}}{2}$ and $N = \frac{\overline{s}-\underline{s}}{2}$. S_m is the average type for the large firm's researcher and N measures the heterogeneity among researchers within the large firm. $\underline{s}$ is the lowest type hired by the firm and $\overline{s}$ is the highest type. We have assumed that S is connex in order to avoid unnecessary computations.

We further take[8] $0 < \alpha < \frac{7}{6}$. With this specification, individuals with a type $s \in S$ are hired by the firm, which means that the firm hires all the

[8] The upper value of α ensures that the firm exists.

individuals with a type within the considered interval. We will see below under what conditions this is true. The chosen specification for h includes two external effects : a homogenizing effect toward the average type, which reduces the efficiency of the more able workers and boosts that of the lesser able; the influence of the firm size on individual efficiency. The homogenizing effect is weaker when the size of the firm increases. With this specification, $\frac{\partial h}{\partial S_m} = \frac{\alpha}{N}$, $\frac{\partial h}{\partial s} = -\frac{\alpha}{N}$ and $\frac{\partial h}{\partial N} = \frac{s-S_m}{N^2}$

More specifically, one has :

$$h(s, S_m, N) = \alpha \left(\frac{\overline{s} - s}{\overline{s} - \underline{s}} + \frac{1}{2} \right)$$

2.2 Demand and incomes

The quality of innovation i gives a quality level q_i for the good that will be developed upon it. Let P and p_j denote the prices charged by the large firm and the individual firms respectively. The quantity of a good demanded by the consumption good sector depends linearly on quality :

$$\begin{cases} x_j = \left(\dfrac{p_j}{a}\right)^{\frac{1}{a-1}} \cdot q_j \\ X = \left(\dfrac{P}{a}\right)^{\frac{1}{a-1}} \cdot Q \end{cases} \tag{5}$$

Profit maximisation leads intermediate producers monopolists to charge $p_j = P = \frac{\eta}{a}$. The profit of an individual firm π_j and the profit of the large firm Π depend only on the quality of their output :

$$\begin{cases} \pi_j = \left(\dfrac{\eta - a}{a}\right) \cdot \left(\dfrac{\eta}{a^2}\right)^{\frac{1}{a-1}} \cdot q_j \\ \Pi = \left(\dfrac{\eta - a}{a}\right) \cdot \left(\dfrac{\eta}{a^2}\right)^{\frac{1}{a-1}} \cdot Q \end{cases} \tag{6}$$

Profit is directly proportional to the quality level of the intermediate good. There is free entry in the intermediate good production so that dissipation of profits means that a blueprint for a good of quality j sells for a price equal to π_j.

The price of blueprint depending linearly on the quality of the corresponding intermediate good, the blueprints produced by individual ventures and that produced by the large firm will have different expressions. As mentioned above, a type s individual innovating alone gives a blueprint with average quality $p \cdot q(s)$. Taking account of (6), the expected gross revenue of the type s individual firm is

$$E[\pi(q)|s] = \left(\frac{\eta - a}{a}\right) \cdot \left(\frac{\eta}{a^2}\right)^{\frac{1}{a-1}} \cdot p \cdot q(s) \tag{7}$$

One can also obtain the expected gross profit for the large firm; the expected quality of the corresponding intermediate good is given by (3), and then the expected price for the blueprint produced by the large firm is:

$$E[\Pi] = \int_{s_L}^{s_H} h(s,S) \cdot E[\pi(q)|s]] \cdot x(s) \cdot f(s)\ ds \tag{8}$$

2.3 Equilibrium

As mentioned earlier, any individual can always secure a sure income of $\overline{w}$ on some subsistence activity. $\overline{w}$ will thus be the outside option for some researchers. Researchers working for the large firm are offered a wage $\omega(s)$ which depends on their type. The wage offered to any researcher is endogenously determined, a consequence of the large firm's profit maximisation. Some individuals will prefer setting up their own business to working in the large firm. They need to obtain financing resources from venture capitalists since their initial endowment cannot meet the business starting cost M. The venture capitalist will provide $M - \Omega$ in exchange for a share $\eta(s)$, $0 \leqslant \eta(s) \leqslant 1$, of the firm profit.[9] The precise form of the contract depends on the respective bargaining power of the investor and the innovator. The participation constraint of the investor is

$$E\left[\eta(s) \cdot \pi(q(s))|s\right] \geqslant (1+r) \cdot (M - \Omega) + c \tag{9}$$

The venture capitalist must earn a return on its investment at least equal to the exogenously given interest rate r, net of its financing cost c. On the other hand, the researcher is interested in setting up his own research firm provided he obtains an income almost as large as his outside option, i.e. the wage obtained when working as a researcher in the large firm. Therefore, the participation constraint of the innovator is:

$$E\left[(1 - \eta(s)) \cdot \pi(q(s))|s\right] \geqslant (1+r) \cdot \Omega + w(s) \tag{10}$$

The left-hand side of the above is the expected income of the innovator in the small firm. The right-hand side displays his outside opportunity, which is the sum of the remuneration on initial endowment $(1+r) \cdot \Omega$ and the maximum wage he can get in the labour market, $w(s)$ which is either equal

[9] Note that if the innovator does not find any blueprint, the venture capitalist receives nothing.

to the competitive wage $\overline{w}$ or to $\omega(s)$ the wage offered by the large firm. A necessary condition for the two participation constraints to be fulfilled can be deduced from (9) and (10):

$$E\left[\pi(q(s))|s\right] \geqslant (1+r)\cdot M + c + w(s) \tag{11}$$

This condition is also sufficient. Indeed, if $E\left[\pi(q(s))|s\right] > (1+r)\cdot M + c + w(s)$, as there are no information asymmetries, the two parties agree on a Pareto-improving contract.

The large firm's choice is twofold: it must decide how many type s innovators to hire and at the same time the wage it offers for each type it hires. The first choice yields a function $x(s)$ which gives the proportion of type s workers the firm hires. ($0 \leqslant x(s) \leqslant 1$) The second choice yields the wage schedule $\omega(s)$, which gives the wage offered by the firm to type s workers. The general program of the large firm can thus be specified in the following way

$$\max_{\omega(.),x(.)} \int_{s_L}^{s_H} h(s,S)\cdot E[\pi(q(s))|s]\cdot x(s)\cdot f(s)\,ds - \int_{-\infty}^{+\infty} \omega(s)\cdot x(s)\cdot f(s)\,ds$$

subject to the constraints:

$$\omega(s) \geqslant E\left[\pi(q(s))|s\right] - (1+r)\cdot M - c \tag{12}$$

and

$$\omega\left(s\right) \geqslant \overline{w} \tag{13}$$

The previous two equations are the participation constraint of the innovators. The first constraint (12) summarizes the fact that the wage offered by the large firm must be larger than the revenue the innovator would obtain if he could finance his project, i.e. when the condition (11) is fulfilled. (13) states under which condition the worker would not want to work in the competitive sector and would resort to the 'subsistence' activity.

2.3.1 Wage schedule in the large firm

The labour demand of the large firm and the wage schedule are determined in two steps. First the two constraints (12) and (13) determine the wage structure of the workers hired by the large firm. Then the large firm chooses its labour demand for a certain type s, granted that if a type s worker is hired, he receives a wage $\omega(s)$. We can therefore express the wage policy of the large firm in the following proposition:

Proposition 1. *Agents with types $s \leqslant s^*$, with s^* defined such that: $E\left[\pi(q(s))|s^*\right] - (1+r)\cdot M - c = \overline{w}$, earn at best $\overline{w}$. Agents with types $s > s^*$ earn $E[\pi(q(s))|s] - (1+r)\cdot M - c \geqslant \overline{w}$.*

Proof. Since $E[\pi(q(s))|s] - (1+r)\cdot M - c$ is an increasing function of s, $s \leqslant s^*$ implies $E[\pi(q(s))|s] - (1+r)\cdot M - c \leqslant \overline{w}$. Therefore, workers with types $s \leqslant s^*$ either do not want to fund their own firm or can not get financed. These workers have only two possibilities, working for the large firm or in the competitive sector. If the large firm wants to hire a worker with a type $s \leqslant s^*$, its optimal contract is to propose him his outside option $\omega(s) = \overline{w}$.

Workers with a type $s \geqslant s^*$ consider two possibilities only: either working in the large firm or funding their own venture. If the large firm wants to hire a worker with a type $s \geqslant s^*$, its optimal contract is to propose the worker his outside option $\omega(s) = E[\pi(q(s))|s] - (1+r)\cdot M - c$ □

The wage schedule of the workers employed in the large firm is thus:

$$\omega(s) = \begin{cases} \overline{w} & \text{if } s \leqslant s^* \\ E[\pi(s)|s] - (1+r)\cdot M - c & \text{if } s > s^* \end{cases} \tag{14}$$

2.3.2 Labour demand of the large firm

The firm chooses its labour demand according to the previous wage schedule, by maximizing its profit. This decision consists in choosing the proportion of research workers with a given signal s that it wishes to hire, $x(s)$. The subprogram of the firm is the following

$$\max_{x(.)} \int_{s_L}^{s_H} h(s,S)\cdot E[\pi(q(s))|s]\cdot x(s)\cdot f(s)ds - \int_{s_L}^{s_H} \omega(s)\cdot x(s)\cdot f(s)\, ds$$

Using (14), the expression of $\omega(s)$, the previous equation yields

$$\begin{aligned}\max_{x(.)} \Pi = & \int_{s_L}^{s_H} h(s,S)\cdot E[\pi(q(s))|s]\cdot x(s)\cdot f(s)ds \\ & - \int_{s_L}^{s^*} \overline{w}\cdot x(s)\cdot f(s)\, ds - \int_{s^*}^{s_H} E[\pi(s)|s] - (1+r)\cdot M - c\cdot x(s)\cdot f(s)\, ds\end{aligned}$$

We first show that the firm will choose to hire all the possible researchers of a given type provided it decides to hire that type. Indeed,

$$\frac{\partial \Pi}{\partial x(s)} = \begin{cases} [h(s,S)\cdot E[\pi(q(s))|s] - \overline{w}]\cdot f(s) & \text{if } s \leqslant s^* \\ \{[h(s,S)-1]\cdot E\left[\pi(q(s))|s\right] + (1+r)\cdot M + c\}\cdot f(s) & \text{if } s \geqslant s^* \end{cases}$$

Since $\frac{\partial \Pi}{\partial x(s)}$ does not depend on the value of $x(s)$, the firm sets $x(s) = 0$ if $\frac{\partial \Pi}{\partial x(s)} < 0$, $x(s) = 1$ if $\frac{\partial \Pi}{\partial x(s)} > 0$ and any $x(s) \in [0,1]$ if $\frac{\partial \Pi}{\partial x(s)} = 0$. In this latter case, we assume with no loss of generality that the firm sets $x(s) = 1$. Thus the program of the firm rewrites

$$\begin{aligned}\max_{\underline{s},\overline{s}} \Pi = & \int_{\underline{s}}^{\overline{s}} h(s,S)\cdot E\left[\pi(q(s))|s]\right]\cdot f(s)ds \\ & - \int_{\underline{s}}^{s^*} \overline{w}\cdot f(s)\, ds - \int_{s^*}^{\overline{s}} E\left[\pi(s)|s\right] - (1+r)\cdot M - c\cdot f(s)\, ds\end{aligned}$$

We can be more precise if we take the specification for $h(s,S)$ given in (4):

Proposition 2. *If* $h(s,S) = \alpha\left(\frac{\bar{s}-s}{\bar{s}-\underline{s}} + \frac{1}{2}\right)$, *with* $\underline{s}$ *defined as the lowest type hired by the firm and* $\bar{s}$ *the largest type, and defining* $D = [\underline{s}, \bar{s}]$ *as the set of all the types that the firm hires in equilibrium, then:*

$$\underline{s} = \frac{6\cdot\overline{w} + \alpha\cdot(K - 5\cdot\overline{w})}{\Theta\cdot p\cdot q\cdot\alpha\cdot[7-6\cdot\alpha]} \qquad \bar{s} = \frac{7\cdot K + \overline{w}}{\Theta\cdot p\cdot q\cdot\alpha\cdot[7-6\cdot\alpha]}$$

with $\Theta = \left(\frac{\eta-\alpha}{\alpha}\right)\cdot\left(\frac{\eta}{\alpha^2}\right)^{\frac{1}{\alpha-1}}$ *and* $K = (1+r)\cdot M + c$

Proof. See Appendix □

In order that the firm exist, we impose $K > 5\cdot\overline{w}$, which means that founding a firm requires a sufficiently high set-up cost compared to the subsistence wage. With this assumption, $\underline{s} > 0$ since $\alpha < \frac{7}{6}$. We can then summarise the equilibrium as follows: with $h(s,S) = \alpha\left(\frac{\bar{s}-s}{\bar{s}-\underline{s}} + \frac{1}{2}\right)$, the employment of individuals s such that types $s < \underline{s}$ exert a subsistence activity, types $s \in [\underline{s}, \bar{s}]$ are employed by the large firm, and types $s > \bar{s}$ set up their own ventures. Research workers are payed $\overline{w}$ if their types are below s^*, and $\omega(s)$ if they are above s^*. The two threshold values defined in the above proposition, $\underline{s}$ and $\bar{s}$, determine the frontiers of the large corporation. The following corrollaries precise the economic implications of this result.

Corollary 3. *A stronger interpersonal external effect leads to an increase in the range of types hired by the large firm. This stronger effect makes the lesser able researchers benefit from the presence of the more able researchers and enhances their productivity. This leads to a decrease in the lowest type joining the large firm.*

Proof. One can check that:

$$\frac{\partial(\bar{s}-\underline{s})}{\partial\alpha} = \frac{6\cdot\left[6\cdot K\cdot\alpha^2 + \overline{w}\cdot(7+6\cdot\alpha\cdot(\alpha-2))\right]}{\Theta\cdot p\cdot q\cdot(7-6\cdot\alpha)^2\cdot\alpha^2} > 0$$

□

This corollary suggests that the frontiers of the large corporation are influenced by the relative efficiency of team research versus individual innovation. The more productive the former type of research is, the greater the size of the large corporation. A traditional Schumpeterian argument distinguishes two phases in a technological, long wave. The first phase is that of exploration of the possibilities opened by the new technological revolution brought about by the bunching of key radical innovations. This stage favours the emergence of small firms both the technological and commercial exploitation of the new technologies is not "stabilised" or focused in a particular direction. This process of all-out exploration of technology does not allow so much for the exploitation of team research, which uses in a better way the advantages given by cooperation and coordination. The latter technological phase on the other hand takes place when the number of possible directions has been reduced drastically and when team research and innovation in the large firm has acquired a comparative advantage over individual innovation. The above corollary expresses this phenomenon. A rise in either α expresses an increase in the large firm's comparative advantage in research. It leads to a widening of its frontiers.

3 The effects of changes in financial conditions

3.1 Effects on wages and employment

The equilibrium of the economy is defined by the boundaries of the large firm. On the higher end of the innovative type range, it defines which researchers are going to found their own technological start-up; on the lower end, it determines which individuals are going to engage in the "subsistence" activity. Therefore, factors affecting the boundaries of the large firm will have an influence on the economy's equilibrium. Among these factors, one may focus on the costs that influence the individual decision to start a research venture. These costs are the initial set-up cost M, the interest rate r and the intermediary cost c. The latter two concern the features of the financial system, whereas M is influenced by different factors : the legal system, technology, etc. Financial liberalisation, increased efficiency in the financial intermediation sector and a drop in the costs of funding one's own firm mean lower values for r, c and M, and these changes all lead to the same outcome : an easier access to technological start-ups for individual researchers. But changes affecting these parameters are not only going to affect the range of researchers joining the large firm (the values for $\underline{s}$ and $\overline{s}$), but also the wage schedule of the large firm (the value for s^* as well as the wages $\omega(s)$ paid to hired researchers with types above s^*). We can state the following proposition on the effects of modifications in the conditions of access to finance for start-ups.

Proposition 4. *Better conditions for start-ups, i.e. lower values for r, M and c lead to lower values for the threshold s^* and for both the lowest and highest types hired by the firm $\underline{s}$ and $\overline{s}$. Furthermore, the range of researchers hired by the firm increases*

Proof. This result stems from the signs of the following derivatives : $\frac{\partial s^*}{\partial K} = \frac{1}{\Theta \cdot p \cdot q} > 0$, $\frac{\partial \underline{s}}{\partial K} = \frac{1}{\Theta \cdot p \cdot q \cdot (7-6 \cdot \alpha)} > 0$, $\frac{\partial \overline{s}}{\partial K} = \frac{7}{\Theta \cdot p \cdot q \cdot (7-6 \cdot \alpha)} > 0$ and $\frac{\partial (\overline{s}-\underline{s})}{\partial K} = \frac{6}{\Theta \cdot p \cdot q \cdot (7-6 \cdot \alpha)} > 0$ □

Financial liberalisation may be thought of as lowering the interest rate r, or at least a decrease in the interest rate and the cost of capital is one of

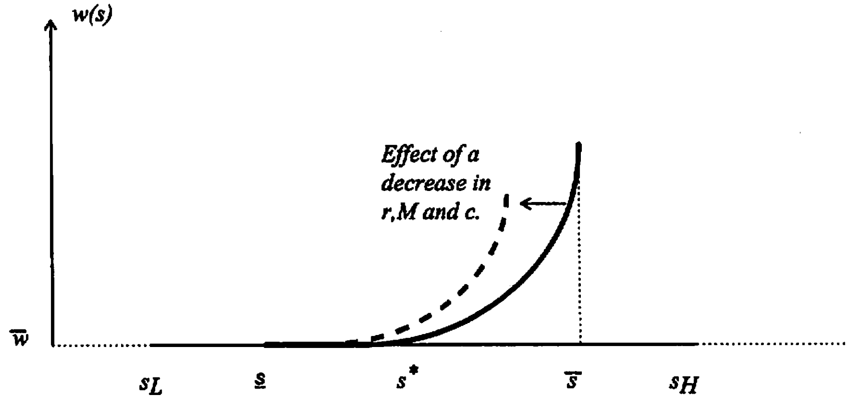

Figure 1 : *Wage schedule in the big firm.*

the aims of financial liberalisation. Increased financial sector efficiency leads to a decrease in the venture capitalists' costs c and different regulations or technological change may lower M. Lower values for these parameters mean that founding one's own venture is made easier. This increases the outside option for individual researchers at the higher end of the innovative types range. Researchers may be led to consider leaving the firm and starting a research venture once access to finance is made easier. This drives the firm to offer better wages to these researchers in order to keep them within the firm. Likewise, an improvement of the outside option also improves the situation of some researchers inside the firm : those who will be paid a wage higher than $\overline{w}$. The wages paid are going to be higher ($\omega(s)$ increases for $s \in [s^*, \overline{s}]$) and the lowest type individual paid a wage higher than the minimum wage $\overline{w}$ decreases (s^* diminishes). One may also notice that changes in the financial conditions do not affect the lower boundary of the firm, $\underline{s}$. Only he best researchers (i.e. those with a high s) benefit from financial liberalisation.

Figure 1 displays the effect on the wage structure of the large corporation.

The following proposition assesses the effect of financial liberalisation on the wage distribution within the firm.

Proposition 5. *Income inequality among individual researchers increases with financial liberalisation for 'moderate' values of the productivity of research and decreases with financial liberalisation for 'high' values of the*

Proof. See Appendix □

A rise in inequality in connection with the "new economy" is often interpreted as a sign of technological bias characteristic of the new information and communication technologies and biotechnologies in favour of the more skilled workers. What we show here is that an increase in inequality may result from institutional rather than purely technical change. Financial liberalisation alone may lead to a widening of income inequalities by improving the outside options of the more skilled researchers, thus leading the large firms to push up their wages.

Two consequences arise from a change in the interest rate, or more generally from better opportunities for founding individual research ventures. The first consequence concerns the exit of the more able researchers from the firm. As seen above, a drop in r favours the creation of start-ups and reduces the size of the firm. The range of types hired by the firm decreases at the higher end and the average type present in the firm decreases too. The exit of the better-type researchers has a detrimental effect on all the remaining researchers' productivity within the firm. A drop in $\bar{s}$ educes the strength of the positive externalities exerted by the better researchers on all the others. This tends to diminish the surplus of the sector. The second consequence of a change in r is more direct. It allows individual researchers to start their own firms, which contributes positively to the sector's output and to the surplus. In order to assess the net contribution of these new firms creations, one must deduct the additional financial costs.

The net outcome of a change in r on the total surplus is the combination of these two effects. When interpersonal externalities are strong (α high) the negative effect of researchers exiting from the firm overcomes the positive effect due to new firms' creations. Therefore, the positive effects due to technological start-ups will be eclipsed by the negative effects due to the shrinking of the large firm.

4 Conclusion

This paper has presented a model of industrial innovation with heterogeneous agents. Each agent is endowed with a certain innovation potential and may either find employment within a large corporation, working for a wage, or be self-employed. In the latter case, the agent may engage in a subsistence activity or alternatively try to develop an innovative project in his own individual firm, provided he can find finance for this venture. The financing conditions and the technologies for innovation define the allocation of researchers and thus the size of the large corporation and the number of small technological firms. Changes in the conditions for financing innovation affect the allocation of individual researchers : a drop in the cost of capital for individual firms favours the development of small technology firms and reduces the size of the large corporation. Considering that research in the large firm is organised collectively, the productivity of a researcher inside the large firm depends on the productivity of all the other researchers in the innovative team. Therefore, the exit of the more able researchers from the large firm in order to launch their own ventures has adverse consequences for the productivity of the remaining researchers. It also affects the wages of the researchers of the large firms and may lead to an increase in the wage dispersion.

We have seen that the increase in income inequality that is often associated with the 'new economy' is present in our model, but results from mechanisms which are not strictly technological, contrary to the skill-bias explanation favoured by most of the literature. Here, the decrease in financing costs, which may also result from the diffusion of information technologies in the financial sector, favours the creation of small technology firms, which improves the outside option of the more skilled researchers and allows them to obtain better wages inside the large corporation. The main factor at work is thus institutional rather than merely technological. Concerning the US case, this may contribute to explaining why the rise in income inequality took place before the appearance of the 'new economy' itself, but at about the same time as the financial liberalisation.

This model may also give a few insights on the possible evolution of industrial organisation as the 'new economy' technologies mature. If the traditional Schumpeterian argument on technological long waves is correct, one should expect that the technological developments of the "new economy" will lead to a narrowing of the focus of research and innovation and thus to an increase in the comparative advantage of large corporations. Therefore, the next years should witness a relative decline of small technology-intensive firms and a reinternalisation of research into large firms' laboratories. This effect will be all the stronger that the current trends in financial markets seem to point toward an increase in financing costs for start-ups. This factor alone would, as our model shows it, favour large firms over small ventures.

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Appendix

Proof of proposition 2

The firm's program is :

$$\max_{\underline{s},\overline{s}} \Pi = \int_{\underline{s}}^{\overline{s}} h(s,S) \cdot E\left[\pi(q(s))|s\right] \cdot f(s)ds$$
$$- \int_{\underline{s}}^{s^*} \overline{w} \cdot f(s)\ ds - \int_{s^*}^{\overline{s}} E\left[\pi(s)|s\right] - (1+r)\cdot M - c\cdot f(s)\ ds$$

Taking the derivatives with respect to $\underline{s}$ and $\overline{s}$ and after simplifying, one obtains the following system

$$\begin{cases} c + M\cdot(1+r) + \frac{1}{6}\cdot\Theta\cdot p\cdot q\cdot[\underline{s}\cdot\alpha + 2\cdot\overline{s}\cdot(-3+\alpha+3\cdot\beta)] = 0 \\ \overline{w} + \frac{1}{6}\cdot\Theta\cdot p\cdot q\cdot[\overline{s}\cdot\alpha - 2\cdot\underline{s}\cdot(2\cdot\alpha+3\cdot\beta)] = 0 \end{cases}$$

The solution of this system are the values given in the proposition. □

Proof of proposition 5

The individual researchers'income grows unambiguously with s, which allows to define the cumulated 'wealth' as a function of s, which writes

$s\cdot\overline{w}$ for $s \leqslant s^*$ and $s^*\cdot\overline{w} + \int_{s^*}^{t}[\Theta\cdot p\cdot q\cdot s - K]ds$ for $s \geqslant s^*$.

We can then define a Gini index-type measure of income inequality as :

$$I = \int_{s_L}^{s_H} tdt - \frac{1}{Y}\cdot\left\{\int_{s_L}^{s^*}\overline{w}dt + \int_{s^*}^{s_H}[\Theta\cdot p\cdot q\cdot t - K]dt\right\}$$

with Y the researchers' total income :

$$Y = \int_{s_L}^{s^*}\overline{w}ds + \int_{s^*}^{s_H}[\Theta\cdot p\cdot q\cdot s - K]ds$$

For convenience and without loss of generality, we take $s_L = 0$ and $s_H = 1$, which gives :

$$I = \frac{(K-\Theta\cdot p\cdot q+w)^2\cdot(2\cdot K+\Theta\cdot p\cdot q+2\cdot w)}{6\cdot\Theta\cdot p\cdot q\cdot[(K-\Theta\cdot p\cdot q)^2+2\cdot K\cdot w+w^2]}$$

$\frac{\partial I}{\partial K}$ has the sign of :

$$-(K-\Theta\cdot p\cdot q)^3 - 3\cdot\left(K^2+(\Theta\cdot p\cdot q)^2\right)\cdot w - 3\cdot(K+\Theta\cdot p\cdot q)\cdot w^2 - w^3$$

For low values of $\Theta\cdot p\cdot q > K$, the above expression is negative. It is positive for high values of $\Theta\cdot p\cdot q$. □