Why information technology leads to smaller firms.

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Abstract

We show why the new information abundance -- the IT revolution -- shifts and distorts the size distribution of firms, explaining the general and continuing downsizing trend of the recent decades, and reversing the previous 1880/1960-70 secular increase of big business. We formulate an information theory of the firm and derive a Coase-Rybczinski effect, which predicts a decreasing employment share of large firms and an increasing share of small ones. Panel data regressions and other evidence provide support for this hypothesis.

Keywords: Firm size, downsizing, information technology,

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1. Introduction

Following what could be called a “Schumpeter (or Chandler, or Ford) era”, spanning the period from the end of the nineteenth to the third quarter of the twentieth century[1] (1880-1970), during which larger size reigned supreme in productive organizations, the last few decades mark a general reversal towards smaller firm size.

By the end of the 1970s many changes impacted the organization of work within and between firms[2], and an increasing number of symptoms have drawn attention, in many developed countries, to the emergence of a new role for the smaller firms in the production process, increasing their share of output while decreasing the economic weight of larger firms. Many authors in the 1980s and 1990s scrutinized various aspect of this general phenomenon. First, in a wide-ranging empirical survey, the OECD 1985 report signaled the increasing employment in small firms, while Piore and Sabel (1984) had earlier analyzed new modes of organization characterized by more flexibility and specialization. Then Sengenberger et al. (1990) diagnosed a re-emergence of small enterprises, while many authors, especially in finance, described a disintegration trend in firms (often following mergers and acquisitions), either vertical (outsourcing, spinoffs) or horizontal (the surprising disappearance of conglomerates and the re-specialization and refocusing trends)[3]. Overall this broad change included a general downsizing replacing the previous quest for large scale, since the breakdown of existing firms gave way to smaller entities, an increased demand for qualified labor, and a significant reduction in the number of hierarchical levels in all organizations.

As Herbert Simon (1991) aptly emphasized, the market economy claimed back its role from the “organizational” (we would say “hierarchical”) economy. That is to say (Meade, 1968) that the organization of production activities readjusted the balance which set “careful forward planning" against the "price mechanism" in favor of the latter, since, as Robertson(1928) had stated much earlier, "lumps of conscious power" are a substitute to the "ocean of market exchange".

Increasingly, the division of labor has been made "between firms rather than within them. This phenomenon represents a major reversal with respect to what only thirty years ago appeared to be the only possible form of development of the industrial system: namely the primacy of large business organizations characterized by a high degree of both vertical and conglomerate integration" (Trau, 2003, p.25).[4]

A few authors, however, express some skepticism about the reality of the phenomenon. Baumol et al. (2003, p. 1) for instance, with regard to the US, write: "During the late 1980s and, especially, the early 1990s, a wave of what was called "downsizing" swept – or allegedly swept - corporate America". And they present a detailed sector analysis showing mixed evidence (upsizing as well as downsizing, especially in services) for the American economy. Should we thus conclude, as the authors hint, that it was basically a matter of temporary adaptation to increased technological innovation, openness and competition in the newly globalized economy? Was the same phenomenon also observable in other countries? Is it still going on today? And if so, what are the causes, or the cause?

The question is important for industrial organization, competition policy and general management. In this paper we first show, using data available until 2004, that the reversal continued unabated in the manufacturing sector of the US and of the three largest European countries, France, Germany, and the United Kingdom. We then develop an information based model of the firm, complemented by a Coase-Rybczinski effect, to explain why technology – the information revolution – is the underlying cause of a shift and distortion in the size distribution of firms, and of the international "great reversal" of organizational structures.

Afterward, we test our theoretical assumptions using data on price and quantity of ICT equipments and panel estimation techniques. The last section concludes.

2. The reversal vindicated

Figure 1 presents, for the three largest European countries and the USA, the evolution of the average size of enterprises in manufacturing industries, over the period 1962 – 2004. In European countries, a downward trend is apparent since the 70s (1977 in our data), reversing the former trend towards larger size, diversification and conglomerate growth which is apparent in the evolution from 1962-67 to 1977. For the USA, data for the 1992-2004 period vindicate the decline that Baumol et al. (2003, p.100) observed for all firms and all industries between 1967 and 1992.[5]

Figure 1 Average number of employees: firms with 20 employees or more. (all manufacturing industry). *Sources: Monnikhof and van Ark (1996) and Eurostat.*

[insert here]

The next four figures -- 2a, 2b, 2c & 2d -- present the evolution of the average firm size for manufacturing sub-sectors in the UK, France, Germany and the USA. The size generally increased between 1962 and 1977 but a majority of sectors clearly show a downward trend after the seventies (1977): 91% of the sectors in France in our sample, 91% in UK, 75% in Germany and 71% in the USA. The evolution does vary depending on the sector. For example, in the sub-sector "office and computing equipments", the average size of firms has decreased by 93% in France, 77% in Germany and 67% in UK between 1977 and 2004. There are some exceptions such as the "drugs and medicines" sub-sector in which firms continued to grow after 1977 by 60%, 48.5% and 1.7% respectively in the three countries mentioned above. Finally, for some sectors, evolutions have diverged from one country to another. In the "railroad equipments" sub-sector, the average size has been increasing by 15% in Germany but decreasing by 17% in France and by 72% in the UK.

Figures 2a, 2b, 2c, 2d Average number of employees, firms with 20 employees or more). *Sources: Monnikhof and van Ark (1996), Eurostat and US bureau of the Census. Authors' calculations.*

[insert here]

Since the mid 1970, the manufacturing sector has contracted in the four countries studied. Between 1977 and 2000, manufacturing employment, as a proportion of total employment, has decreased by 36.89 % in France, 34.79 % in Germany and 46.57 % in the UK. It has dropped by 25.08 % in the USA between 1992 and 2003.

The evolution has also differed, inside countries, between large and small firms (table 1). The number and the average size of the largest firms have decreased significantly between 1977 and 2000 in France, Germany and UK, as in the USA between 1992 and 2004. During the same periods, the number of small firms (20-99 employees) has increased in France and in Germany and contracted in UK and in the USA, but at a lower rate than in the case of largest firms.

The drop in the number of small firms was certainly explained in part by the overall contraction of the manufacturing sector which has been stronger in UK than in other the countries. The average size of small firms increased in Germany and remained quasi constant in the US. It has decreased in France and in UK, but here again, the percentage is much lower than in the case of the largest firms and has to be brought in parallel with the general contraction in the manufacturing sector.

Table 1 Percentage change in the number and in the average size of firms, per class of size

	Largest firms, ≥ 500 employees		small firms, 20-99 employees	
	average size	number of firms	average size	number of firms
USA 1992-2004	-21,70%	-11,88%	-0,31%	-10,67%
UK 1977-2000	-21,27%	-55,80%	-2,60%	-13,12%
Germany 1977-2000	-15,81%	-9,95%	2,81%	8,44%
France 1977-2000	-28,80%	-26,87%	-5,58%	5,36%

Facts thus do seem rather uncontroversial: a downsizing trend replaced, after 1977, the previously upsizing one. It is due mostly to the decrease of employment in the higher deciles and increase of employment in the lower deciles.

This confirms previous studies. In the case of UK, France, Germany and Italy, Dosi et al. (2008) indicate clearly that the largest firms accounted for a decreasing share of total manufacturing employment during the 90s. In the case of small firms, their share remained quite stable or increased, depending on the country.

Supporting Baumol et al. (2003) observations, Baldwin et al. (2002) show, for the US and Canadian manufacturing sectors, that between the 1970s and the 1990s, the share of small plants in total employment has been growing. Then, it remained stable during the 1990s.[6]

In the perspective of Stigler's "survivor principle", according to which the competition between firms of different sizes sifts out the more efficient enterprises, the data thus point to an overall reduction of the optimal firm size[7] and especially in the largest firms.

This begs the question of which are the determinants of firm size that can explain that evolution.

3. The determinants of firm size: prominence of technology factors

In their survey of what determines firm size, Kumar et al. (1999) classify extant theories of the firm broadly in three categories, as technological, organizational, and institutional, based on whether they focus on the production function, the process of control, or environmental influences.

It is not evident that the last two categories of factors, including asset specificity for instance, or legal and anti-trust environment, have been characterized by a sharp trend reversal occurring in the 1970s, that is necessary to explain the general trend reversal in firm size.

Moreover they could hardly explain such an overall change since the factors in the second category tend to be industry specific, while those in the third category should be mostly country specific. Such factors nevertheless have to be included in empirical tests as normalization variables in order to check for their possible influence on differences of size across sectors and across countries[8].

The main common determinants of firm size are more likely technological, as suggested by Langlois (2003). He considers that technology is the key driver of the "vanishing hand", i.e. a movement toward more market-centered organization of economic activities and away from the Chandlerian multidivisional corporation. Similarly, and commenting their observation of a larger share of small firms in manufacturing employment, in US and Canada, Baldwin et al. (2002) suggest that determinants of this trend should be looked for in technological factors, common to the two countries.

Among these technological factors Kumar et al. (1999) consider first the size of the market (following Adam Smith (1776) and Stigler (1951)) which allows more specialization among workers. Specialization is productive in that it reduces the "set up" fixed costs incurred by workers when they change tasks. The extent of specialization being limited by the extent of the market and the size of the firm being linked to its use of specialized workers, we would expect firm size to be correlated with the overall size of the market. This prediction, however, appears to be contrary to what we have observed: the size of markets has been expanding with the economic growth of the last decades, while firm size consistently declined[9].

Indeed, Smith's prediction has been challenged by Becker and Murphy (1992) who point to the existence of multiple firms serving most markets to argue that specialization is not limited by the size of the market. In their theory, internal coordination costs play a major role in limiting the size of firms, before the size of the market becomes binding. It has to be shown then whether internal coordination costs have increased recently, which is rather counter-intuitive since the costs of communication, and of internal storing and processing of information on computers, has been falling rapidly.

Focusing on the production function, Lucas (1978) explains the distribution of firm sizes by the distribution of 'managerial talent' in the population. In his model, individuals make a choice between a managerial position and a salaried one, based on the comparison between managers/entrepreneurs' expected earnings (managerial rent) and employees' wage. In equilibrium, and for a given population, the average firm size is determined by the number of managers in the total workforce.

Lucas forecasts a general increase in firm size due to the accumulation of capital which increases labor productivity and therefore wages relative to profits. Indeed, this motivates talented individual to choose a wage earner position rather than an entrepreneurial one, and as the number of managers decreases, the average firm size increases.

Supporting his predictions, Lucas finds a positive relationship between firm size and per capita GNP (a proxy for per capita capital) based on US data for the period 1929-1963. Since the Lucas study however (1978), the trend size of firms has reversed and higher per capita capital (or per capita GNP) has been accompanied by smaller firm size, directly contradicting the Lucas prediction for the then future, and now past, post-1978 period.

In the Baumol et al. (2003) framework, the size reducing impact of new technology should be felt mainly through a decreased revenue schedule for established, obsolete, firms, and because of "churning". As explained by the authors, however, technological innovation could increase as well as decrease the optimal size of firms: "When technology changes, sometimes bigger becomes better, but sometimes the reverse is true: smaller can become more beautiful" (op.cit. p. 67). In the nineteenth century as railroads replaced animal-drawn vehicles in the US, firm size increased in the transportation industry, while after World War II, completion of the interstate highways system led to a replacement of railroad transportation by truck transportation, and thus to a dramatic reduction in firm size in the transportation industry. This specific technological approach thus leaves us with a case by case analysis, making it difficult to explain the general move to smaller size.

Brynjolfsson et al. (1994) single out the revolution in information and communication technologies (ICT) as the main cause of the recent, post 1975, downsizing wave. However, they too suggest ambiguous theoretical predictions. They explain that the development and the diffusion of ICT equipments reduce both: (1) firms' internal coordination costs which leads them to do more things internally and to grow in size; and (2) firms' external transaction costs which favors outsourcing and results in downsizing. The Information Revolution can therefore lead to downsizing but only if (2) dominates (1), and so no general theoretical conclusion can be drawn.

This is not obvious however since it is difficult to see why a reduced cost of telephone calls, for example, should affect differentially calls within the firm and calls outside the firm.

Moreover Brynjolfsson et al.'s empirical results are not conclusive. They study the evolution of establishments and firms' size in various US industries over the period 1976-1989, and consider investment in office computers, lagged and observed at the sub-sector level, as the main independent variable. They find that this investment exerts a strongly significant and negative effect on the size of establishments, but a non significant and both positive and negative correlation (depending on the investment lag) on firm size.

All these studies thus fail to explain the firm size ‘great reversal’, either on theoretical grounds because the technological factors they consider exert in their models an ambiguous effect on firm size, or on empirical grounds because their predictions are either not conclusive or contrary to the observed facts of the recent decades.

In what follows, we develop a theory of optimal firm size evolution based on the changing cost of information impact on the production function and the input mix of the firm.

4. An information theory of firm size

What type of model is necessary to explain the observed evolution of firm sizes in general terms rather than on a case by case approach?

The Coase (1937) framework is based on the comparative market and organization costs of transactions and information. While it leads to ambiguous predictions regarding the impact of a falling cost of information on firm size, it can be modified to center the analysis on the input combinations of factors of production (including the information factor) that varies systematically with firm size. We are thus able to derive the non ambiguous Rybczinski effect of an increase in the quantity of information on the respective size changes of small and large firms.

4.1 Coase and the impact of information cost and quantity

A satisfactory model should build upon Coase, whose explanation of firms' existence by the cost of transactions (and information) on the market is generally accepted today. There are, two basic mechanisms by which productions can be coordinated in a specialized economy: coordination by the price mechanism or coordination by an entrepreneur. Firms as centralized production processes exist because the hierarchical mode of production economizes on transactions. Coase hints to the fact that information costs (the costs of "discovering what the relevant prices are") are a main component of transaction costs. But we can add further that the other costs, the costs of contracting and negotiating contracts, are also information costs. If complete information were available to all participants, there would be no need for negotiation, as all participants, cognizant of all relevant specific circumstances, would readily go for the best solution (the best contractual terms available). It follows that it is chiefly the cost of information that explains the existence of firms in the coasian perspective. Information (or the lack of it) is the single major determinant of the use of the centralized production process.

Since information is necessary to all producers, variations in its price could explain the choice, at the margin, of using more the price mechanism or the hierarchical mechanism, for all firms and all transactions. A rising cost of information should favor firm expansion, while a falling cost of information would favor firm contraction (outsourcing etc.). This results from the fact that the market mode of production relies on more transactions than the hierarchical mode, which, as noted by Coase, replaces a large number of bilateral contracts between individual suppliers of inputs with a smaller number of contracts between these suppliers and a central party, the entrepreneur. Accordingly, the decentralized market process necessitates more information, as we emphasize, than the centralized firm process. The firm reduces the number of contracts necessary for a given production and thus the amount of information, compared to what a decentralized market process requires. As a consequence, an increase in the quantity of information (a decrease of its cost) should reduce the dimension of all firms[10].

But Coase then has to address the question of why there are many firms in the economy and not only one gigantic firm encompassing all productions, as soon as the market process is more costly than the management process. He reminds us that there are also management costs, or "diminishing returns to management" (as noted by Kaldor, 1934 and A. Robinson, 1934), besides marketing costs. These rising managerial costs deter firms from growing without limits. He then claims that the size of firms is determined by a moving equilibrium between marketing costs (the costs of transactions on the market) and the managing costs, for the marginal transaction. The determination of firm size is due to a calculation at the margin of the relative benefits of integrating an additional transaction or outsourcing it to some other producer.

The balance between the marketing cost and the managing cost can be shifted of course by a change of their common basic component, the cost of information. The effect on size of such a change is ambiguous however since it affects both the cost of the market and the cost of managing. Coase gives the example of the telephone and the telegraph (footnote 26):

« It should be noted that most invention will change both the costs of organizing and the cost of using the price mechanism. In such cases, whether the invention tends to make firms larger or smaller will depend on the relative effect on these two sets of costs. For instance, if the telephone reduces the cost of using the price mechanism more than it reduces the costs of organizing, then it will have the effect of reducing the size of firms."

In this case the evolution of firm size becomes a priori indeterminate. It all depends on the specific characteristics of each information-augmenting technology. Brynjolfsson et al. (1994) are confronted with precisely this problem. In that case, no general rule can link the abundance of information (the main factor of divergence between the management process and the decentralized market process according to Coase's first assertion) to the choice of one process over the other, and thus to the determination of average firm size.

The main criticism that we address to this theory is that it is difficult indeed to understand how a same technology – e.g. the telephone – can affect differentially the cost of a given transaction, depending on its taking place within the firm or with some external agent (between firms).

In what follows we shift the analysis from one of the differential effect of a changing information cost (or quantity) on the market cost and the management cost at the level of an individual transaction, and in the same way for all firms, to *an analysis of the differential impact of the changing information cost on firms of different size*. Indeed, different firm sizes imply a different intensity in the use of information relative to labor and capital.

Of course, we are left with another difficulty: what explains the coexistence of firms of different sizes in a same sector? An answer has been provided by considering the role of entrepreneurs of diverse managerial talent. This is the Lucas model of the firm, which relies on a distribution of managerial talent in the population, more talented entrepreneurs managing the larger firms, as further demonstrated by Rosen (1982).

4.2. Information cost, input mix, and firm size

Small firms are more intense in information (and less intense in labor or capital) than large firms, for two reasons:

(a) Small firms rely more on outside procurement, and thus make more use of the market than large ones which are more integrated. They have to use more information per unit of output than large ones since they use a larger number of outside contracts (Coase).

(b) In their product market, we can assume that the same amount of information is necessary for all firms operating in a same sector, whether small or large.

This amount of information is bought only once for the whole firm, and used and replicated at will by the manager through his directives and orders to his subordinates, whatever their number (in the Rosen-like cascade multiplying the efficiency of subordinates by that of the manager).

It follows that the average cost of information is decreasing in firm size. There are strong economies of scale in information. The combination of factors in firms thus varies with firm size. The ratio of information to labor is higher for small firms and lower for large firms.

As a consequence, the decrease of the cost of information -- whatever the details of the innovations which brought it about --, has a more cost-reducing effect on small firms than on large ones, and gives a competitive advantage to small firms. Then, borrowing from the theory of international trade, one may easily derive a 'Coase-Rybczinski' theorem (Rosa, 2006) relevant in organization:

"with a lower cost of information (a higher quantity), large firms will downsize and/or disappear while small firms will upsize and new small firms will enter the economy. And the reverse is true".

In order to simplify the exposition, one may consider, in a same sector, two sub-sectors, one using intensively information (the small firms) and the other more intensive in labor (the large firms). The Rybczinski theorem then applies showing that an increase in the quantity of information will determine growth of the information intensive sub-sector and a contraction of the labor intensive sub-sector.

This is because the information intensive firms will benefit more than the labor intensive ones from the fall in the price of information. They are thus able to attract employees from the large firms due to a superior competitive advantage.

We obtain an explanation of the facts observed: with the information revolution, the share of large firms in the economy contracted, while the share of the small ones increased. Not all classes of firms moved together simultaneously in the same downsizing direction.

Contrary to Coase (1937) and to Brynjolfsson et al. (1994), we claim that the direction of the impact of information on firm size does not change with each specific innovation, but that all increases in the quantity of information, whatever the innovation characteristics, impacts differentially the costs of firms of different sizes because firms of different sizes have a different intensity in the use of information (thus Rybczinski).

Moreover this model can account for the simultaneous decrease of the large firms' share of employment and increase of the small firms' share, while the simple comparison of the cost of information in management and in the price mechanism could only forecast a general decrease of the sizes of all firms. Some more precision in the model can be obtained from a formal presentation.

5. A formal presentation of the model

Consider two firms $j = 1, 2$ operating in the same product sector but of different sizes, with output x_1 and x_2 such that $x_1 > x_2$ (e.g. $x_1 = 1000$ and $x_2 = 500$) and number of employees $L_1 > L_2$ (e.g. $L_1 = 1000$ and $L_2 = 500$). We assume for simplicity that labor is strictly proportional to output with a one to one correspondence.

In order to run their operation, they need another factor of production, information. To make a same product, different firms need the same kind of information and in the same quantity I_1 = I_2 (e.g. I_1 = I_2= 10), whatever the output level. The input coefficients are $i_j = \frac{I_j}{x_j}$ for information and $l_j = \frac{L_j}{x_j}$ for labor.

In our numerical example, $i_1 = 0{,}01$, $i_2 = 0{,}02$ and $l_1 = l_2 = 1$ (labor is proportional to output). Factor relative intensity is given by the ratio $\frac{i_j}{l_j}$. $\frac{i_1}{l_1} = 0{,}01$ and in our case, firm 1 is more information-intensive than firm 2, $\frac{i_2}{l_2} > \frac{i_1}{l_1}$.

The development and diffusion of ICT (microprocessors, computers, satellite communications, mobile phones), at a much lowered price, has led to a vastly larger quantity of information available in society. One may show easily that in theory, this increased abundance of the information factor of production favors the firms that are more information-intensive. Accordingly, smaller firms 2 will become both more competitive and more numerous relative to larger firms 1.

5.1 Competitiveness and the price of information.

Let *w*, the unit price of labor, be constant, *p*, the unit price of good *X*, be constant (the labor market and the product market are competitive, no economies of scale), and *z*, be the unit price of information. The unitary profit is: $\pi_j = p - wl_j - zi_j$.

Holding every else constant, the marginal profit for a variation of the price of information is:

$$\frac{\partial \pi_j}{\partial z} = i_j \quad \text{which is higher for the smallest firm.}$$

This result holds if one considers a continuum of firm sizes in the economy, instead of just two sizes, the value of i_j continuously declines with the size of the firm (in output or employment), and thus the marginal profit for a variation of the price of information also declines with size. Large firms profit less from a falling price of information than smaller ones. In other terms, the relative costs (the dual of profitability) of large firms and small firms are changed to the detriment of the largest. While all firms have reduced their total costs due to the lower price of the information input, the gain is much more important for the smaller firms which benefit therefore from an increased competitiveness relatively to larger ones. It follows that the larger the firm, the more vulnerable from the competition of smaller firms it will be, and especially from the more intense competition of the smallest. This should result in the replacement of the firms in the largest deciles in the size distribution, for instance, by more firms in the smallest deciles. Large firms have to cut their size much to face the new competitiveness of smaller firms.

5.2 Consequences on the average size of firms.

Consider that a product sector *X* is composed of *K* sub-sectors *k*, and each *k* corresponds to different size-classes of firms. Each sub-sector *k* is thus composed of n_k firms *j* that are of the same size: x_{kj}, L_{kj}, and I_{kj} are constant. The size of firms is characterized either by output or employment level. The aggregate output in the product sector *X* is such that:

$$X = \sum_k X_k = \sum_{k,j} x_{kj} \; .$$

In the sub-sector *k*, the aggregate output X_k can only increase with the number of firms n_k and such that $X_k = f(n_k)$, $\frac{\partial X_k}{n_k} > 0$ and $n_k = f^{-1}(X_k)$ and $\frac{\partial n_k}{\partial X_k} > 0$.

For ease of the presentation, assume that there are only two sub-sectors $k = s, b$, the first, *s*, composed of small identical firms and the second, *b*, of large identical firms. The total quantities of information and of labor used in sector *X* are given by the following relations[11]:

$$L = X_s l_s + X_b l_b$$

$$I = X_s i_s + X_b i_b \qquad (1)$$

Taking the total differential:

$$dL = l_s dX_s + l_b dX_b \qquad (2)$$

$$dI = i_s dX_s + i_b dX_b$$

Solving for these equations, one gets:

$$dX_s = \frac{l_b dI - i_b dL}{l_b l_s \left(\frac{i_s}{l_s} - \frac{i_b}{l_b} \right)} \qquad (3)$$

$$dX_b = \frac{-l_s dI + i_s dL}{l_b l_s \left(\frac{i_s}{l_s} - \frac{i_b}{l_b} \right)}$$

Note that in each case, the sign of the partial derivative depends on the denominator and, in particular, on the difference in sub-sectors' relative factor intensity: $\frac{i_s}{l_s} - \frac{i_b}{l_b}$. In the case of small firms that are more information-intensive than larger ones, $\frac{i_s}{l_s} > \frac{i_b}{l_b}$, as previously shown, and one can read the partial derivatives from (3) and such that:

$$\frac{\partial X_s}{\partial I} = \frac{1}{l_s \left(\frac{i_s}{l_s} - \frac{i_b}{l_b} \right)} > 0$$

$$\frac{\partial X_b}{\partial I} = \frac{-1}{l_b\left(\frac{i_s}{l_s} - \frac{i_b}{l_b}\right)} < 0$$

This result can be defined as a “Coase-Rybczinski theorem”:

An exogenous increase in the quantity of information will lead to a development of sub-sector X_s and a contraction of sub-sector X_b, and given our assumption that $\frac{\partial n_k}{\partial X_k} > 0$, this will lead to a different distribution of firms among class size and to a decrease in the overall average size of firms.

This can explain the observed correlates of the downsizing trend: de-layering of the firm hierarchies, outsourcing, spinoffs, re-specialization and refocusing, end of conglomerates, as well as the increased demand for highly qualified labour and decreased demand for unqualified labour, while the sector of the smaller firms expands, all characteristic evolutions of the recent decades that other theories do not explain.

6. Empirical tests

6.1 Methodology and variables definition

In order to measure the size of firms, one can alternatively use gross output, value added or the number or the level of employment (Kumar et al., 1999). The last one is preferable for our purpose, as coordination costs, the purpose of this paper, are linked to the number of employees, not to their productivity. We compute the average number of employees per enterprise, for enterprises with 20 employees or more in an industrial sub-sector. We have data for 27 manufacturing sub-sector (3 and 4-digit levels).[12] See Appendix for sources, construction and scope of the variables.

To assess the level of information and communication technologies and the costs of information transmission, we use two kinds of variables.

First, the number of main telephone lines per 100 habitants in a country, an indicator available over a long period and for several countries. Second, we use Dale Jorgensson's long term series on prices of ICT equipments and of computer. We expect a positive correlation between these prices estimates and firm size, as a lower price of ICT equipments would foster access to information.

Due to data availability, our empirical analysis proceeds in two steps corresponding to different samples. The first one covers France, Germany and the UK, over the period 1967 to 2004, with exogenous variables that are mostly countrywide. The second sample covers a shorter period of time (1990 to 2004) but includes the USA and sector level explanatory variables. As we use data at the sector level, for several countries and for several years, we conduct panel estimations.

6.2 First sample: France, Germany, UK, 1967-2004

In this first step, the average size of firms and the market size are observed at the sector level whereas all other variables are countrywide. Our model intends to measure the relationship between the level (price) of ICT equipments in the economy and the average size of enterprises for a given manufacturing sector, in a given country and for a given year, while controlling for market size, foreign competition, price of investments, human capital and industry-specific effects. The basic regression model is:

$$Size_{j,z,t} = \alpha + \beta_i ICT_{j,t-i} + \gamma Market_{j,z,t} + \rho INV_{j,t} + \delta HUMCAP_{j,t} + \mu TRADE_{j,t} + \varepsilon_t \quad (1)$$

where $Size_{j,t}$ is the log of average firm size in country *j*, sector *z* and year *t*; $ICT_{j,t-i}$ is either: i) The log of the number of telephone main lines per 100 habitants in country *j* and period *t* or, ii) The price of ICT equipments or of computers, in country *j* and year *t-i* with *i=0,1,2* or *3*. Following Kumar et al. (1999), $Market_{j,z,t}$ is the log of total employment in a sub-sector *z* as a proxy for its market size in country *j*, at period *t* and $HUMCAP_{j,t}$ is the average schooling years of population aged over 25, as an indicator of *human capital*. If it determinates “talent for managing”, we may expect a positive correlation with enterprise size. $INV_{j,t}$ is the *investment price level* in country *j* at period *t*, and according to Brynjolfsson et al. (1994), it should discourage business expansion and lead to decline in firm size. $TRADE_{j,t}$ is the degree of trade openness of country j at period t. It is used as an indicator of foreign competition that leads to downsizing according to Brynjolfsson et al. and to Baumol et al. (2003). Finally, ε_t the error term. We introduce a sector fixed effect in the panel estimation procedure in order to control for potential factors that would not change over time.

We consider that heterokedasticity is a potential problem given that the size of the twenty seven sectors varies significantly in our data set. Following Brynjolfsson et al., we solve this difficulty using the weighted least squares correction technique. Each observation on a sector is weighted by the size of the sector, as proxied by a sector’s share in total employment (emp). In order to do so, we first computed the average employment share (EMP) over the 27 sectors (for each country, each year) and multiplied each variable by its corresponding ratio (emp/EMP). This procedure is correcting for heterokedasticity while providing efficient parameter estimates.

In this first step, we conduct two sets of regressions, the first one using the diffusion of telephone lines and the second using prices of ICT equipments and of computers.

Results

The Table 2 presents the results of weighted panel OLS regressions with sector fixed effect, and using the *number of main telephone lines* as explanatory variable. The first three columns differ with the year (t, t-1, t-2) at which this variable was observed. This allows us to account for a potential lag in the influence of telecommunication equipments diffusion on firm size. We use only one of these alternative measures at a time in order to avoid problem of collinearity. The estimated coefficient for this variable is negative, as expected, and significant. Over this long period, the development of telecom equipments accompanied firms' downsizing.

The positive estimates for *Market* size are also conform to theoretical predictions and strongly significant. We observe a positive and significant estimated coefficient for *investment price*. This suggests that a lower cost of investment has a downsizing effect on firms due to a factors substitution effect. The estimated coefficients for *trade openness* and *human capital* are not significant.

The fourth column presents the results of a test in which we introduced countries' real GDP per capita as an additional explanatory variable in order to account for Lucas (1978) assumption. The estimated parameter is negative, contrary to expectations, but not significant. The correlation matrix (not shown here) reveals that this variable is strongly correlated with *human capital* and *trade openness*.

Kumar et al. (1999) suggest that market size, measured by employment, can be endogenous. Indeed, some external factors influencing the size of firm could affect a sector's total employment as well. To avoid this problem, we instrument market size with the log of population and of GDP and we conduct weighted 2SLS (two stages least-squares) regressions. In order to avoid correlation problems with the two instrumental variables, we omit *human capital* and *trade openness*. The last three columns present the results of regressions for various measures of the *number of main telephone lines*. The results remain robust.

Table 2 Results with number of telephone lines per 100 habitants

	Weighted OLS				*Weighted 2SLS*		
nb Telephone lines t	-0.366			-0.326	-0.278		
	(0.264)			(0.285)	(0.099)***		
nb Telephone lines t-1		-0.408				-0.265	
		(0.236)*				(0.091)***	
nb Telephone lines t-2			-0.412				-0.259
			(0.226)*				(0.088)***
Market size	0.596	0.577	0.571	0.558	0.64	0.636	0.634
	(0.056)***	(0.058)***	(0.059)***	(0.068)***	(0.034)***	(0.034)***	(0.034)***
Trade openness	0.160	0.155	-0.0007	0.159			
	(0.162)	(0.159)	(0.001)	(0.160)			
Investment price	0.344	0.339	0.333	0.267	0.251	0.246	0.244
	(0.122)***	(0.112)***	(0.108)***	(0.124)***	(0.109)***	(0.104)***	(0.103)***
Human capital	-0.089	0.001	0.024	0.045			
	(0.314)	(0.319)	(0.32)	(0.331)			
GDP per capita				-0.126			
				(0.243)			
Constant	-2.943	-2.498	-1.98		-2.805	-2.571	-2.272
	(0.522)***	(0.598)***	(0.767)***		(0.31)***	(0.254)***	(0.218)***
Observations	389	389	389		389	389	389
R^2	0.753	0.754	0.754		0.752	0.753	0.753
F	218.11	218.96	219.24				
Wald khi2					87205	87433	87506

*** significant at 5%, *** at 1%*
Notes: dependent variable is the average size of firms with 20 employees or more.
Standard errors in parentheses.
All regressions use panel techniques and include an industry fixed effect.
In two stages least-squares (2SLS) regressions, market size is instrumented.

The Table 3 presents the results of similar regressions but using the prices of computer and of ICT equipments as explanatory variables. We find positive and significant estimated coefficients for these two variables, confirming that a cheaper access to information and communication technologies favoured firms downsizing.

Table 3 Results with the prices of computers and of ICT equipments

	Weighted OLS		*Weighted 2SLS*
ICT equipments price	0.171 (0.048)***		0.112 (0.035)***
computer price		0.055 (0.015)***	
Market size	0.442 (0.070)***	0.428 (0.073)***	0.534 (0.047)***
Trade openness	0.239 (0.159)	0.266 (0.161)*	
Investment price	0.107 (0.1)	0.187 (0.094)**	0.062 (0.068)
Human capital	0.183 (0.226)	0.146 (0.229)	
Constant	-0.969 (0.767)	-1.356 (0.691)**	-1.294 (0.369)***
Observations	389	389	389
R^2	0.761	0.76	0.758
F	226.88	226.78	
Wald khi2			89363

We introduce a country fixed effect in the analysis to account for structural differences between countries such as institutional factors. Kumar et al. (1999) suggest indeed that the efficiency of the judicial system, the regime of patents protection, the quality of accounting standards, the statutory corporate taxes, and the level of regulatory constraints may influence the size of firms[13]. Table 4 indicates de result of linear OLS regressions with the number of telephone lines, ICT and computer prices as alternative endogenous variables. The results are the same as before, but more significant.

Table 4 Regressions with number of telephone lines, ICT or computer prices

	Weighted OLS				
nb Telephone lines t	-0.579 (0.161)***		-0.324 (0.264)		
nb Telephone lines t-1		-0.495 (0.138)***			
ICT equipments price				0.323 (0.054)***	
Computer price					0.108 (0.017)***
Market size	0.558 (0.034)***	0.555 (0.034)***	0.527 (0.043)***	0.223 (0.072)***	0.182 (0.076)***
Trade openness	0.341 (0.142)	0.299 (0.133)***	0.376 (0.145)***	0.433 (0.113)***	0.571 (0.128)***
Investment price	0.277 (0.098)	0.243 (0.092)***	0.315 (0.102)***	-0.075 (0.071)	0.081 (0.069)
GDP per capita			-0.277 (0.223)		
Constant	-2.708 (0.322)***	-2.185 (0.229)***	-0.426 (1.901)	1.22 (0.543)***	0.045 (0.412)
Observations	389	389	389	389	389
R^2	0.783	0.783	0.784	0.798	0.799
F	274.49	274.47	220.24	299.83	303.30

****significant at 1%*
Notes: dependent variable is the average size of firms with 20 employees or more.
Standard errors in parentheses.
All regressions use panel techniques and include industry and country fixed effects.

6.3 Second Sample: France, Germany, UK, USA, 1990-2004

In a second step of our empirical study, we conduct econometric tests using the price of ICT equipments and of computers and a different set of explanatory variables observed at the sector level (3 or 4-digit level) selected following Kumar et al. (1999) and Baumol et al. (2003). We intend to test a reduced form of the model:

$$Size_{j,z,t} = \alpha + \beta_i ICTprice_{j,t} + \gamma Market_{j,z,t} + \delta Wage_{j,z,t} + \upsilon Trade_{j,z,t} + Investment_{j,z,t} + CORRUPTION_{j,t} + \varepsilon_t \quad (2)$$

Market is the log of market size, *Wage* the log of wage per worker, Investment the log of investment per worker, and *Trade* the degree of trade openness. We use a corruption perception index as a measure of the degree of rule enforcement (country wide). We omit *Human capital* given the problem of correlation previously raised[14].

The data set covers 27 sub-sectors of the manufacturing industry, over the period 1990-2004, for France, UK and USA (four years observed) and Germany (three years observed).

Results

We conduct panel weighted 2SLS regressions, with sector fixed effect. The weight is the same as before and the variable *Market* is instrumented using the log of GDP and of population. The Table 5 presents the results of 6 different regressions, each one involving a different set of variables. The second column gives the results of regression (1) of model (2) (all variables included).

The matrix of correlation (not shown here) reveals cross correlation between the variables *investment per worker*, *wage per worker* and *degree of trade openness*. In particular, there is a negative correlation between *Trade openness* and *wage*, consistent with Baumol and al. (2003, p.17) explanations. Low-wage labor abroad exerts a downward pressure on wages and this pressure is stronger in sectors more exposed to trade competition. In order to correct for this collinearity problem, the next four regressions (2-5) consider only one of these three variables at a time. In all the regressions, the estimated coefficients for the variables *ICT price* and *Market size* are positive and strongly significant. They range between 0.135 and 0.242 for the latter variable and between 0.123 and 0.251 for the former. The estimated coefficient for *CORRUPTION* is positive and significant (except for regression (1)). These results are contrary to Beck et al. (2002) predictions. Omitting this variable doesn't affect the results as shown in column (5).

In regression (2), we omit *Investment* and *trade openness*, and the estimated coefficient for *Wage per worker* is positive and significant. In regression (3), we omit *Investment* and *Wage* and find a significant positive correlation between *firm size* and *trade openness*. These two results are contrary to Baumol et al (2003) predictions.

In regression (4), we omit *trade openness* and *wage* and we find a strongly significant negative estimated coefficient for *Investment per worker*[15]. This confirms the assumption of a capital for labor substitution effect that led to downsizing.

In order to check for the robustness of our results, we use the price of computers instead of ICT equipments (actually, computer price enters in Jorgensson's calculation of ICT equipments' price). The results shown in the last column (6) (a positive and significant coefficient for computer price), confirm our previous results. A better access to information, either due to a lower price of ICT equipments or a higher diffusion of these equipments, led to a downsizing of firms in France, Germany, the United Kingdom and the United States. This supports our assumption on the role of information costs in the decision to internalize versus outsource activities.

Our empirical results confirm that *market size* and *investment* (per worker), are also determinant factors in this decision, and consistent with prediction by the theoretical literature. However, our results for *corruption*, *wage per worker* and *trade openness* are contrary to expectations, but must be considered cautiously.

Table 5 Regressions with ICT and computer prices

	Weighted 2SLS					
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
ICT equipments price	0.247 (0.050)***	0.197 (0.048)**	0.186 (0.043)***	0.123 (0.044)***	0.251 (0.038)***	
Computer price						0.067 (0.017)***
Market size	0.184 (0.045)***	0.135 (0.031)***	0.242 (0.038)***	0.199 (0.025)***	0.196 (0.04)***	0.194 (0.045)***
Investment	-0.037 (0.011)***			-0.029 (0.009)***	-0.036 (0.011)***	-0.033 (0.011)***
Trade openness	0.084 (0.055)		0.129 (0.050)***		0.108 (0.042)***	0.094 (0.056)*
Wage	0.353 (0.106)	0.181 (0.093)**			0.386 (0.098)***	0.348 (0.108)***
Corruption	0.106 (0.73)	0.360 (0.115)***	0.255 (0.125)**	0.565 (0.076)***		*0.235* *(0.135)**
Constant	1.613 (0.245)***	2.197 (0.235)***	1.879 (0.261)***	1.742 (0.236)***	1.566 (0.232)***	1.234 (0.237)***
Observations	364	396	397	364	364	364
R^2	0.746	0.702	0.715	0.733	0.745	0.742
F						
Wald khi2	101708.48	93069.31	97739.02	97282.92	101914.66	100258.99

** significant at 10%,** at 5%, *** at 1%*
Notes: dependent variable is the average size of firms with 20 employees or more.
Standard errors in parentheses.
All regressions use panel techniques and include an industry fixed effect.
In 2SLS regressions, market size is instrumented.

We add a country fixed effect and conduct OLS linear regression. Table 6 presents the results which remain robust for the incidence of ICT equipments and computer prices.

Finally, in order to control for some potential correlation problem in the dataset, we use the panel-corrected standard errors procedures. The results, presented in table 7, indicate that our results on the incidence of the prices of computers and ICT equipments remain robust.

Table 6 Regressions with ICT or computer prices, Industry and country fixed effects

	Weighted OLS	
ICT equipments price	0.139 (0.049)***	
Computer price		0.039 (0.016)***
Market size	0.395 (0.078)***	0.451 (0.069)***
Investment	0.096 (0.033)***	0.092 (0.033)***
Trade openness	0.129 (0.065)**	0.126 (0.068°*
Wage	0.043 (0.093)	0.041 (0.097)
Constant	0.321 (0.776)	-0.357 (0.642)
Observations	364	364
R^2	0.837	0.835
F	264.28	261.51

Table 7 Regressions with ICT and computer prices

	linear regression, correlated panels corrected standard errors	
ICT price	0.324 (0.074)***	
Computer price		0.077 (0.032)**
Market size	0.307 (0.035)***	0.426 (0.014)***
Constant	1.424 (0.429)***	-0.043 (0.188)
Observations	397	397
R^2	0.788	0.781
Wald khi2	11988.58	15633.48

6.4 Remarks

A corollary of our theory is that an increasing availability of information should exert a differentiated effect on small and large firms' share of total employment, expanding the share of small firms and contracting that of large ones. We do not however directly test this distortion effect since necessary data are not available throughout the period. But empirical evidence in other work is compatible with our prediction.

In their cross sector study of the US economy, Baumol et al (2003, Figure 1.1) find that downsizing (measured by the average number of employees per firm) did characterize the overall evolution of U.S. Business concern since the end of the 1970s to 1998 (and contrary to the previous trend of continuously increasing size in the 1885 to 1980 period).

That was true also of manufacturing industry at large in the 1958-1992 period, but with an interesting twist that they do not comment upon: the average employment per firm for all manufacturing industries went from 65.5 in 1958 to a peak of 92.6 in 1967, then to 83.5 in 1977, and finally to a low of 65.8 in 1992 (Table 4.3). On the contrary, upsizing occurred in retail and services: "..the overwhelmingly predominant pattern in both retailing and services is upsizing rather than downsizing" in the same 1958-1992 period (p. 105).

However, since the average firm size in manufacturing was large, while in retail and services it was small (for the year 1992, Baumol et al. mention an average number of employees per firm of 66 in manufacturing, 20 in retail trade, 20 in finance, insurance, and real estate, and 17 in selected service industries, op. cit., Figure 3.1) we consider that the differential of increased information on small and large firms that our theory predicts is vindicated by their findings. The small retail and service firms benefited from an increase competitive advantage during the information revolution, while the large industrial firms saw their competitive position eroded, with the corresponding divergent adaptation of their respective sizes.

This interpretation is further confirmed by the Baumol et al. data on the changing distribution of firm sizes within the manufacturing sector (op. cit. Figure 5.4, Size distribution of employment by size of firms in number of employees, 1958 to 1992, p.153). The two categories of smaller firms, 1-19 and 20-99 employees, have been uspsizing from 1977 to 1992, while the largest category of 10,000 employees or more has clearly been downsizing.

We thus consider that available evidence is in favor of our corollary regarding the information induced distortion of the firm size distribution.

7. Conclusion

Using industrial panel data (27 sub-sectors, 3-4 digit on four countries -- France, Germany, UK and USA -- for the 1967 to 2004 period), we test our information based theory of the determinants of firm size. Contrary to extant theories that find an ambiguous effect of information on firm size, depending of the precise characteristics of each innovation (Coase), we derive a general, size reducing effect of an increase on the quantity (and decrease of the cost) of information on average firm size, in accord with Langlois (2003). Our analysis also contradicts the theories that predict a general increase of average firm size (Smith, Lucas) in a growing economy.

Using other determinants of firm size found in the literature as normalizing variables, we show the role of information as a determinant of size and thus as the factor explaining the new downsizing trend that started in the 1970s in industrialized countries and continued in the 1990s, replacing the previous upsizing trend. Specifically, we find that: i) the number of telephone lines per 100 inhabitants has a robust negative and significant effect on average firm size and, ii) that the price of ICT equipments and of computers has a positive and significant impact.

These findings thus support our Coase-Rybczinski theorem. The higher quantity and lower cost of information increased the competitiveness of small firms from the retail and service sectors relatively to the larger firms in the manufacturing sector, leading to an expansion of the former in the economy's total employment.

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Appendix: data description and sources

Country variables

Number of telephone main lines per 100 habitants: World Telecommunication Indicators database from the International Telecom Union. Data range from 1965 to 2004.

Price of computers and of ICT equipments: Dale Jorgenson, at Havard University. Prices are normalized to one in 2000. Data are only available for the USA and are assumed to be good proxies for other countries.

Corruption: Transparency International's Corruption Perception Index (CPI) which is available back to 1996. It is ranking from 1 (high level of corruption) to 10 (low level). For the years 1990 and 1992, we use the corruption index from the Political risk service (PRS, ICRG) and we rescaled. We assume that these two different sources are homogenous enough.

Price level of Investment: Penn World Tables

Degree of Trade Openness: Penn World Tables (exports plus imports divided by GDP)

Human capital: average schooling years in the total population over age 25, from the Barro and Lee's dataset (2000). As the series end in 2000, we estimate values for 2003 or 2004 assuming a linear rate of change since 2000 and similar to the one between 1999 and 2000.

Population: Penn World Tables, thousands

GDP: Penn World Tables. Real GDP, constant prices.

Sector variables

Average size of firms: Monnikhof and van Ark (1996) provide data on the number of enterprises and the level of employment per size class of manufacturing unit. Data range from 1962 until 1990 and for 38 sub-sectors of manufacturing industries at the 3-digit and 4-digit level (ISIC Rev2 classification). For the more recent years, data are from Eurostat (Structural Business Statistics database), classified following the NACE Rev1 codes. We translated them to ISIC codes in order to make comparison across time. For France, data are for 1977, 1990, 1996, 2000 and 2004. For Germany, 1967, 1977, 1990, 2000 and 2004. For the United Kingdom, 1968, 1977, 1990, 1996, 2000 and 2003. For USA, data are from the US Census of manufactures, for the year 1992, 1997, 2000 and 2004. The sectors classified following NAICS 1997 and SIC codes were converted to ISIC codes. The average size of firm is calculated by dividing the number of employees by the number of enterprises, in each sub-sector and considering only units with 20 employees or more.

Market size: The total employment in a 3(4)-digit industry. The construction is the same as above. Data are from Monnikhof and van Ark (1996), Eurostat and the US Census Bureau. Some missing values where completed using the STAN database. For example, in the case of France and Germany, for tobacco and Oil and refineries. The year 1996 for Germany.

Investment per employee: The OECD STAN database contains data on total investment and total employment in each ISIC sector of selected countries. The coverage ranges from 1970 to 2003 but is not uniform. Data on investment are given in current price, in Euro (1999) for France and Germany, in Pound for UK, and Dollar for the US. Figures were adjusted (into constant price) using the corresponding country's Producer Price Index (manufacturing goods) as a deflator (reference year 1999). Finally, all data on investment were converted in US dollar, using the 1999 exchange rate taken from the Economic report to the US president. Investment per worker is obtained by dividing the total investment in a manufacturing sector by the total number of employees in that sector, that year. When data was not available at the 3 (or 4) digit level, we took the corresponding one at the 2 (or 3) digit level.

Wage per employee: The OECD STAN database provides data on total labor compensation and the total number of employees per sector. The construction is as above, using the Consumer Price Index (OECD statistics). Data for France are only until 2002.

Degree of Trade Openness: Sum of exports plus imports over production. Sector data on total imports, exports and production are from the STAN database.

Notes

[1] See Chandler (1962, 1990) and Schmitz (1993).

[2] Piore and Sabel (1984).

[3] Markides (1996) summarizes the argument in favor of refocusing.

[4] See also Rajan and Zingales (2003) on the "great reversals" of the century, and Rosa (2006), on the broad reversal for all kinds of hierarchical organizations, including political ones, during the "second twentieth century" (1975-2000).

[5] They obtain these observations for industry using alternatively data from the US bureau of the census and the Standard & Poor's COMPUSTAT database.

[6] Dosi et al. (2008) observe an opposite trend in the case of the US, based on data from the US Census. Small firms' share in total manufacturing employment decreased between 1972 and 1997 (and even 2003) whereas the share of the largest firms increased. They make a similar observation for Japan between 1975 and 1990. An explanation may lay in the data that are from the OECD STAN database. For Japan, the distribution of manufacturing employment is given by size-classes of establishments, not of firms (Monnikhof and Van Ark, 1996). The upsizing of the largest establishments can coexist with the downsizing of the largest firms if the former have fewer but larger establishments.

[7] As explained by Stigler "the survivor technique proceeds to solve the problem of determining the optimum firm size as follows: Classify the firms in an industry by size, and calculate the share of industry output coming from each class over time. If the share of a given class falls, it is relatively inefficient, and in general is more inefficient the more rapidly the share falls" (Stigler, 1958).

[8] Kumar et al. (1999) test international and sector differences in firm size in 1991 or 1992. They conclude that "countries that have better institutional development, as measured by the efficiency of their judicial system, have larger firms" (op. cit. p. 22). It is a bit difficult, however, to claim that the French, British, German and Us judicial systems have underwent a complete overhaul in the 1970s which changed the evolutionary trend of firm sizes. A similar remark can be raised on Beck et al. (2002) who underline the incidence of corruption but in a cross section perspective.

[9] Baumol and al. (2003, p.260) consider that decrease of demand for industrial products explains downsizing in the manufacturing sector in the short run, but in the long run, this is technology. Kumar et al. (1999) find empirically that market size explains positively and significantly firms' size, but this is in a cross-industry and cross-country perspective, and for a single year

[10] Dosi et al. (2008) suggest on the contrary that the ICT revolution, rather than leading to increased coordination through markets, has led to greater organizational complexity, requiring firms to engage in more organizational interaction as opposed to market interactions.

[11] The following model is adapted from the Rybczinski theorem demonstration in Dixit Norman (1998, p.11-13).

[12] This measure enables us to observe the evolution of the average size of firms within sub-sectors, but note that this variation may result from simultaneous changes in the number and size of large firms and in the number and size of small ones as revealed in section 2). Due to data limitations, we were not able to decompose and observe such variations over the entire period.

[13] They find empirically that only the judicial efficiency has a clear correlation with firm size (Kumar et al. (1999, p23).

[14] The problem may be significant between human capital and wages as it is well known that larger firms pay higher wages (Oi and Idson, 1999a and 1999b) and thus hire higher human capital employees.

[15] This result is robust when we consider investment per worker with various lags: t-1, t-2, t-3 and t-4.