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The Shrinking Hand: Why Information Technology Leads to Smaller Firms

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Abstract

We explain the firm downsizing trend of the recent decades by the new abundance of information – the ICT revolution. Production processes differ in their information requirements: while decentralized production by means of market exchanges is information-intensive, less information per unit of output is needed in the hierarchically integrated production of firms, and the information/output ratio is decreasing in firm size.

We formulate a quantity of information theory of the firm embodying these differences and derive a Coase-Rybczinski effect for the aggregate economy, which predicts a decreasing employment share of large firms and an increasing share of small ones when the aggregate quantity of information increases. Panel data regressions and other evidence provide support for this hypothesis.

Key Words: Firm Size; Downsizing; Information Technology.

JEL classifications: D23, G30, K40, L20.

> "There is some debate about whether IT will, over the long run, lead to larger or smaller firms. It is too early to have a clear answer on this question, but we can discuss a few likely effects." (Lazear and Gibbs 2009, p.218).

1. Introduction

1.1 The rise and decline of the visible hand

For most of its course, the twentieth century has seen the triumph of the Chandlerian Visible Hand of the large corporation, over the Invisible Hand of the market, and more generally the continuous rise of all hierarchical institutions, whether private firms or public bureaucracies. However, at the very time when Chandler (1977) celebrated the triumph of the giant firm and the managerial economy, new forces were actually reversing the previous trend and hierarchies were fragmenting, replaced by smaller ones and more market transactions.[1]

The "first twentieth century", 1875-1975, during which hierarchies kept increasing in size, is thus followed, since the mid-1970s, by a "second twentieth century", characterized by contracting hierarchies and expanding markets, according to a trend that is spilling over the first decade of the twenty-first (Rosa, 2006).[2] The first organizational revolution was due, according to Chandler, to a major increase of firms' throughput. That rapid increase in the rate of production created a control problem (Beniger, 1986) as far as production growth was not matched by a comparable growth of information, required for coordinating these enormous new production and distribution flows. The higher throughput rate was obtained by recourse to larger managerial hierarchies, a traditional information-saving device (Coase, 1937;

[1] See the references in Brynjolfsson et al. (1994). The smaller firm size is but one aspect of the organizational revolution, alongside the vanishing of conglomerates, a shift to outsourcing, and less well defined firm structures and blurred boundaries such as those of network firms.

[2] Greenwood and Yorukoglu (1997), and Jovanovic and Rousseau (2005) justify the date of 1974 as the beginning of the IT revolution.

Beniger, 1986).[3] Hierarchical organizational structures reduce communication costs because they minimize the number of communication links required to connect multiple economic actors, as compared with decentralized structures (Malone 1987; Radner 1993). In this perspective the second organizational revolution of the last quarter century – the anti-chandlerian revolution – is due to the new abundance of information, not simply in absolute level, but relative to the increase of production flows. This "relative information" hypothesis is capable to explain both organizational revolutions: the Chandlerian one of the beginning of the first twentieth century, as well as the current anti-Chandlerian one of the beginning of the second twentieth century. Production should be integrated into larger hierarchies when information is becoming relatively scarce, while it can be decentralized in smaller firms and more market transactions when information becomes relatively abundant, as further explained below.

The current organizational era is not so much defined by a Vanishing Hand, as Langlois (2003) claims, since firms are not disappearing altogether in the process, but on the contrary multiply as they become smaller. This new trend is more aptly defined as ushering industrial organization into a "Shrinking Hand" or "Shrinking Hierarchies" era.

Two main explanations of that organizational revolution are suggested in the literature and presently dominate the field: the IT hypothesis, and the market expansion-firm specialization hypothesis.

1.1.1 The IT hypothesis

It is well understood since Coase (1937) that the *raison d'être* of the firm is to substitute a centralized decision-making mechanism to a high transaction cost market mechanism. Since

[3] See also posterior literature modeling both firms and markets as information processing entities (Arrow, 1973; Galbraith, 1977; Hayek, 1945).

information costs are a large part of transaction costs, a new abundance of information should expand markets and contract firms. Indeed, Brynjolfsson et al. (1994) note that the organizational and the informational revolutions happened simultaneously,[4] and Brynjolfsson and Hitt (2000, p. 24) conveniently summarize the hypothesis:

"The fundamental economic role of computers becomes clearer if one thinks about organizations and markets as information processors (Galbraith, 1977; Simon, 1976; Hayek, 1945). Most of our institutions and intuitions emerged in an era of relatively high communications cost and limited computational capability. Information technology, defined as computers as well as related digital communications technology, has the broad power to reduce the costs of coordination, communications, and information processing. Thus, it is not surprising that the massive reduction in computing and communications costs has engendered a substantial restructuring of the economy. The majority of modern industries are being significantly affected by computerization."

But Brynjolfsson et al. (1994) acknowledge, in line with Coase (1937), that most inventions will change both the costs of managing and the cost of using the price mechanism. Whether the invention tends to make firms larger or smaller will depend on its 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 managing, then it will have the effect of reducing firm size and vice versa if it reduces the cost of managing more. It follows that the evolution of firm size becomes a priori indeterminate with respect to information technology in general. It all depends on the specific characteristics of each information-augmenting technology.

In that case, no general rule can link the abundance of information to the choice of one process over the other, and thus to the determination of average firm size, and a case by case analysis of each specific technological innovation is required. Thus, "a better understanding of the theory of the firm and a more formal theory of the relationship between IT and firm structure are needed for more definitive hypothesis testing"(Brynjolfsson et al. 1994, p. 1643).

They further note that: "our finding that IT is related to the decline in firm size may shed light on another aspect of the current restructuring of the Western economies: the recently-discovered benefits of "focus" by firms".
"Because diversification is typically modeled as a response to market failures, it would be interesting to assess whether IT has helped enable the emerging strategy of increased focus by increasing the relative efficiency of products and capital markets."

Another shortcoming of the current IT hypothesis is that although it recognizes that many of the past century's most successful organizational practices reflect the historically high cost of information processing, it does not try to explain the first organizational revolution that favored the growth of giant firms, despite the fact that information innovations were not scarce (the telegraph, telephone, radio). These information technologies then had apparently an effect on firm size diametrically opposed to that of recent IT innovations.

The difficulty of finding a common explanation for the two opposite organizational revolutions is what motivates, in part, the efforts of the market-expansion theorists, notably Langlois (2003), and Lamoreaux, Raff and Temin (2002).

1.1.2 The market expansion-firm specialization hypothesis

Langlois (2003) broadens the picture of the "substantial organizational change" of the recent IT revolution by extending the analysis to "first market revolution" of the end of the nineteenth century. On his reading of Chandler, the Visible Hand is the response of business institutions to the dramatic increases in population and per capita income in the US after the civil war, coupled with the equally dramatic fall in transportation and transaction costs attendant on the railroad, the inland water network, and the telegraph. These changes required a better coordination of flows, obtained by vertical and lateral integration.

Regarding the second "market revolution" – the present one – he notes that it is precisely "an *unmaking* of Chandler's revolution, (…) a dramatic increase in vertical specialization – a thoroughgoing "de-verticalization".

His basic argument relies on increases in population and in income and on the reduction of technological and legal barriers to trade, which drive to the Smithian process of the division of labor, always leading to finer specialization of function and increased coordination through markets, much as Allyn Young (1928) claimed long ago"

The problem here is that a same broadening of markets and falling costs of transport and communication, which determined hierarchical integration by the end of the nineteenth century, entailed, at the end of the twentieth century, exactly opposite consequences: shrinking firms. Langlois tries to solve this inconsistency by arguing that the latter, downsizing, trend is explained by "new institutions" growing out of "thick markets" that reduce the costs of exchange.

This however is more a description or a narrative than a non ambiguous explanation based on theory. As is the case for the IT hypothesis, a same technological change apparently can in one case determine a larger firm size, and in another context cause a smaller one.

Lamoreaux, Raff and Temin (2002, p.56) are well aware of that difficulty. They observe that since the early nineteenth century, the decline in transportation and communication costs has been almost continuous, induced notably by the development of railroad and telegraph during the first market revolution, and by the computer era during the second market revolution. Despite this unidirectional and almost linear trend, the degree of hierarchical organization has followed a hump-shaped pattern over time.

Their explanation relies on the expansion of the market which consists of two components, the geographical extent of the market, and income per capita, i.e. the extensive and the intensive margins of the market size, which both impact the location and organization of firms. They suggest that when transportation costs are high, activity is local and consequently small in scale. When these costs decline, production can be concentrated in specific location and in larger firms. In addition, consumers' preferences also affect firms' size and organization. Poor consumers demand basic, standard goods, and focus on price. Rising per capita income shift the demand towards diversified goods, which (somehow) imply greater firm specialization and outsourcing, substituting long term relationships for vertical and lateral integration. The hypothesis is plausible but unproven and the authors do not develop a theory of the firm to comfort their assertion.

To sum up, both hypotheses suffer from serious weaknesses. They fall short of explaining, within a same theoretical framework, the Chandlerian and the anti-Chandlerian organizational revolutions. They are dissimilar, however, in their respective theoretical strength.

While the IT hypothesis is basically ambiguous with regard to the impact of information on the comparative costs of managing and of market exchanges, it is nevertheless based on a generally accepted, Coasian, theory of the firm.

On the other hand, the market expansion- firm specialization hypothesis neglects the fact that market expansion is endogenous with respect to transaction (transport and information) costs. It is thus difficult to consider market size as an independent explanatory factor.[5] Moreover, the link between market size and firm size is weak in theory: The market size may not be the principal constraining factor on firm specialization (Becker and Murphy, 1992) and moreover firm specialization could lead to larger as well as to a smaller firm size (Baumol et al, 2003)[6]. Even more damaging to the hypothesis, a thorough analysis of firm size dynamics in a general equilibrium model, as developed by Lucas (1978), even concludes that the average firm size should increase with per capita income, contrary to the conclusion of the market expansion theory. And the Lucas proposition is comforted by his empirical tests on the period up to the mid-1970s.

Given that asymmetry in the theoretical foundations of the two hypotheses, we conclude that a research strategy trying to further develop the IT hypothesis in order to obtain unambiguous conclusions regarding the impact of an increase of information innovations on firm size is more promising. It should also be capable of explaining both the increasing firm

[5] Oliner and Sichel (2000) indeed show that increased growth rate of the 1990, and therefore worldwide expansion of the economy and markets-globalization, are a result of ICT, not an independent cause.

size of the first organizational revolution, and the decreasing firm size of the send one, as we suggest below.[7]

In the next section, we present evidence on the existence of a general trend towards smaller firm size. In the third section, we develop a quantity of information theory of firm size that can account for the two organizational reversals and contrasting eras of the Visible Hand and of the Shrinking Hand, while the main causal factors, information and market expansion, both proceeded in a same direction throughout the period. We show that what matters is not the detail of information asymmetries in various contracts (the Williamson specific assets problem) nor the relative effect of information on the costs of managing and costs of markets, but the evolution of the overall quantity of information available in the economy, relative to production levels. This is because information is a factor in the production of management, and management is a club good that is also a factor of production of the firm. When information cost falls, the cost of managing falls, and small firms, which are relatively management-intensive compared to large ones, become more competitive relative to the latter. The fourth section presents a formal model of that theory.

In the fifth section, we find empirical support for our theory using an international and cross sectors panel of the size distribution of firms. The last section presents our conclusions.

2. The evidence on shrinking firm size

There is a large but disparate literature on whether a shrinking in the average size of firms occurred during the last decades (Piore and Sabel, 1984; OECD, 1985; Sengenberger,

[7] In this paper, we concentrate the analysis on firm size, as the variable to be explained, because it is linked to other organizational changes (vertical and lateral disintegration, refocusing, re-specialization, outsourcing, substitution of computers to labor, vanishing conglomerates, substitution of long term contractual relationships to hierarchical relationships), and because of data availability.

Loveman and Piore, 1990; Lichtenberg, 1990; Monnikhof, and van Ark, 1996; Feenstra, 1998; Baldwin, Jarmin, and Tang, 2002, Trau, 2003). It is generally concluding to the reality of that effect, but relying on older data or data with a limited coverage in terms of sector or geographical scope.[8] We use in this paper a broader and more up to date database. Accordingly, it is necessary to check first the persistence of the previously observed trend of shrinking firm size in our broadened sample.

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. The size is measured as the number of employees. 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.[9]

Figure 1. Average number of employees for firms with 20 employees or more
(All manufacturing industry)

[insert here]

Table 1 presents the results of a test of differences in mean size between the two periods 1962-1977 and 1990-2004, for 27 sub-sectors of the manufacturing industries (ISIC 3

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[8] Baumol et al. (2003, p. 1) find mixed evidences for the US services sectors with upsizing as well as downsizing. Dosi et al. (2008) observe downsizing in Europe but not in the case of the US, where 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. Note however that these results suffer from a bias in the data.. For Japan, the distribution of manufacturing employment is given by size-classes of establishments, not of firms (cf. 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. There is a similar problem with their data on US.

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

and 4-digit levels) of France, Germany and United Kingdom. The results confirm the trend. The p-values reported at the bottom of the table indicate that we can reject the hypothesis that average firms size in the period 1962-1977 was lower than in the period 1990-2004.

Table 1. Test of differences in mean size, across periods, Fr, Ger, UK.

[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)

[insert here]

Since the mid 1970s, 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 2). 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 2. Evolution in the number and in the average size of firms, per class of size

[insert here]

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.

This begs the question of which are the determinants of firm size that can explain that "great organizational reversal" of the late twentieth century, relative to the previous Chandlerian era of large firm dominance since the late nineteenth century.

3. A quantity of information theory of firm size

The theory that we propose includes a determining role for information, in conformity with the Coasian framework, as far as the more obvious of the transaction costs that determine the choice between the market (the price mechanism) and the hierarchical coordination by firms, is the cost of "discovering what the relevant prices are" (Coase 1937, section 3) that is, the cost of information.[10] This theory rests on a series of key assumption:

1. The manager is the firm's ultimate fixed factor of production. He produces "management", i.e. coordination, with his own information as the main input in that production. With no information, there is no management, and therefore, no production.

2. He transforms his private information about the environment into a "club good" within the firm, a service that can be applied to various production levels through the issuance of orders and their duplication down the hierarchical pyramid levels. Indeed, 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 transmitted to his subordinates, whatever their number. Each subordinate combines the information he receives from his immediate superior (and thus indirectly from the top manager) with his own competence, to produce directives for his own subordinates in a Rosen-type cascade multiplying the efficiency of subordinates by that of the manager (Rosen 1982). This is made possible by virtue of the costless duplication

[10] A more developed and explicit analysis is presented in Rosa (2000, 2006).

of information and instructions within the firm (Rosa, 2006), or by the "reuse" of information (Langlois 2003).

3. Firms of various sizes operating in a same sector need about the same amount of information on their business environment, the consumers, the labor force, and the intermediate product suppliers. As a consequence, smaller firms are more information-intensive than larger ones, because they have to spread this information cost on smaller outputs. Their information/output ratio is higher.

4. Moreover, for a given level of overall production, smaller, more specialized firms rely more on market exchanges, because markets and firms are rival modes of production (Coase 1937). Thus an additional need for information is generated in an economy of small firms. The market (decentralized) mode of production relies on more transactions than the hierarchical mode. The latter, as noted by Coase, replaces a large number of bilateral contracts between individual suppliers of inputs and other producers by a smaller number of contracts between of few in-house suppliers and a central party, the entrepreneur or manager in order to reduce transaction costs.

5. Since smaller firms are more information-intensive, the fall of the cost of information makes them more competitive vis-à-vis larger ones.[11] By the Rybczinski theorem, the "sector" of small firms using more of the now cheaper factor (information) grows, whereas the "sector" of large firms, using less of it, contracts. A "Coase-Rybczinski" theorem thus obtains that explains the evolution of organizations (Rosa, 2006, p. 243). Moreover, 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 for a higher cost of information. There is thus both a number of firms, and a size of firms, effect of

[11] There are, of course, other determinants of differences in firm sizes. Lucas (1978) explains the size distribution by the distribution of managerial talent in the population, the most talented entrepreneurs managing the larger firms. Rosen (1982) develops a model of the internal economics of such a firm in which the talent (human capital) of the top manager enhances that of intermediate managers at each hierarchical level. More talented managers enhance the efficiency of intermediate managers more than les talented ones do.

the organizational change. A reduction of transaction (information) costs thus exerts a differential effect on different size classes of firm, not a uniform one across all classes.

6. As the cost of information fell by 99.9 percent since the inception of the IT revolution (Jovanovic and Rousseau, 2005)[12], the competitive advantage of smaller firms has been growing considerably, and this explains a large shift in the size distribution of firms. Smaller firms are thus able to multiply and attract employees from the large firms. The figure 3 shows the continuous and important decline in the relative price of ICT equipments in the US over the period 1967-2004.

Figure 3. Relative price of ICT equipments 1967-2004, USA

[insert here]

To sum up, one may conclude that the overall quantity of information has a non ambiguous negative effect on centralization and firm size. For a given overall production level, an increased quantity of information increases the competitive advantage of smaller, information-intensive, firms. A decrease of information availability (increasing transaction costs) increases the competitive advantage of larger firms. This is also true of a growing production economy: increasing production flows require an increased use of information (the Chandler story regarding the last quarter of the XIXth century). If the availability of information does not increase in step with the production level, hierarchies will expand to mitigate the increasing cost of the information factor. On the contrary they will shrink if information expands more rapidly than production.

As a corollary, this theory can explain the Chandlerian revolution. The information availability grew, due to innovations such as the telegraph, telephone, typewriter, and other

[12] They underscore the extraordinary decline in computer prices since 1960 (up to the end of the 1990s) compared to earlier technologies. While the electricity and the automobile indexes fall by a factor of 10, the computer index falls by a factor of 10.000.

(Beniger, 1986), but at a lesser rate than production did, thus raising the relative scarcity of information and its relative cost, and leading to an increased optimal firm size (giant diversified corporations, trusts, conglomerates). On the contrary, the recent ICT revolution has increased the quantity, and decreased the cost, of information much more than it raised output. The growing information/output ratio led to a shrinking of the visible hand and the return of the invisible hand.

Thus a same theory explains both organizational revolutions. 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 (or increase) of the sizes of all firms.

The key to this result is that instead of focusing attention on the differential impact of each IT innovation on the costs of market exchanges and on that of managing, we concentrate the analysis on the differential information factor intensiveness of smaller and larger firms, and hence on the Coase-Rybczinski effect of the increasing relative abundance of information. Some more precision in the model can be obtained from a formal presentation.

4. 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.

4.1 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:

$\frac{\partial \pi_j}{\partial z} = i_j$ 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.

4.2 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 $X_k = f(n_k)$, $\dfrac{\partial X_k}{n_k} > 0$ and $n_k = f^{-1}(X_k)$ and $\dfrac{\partial n_k}{\partial X_k} > 0$.

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:[13]

$$L = X_s l_s + X_b l_b$$

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

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:

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

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

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

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 expand, all characteristic evolutions of the recent decades that other theories do not explain.

5. Empirical tests

The above theory purports to unambiguously explain both historical periods of “expanding visible hand” and of “shrinking hand” by the changing relative availability of information in production. While it is symmetric and should be tested simultaneously on both periods, obviously adequate data are not available for the “chandlerian era”, first for lack of a well developed data collection apparatus, and second because the evolution of the various information augmenting innovations has not been recorded in long term series of prices and quantities.

We thus have to test the theory on the current information revolution era only. Given, however, the symmetry of the theory we feel that if the results vindicate our hypothesis for this truncated sample, they should also validate the theory for both the expanding and the shrinking hand cases.

5.1 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 (ISIC 3 and 4-digit levels). Until 1990, data are from Monnikhof and van Ark (1996). For the more recent years, data are from Eurostat (Structural Business Statistics database). 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. As the various sources use different classifications (NAICS, NACE, ISIC rev. 2), all data were converted to the same standard classification ISIC.

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. Data are taken from the *World Telecommunication Indicators* database (International Telecom Union) and they range from 1965 to 2004. Second, we use Jorgensson’s (2001) long term series on prices of ICT equipments and of computers. ICT

Prices are taken relative to US GDP price and both are normalized to one in 2000. Similarly, we consider the relative price of computers as the ratio between computer prices and GDP prices. Data are only available for the USA and are assumed to be good proxies for other countries. We expect a positive correlation between these prices estimates and firm size, as a lower price of ICT equipments would foster access to information. But we feel that the relative price of ICT equipments, a broader variable than the relative price of computers (see the definition of these variables in Jorgenson 2001), is much more relevant as a proxy for the price and availability of information.

Due to data availability, our empirical analysis proceeds in two steps corresponding to two 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 more sector level explanatory variables. As we use data at the sector level, for several countries and for several years, we conduct panel estimations.

5.2 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 (relative 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:

$$Size_{j,z,t} = \alpha + \beta_i ICT_{j,t-i} + \gamma Market_{j,z,t} + \rho INV_{j,t} + \delta HUMCAP_{j,t} + \mu TRADE_{j,t} + \varepsilon_t \quad (4)$$

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 relative to GDP price, 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*. Data are from the same source as for firms' size, except that some missing values were completed using the OECD STAN database. This is the case of France and Germany, for tobacco and Oil and refineries, and the year 1996 for Germany. $HUMCAP_{j,t}$ is the average schooling years of population aged over 25, taken from the Barro ad Lee's (2000) dataset. It is used 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. Data are from Penn World Tables. $TRADE_{j,t}$ is the degree of trade openness of country *j* at period *t*, (exports plus imports divided by GDP) and data are from the Penn World Tables. It is used as an indicator of foreign competition that leads to downsizing according to Brynjolfsson et al. (1994) and to Baumol et al. (2003). Finally, ε_t is 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. The table 3a presents the correlation matrix for these variables.

Table 3a. Correlation matrix. First sample: Fr, Ger, UK, 1967-2004

[insert here]

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. (1994), 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.

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 real GDP, both taken from the Penn World Tables, and we conduct weighted Instrumental Variable (IV) regressions.

In what follows, we present the results of OLS and then IV regressions, using the diffusion of telephone lines and the relative prices of ICT equipments and of computers as alternative explanatory variables.

Results

The Table 4 presents the results of weighted OLS regressions with sector fixed effect. The first four columns correspond to specification of the model using the *number of main telephone lines* as explanatory variable. The first one reports results of the full model. The estimated coefficients for *trade openness* and *human capital* are not significant. The correlation matrix (Table 3a) reveals that these two variables are strongly and significantly correlated together and with our measures of ICT prices and level of equipment. For this reason, we exclude these two variables from the next regressions.

The next three columns differ with the year (*t, t-1, t-2*) at which the variable *number of telephone line* 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 and strongly significant estimates for *Market* size are conform to a scale effect as suggested by Kumar et al (1999) and Baumol et al. (2003). However, this contradicts the theoretical predictions by Lamoreaux, Raff and Temin (2002). 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 columns (5) and (6) present 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.

We introduce a country fixed effect in the analysis in order 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.[14] The columns (7), (8) and (9) of table 4 indicate de result of linear OLS regressions with the number of telephone lines, ICT and computer prices as alternative exogenous variables. The results remain the same.

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

In a test, not shown here, 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. This variable is strongly correlated with our measures of ICT prices and level of equipment.

Table 4. Effect of ICT equipments and prices on firm size, Fr, Ger, 1967-2004,

OLS estimates

[insert here]

The table 5 presents the results of IV regressions and they confirm our previous results. At the bottom of this table, we report a series of tests of underidentification, of the relevance and weakness of instruments, and of overidentifying restrictions. They always lead us to consider our instruments as valid and robust.

The US relative prices of ICT equipments have been decreasing continuously since the late 1960s as shown on figure 3. This decline was even more pronounced in the case of the relative price of computers (Jorgenson, 2001). As we take these US prices as explanatory variables for the four countries of our sample, they may act as trends. In order to turn this problem, we have introduced a trend that is likely to capture this effect. Results are presented on Table 4, columns (10) and (11) for OLS regressions, and on Table 5, columns (6), (7) and (8) for IV regressions. They indicate that ours previous results are robust to the inclusion of a trend.

Table 5. Effect of ICT equipments and prices on firm size, Fr, Ger, UK, 1967-2004,

IV estimates

[insert here]

5.3 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, relative to GDP, 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). This enables us to improve the specification of the model. We intend to test a reduced form of the model:

$$Size_{j,z,t} = \alpha + \beta_i ICTprice_{j,t} + \gamma Market_{j,z,t} + \delta Wage_{j,z,t} + \upsilon Trade_{j,z,t} + Investment_{j,z,t} + CORRUPTION_{j,t} + \varepsilon_t \quad (5)$$

Wage is the log of wage per worker and *Investment* is the log of investment per worker. Data are from the OECD STAN database and were deflated using respectively the Producer Price Index (manufacturing goods, reference year 1999) and the Consumer Price Index. All values were converted into US dollars.[15] We use a corruption perception index as a measure of the degree of rule enforcement in a country, as it might affect firms' size as suggested by Beck et al. (2002). It is from Transparency International and 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.

We omit *Human capital* given the problem of correlation previously raised.[16] Only the price of ICT equipments and the corruption index are observed at the country level, whereas all the others are sector-level.

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[15] When data were not available at the 3 (or 4) digit level, we took the corresponding one at the 2 (or 3) digit level.
[16] 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.

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). The table 3b presents the correlation matrix for these variables.

Table 3b. Correlation matrix. Second sample: Fr, Ger, UK, USA, 1990-2004

[insert here]

<u>*Results*</u>

We test the relation (5) with OLS and then IV regressions, with sector fixed effect. We use the same weight as before and the variable *Market* is instrumented using the log of GDP and of the squared population. The table 6 presents the results. Here again, we find positive and strongly significant estimates for the explanatory variables price of ICT equipments and price of computers, with both OLS regressions, columns (1) and (2), and IV regressions, columns (5) and (6), as predicted by our theoretical assumption. These results are robust to the inclusion of a trend in the case of the relative price of ICT equipments (columns (3) and (7)) but not for the relative price of computers as shown by columns (4) and (8).

Our empirical results confirm that *market size* is also a determinant factor in this decision, and consistent with prediction by the theoretical literature. However, our results for *investment per worker, wage*, *trade openness* and *corruption* are not always significant in both OLS and IV regressions, and should be considered cautiously. In addition, the correlation matrix (table 3b) reveals cross correlation between explanatory variables, including in particular *wage, trade openness* and *corruption*.

Table 6. Effect of ICT and computer prices effect on firm size, Fr, Ger, UK, USA 1990-2004, OLS and IV estimates

[insert here]

We have conducted Wooldridge (2002) test of autocorrelation in panel data for the two samples, and in each case, the *F*-statistics leads us to reject the null hypothesis of no serial correlation (see table 7).

Table 7. Wooldridge test of autocorrelation in panel data

[insert here]

Given this diagnostic, we have conducted additional regressions with correlated panel corrected standard errors, and excluding the correlated explanatory variables. The results are presented on columns (12)-(14) of table 4 and on columns (9) and (10) of table 6. They confirm the robustness of our results.[17]

Finally, a series of tests conducted at the sector level, not shown here but available from the authors, confirm our result. They should nonetheless been consider cautiously as far as, for each test, the sample size was small.

Our empirical tests, conducted on two samples and with various variables, confirm that a better access to information, due to a lower price of ICT equipments and of computers, 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.

[17] Note however that one way to correct for serial correlation is to adopt a dynamic structure for the panel data (i.e. introducing lagged dependent variable as explanatory). We were not able to do this because of insufficient observations.

6. Conclusion

The contracting firm size and organizational revolution of the last few decades, the new Shrinking Hand era replacing the former Chandlerian one of growing dominance of the Visible Hand, has eluded a clear explanation in the literature. The main theoretical hypotheses about the causing factors – whether the progress of information technology increasing the efficiency advantage of markets over firms (depending on specific innovations in information technology), or the unidirectional increase of income and population allowing an increased specialization of firms and an increasing consumer demand for more diversified products, thus leading to shrinking equilibrium firm size – run into serious difficulties. Their predictions are theoretically ambiguous, and they do not account for the overall evolution of rise and decline of the visible hand over the course of the twentieth century. As noted by Lamoreaux, Raff and Temin 2002), the hump shaped trajectory of organizational centralization (and firm size) – due to the two successive organizational revolutions of respectively the late nineteenth and late twentieth century – cannot be explained in terms of the unidirectional increase of income per capita and population, nor by the details and specificities of the various technological innovations that all contributed to decrease the cost of information and communication, that have characterized the modern period since the late nineteenth century.

We have presented in this paper a solution to the conundrum relying on a quantity of information theory of firm size in which the relative growth of information and output is the key determinant of the competitive advantage of smaller, information intensive firms, over larger firms that use information more sparingly.

We thus bypass the need to consider the precise impacts of transaction costs reducing innovations on both markets and firms (Coase 1937), to derive a general, size reducing effect of an increase of the quantity (and decrease of the cost) of information on average firm size.

Our analysis does not rely on auxiliary and contestable hypotheses regarding new institutions that could have increased the markets' efficiency (Langlois 2003), or about the effects of market expansion on firm specialization and size, or on consumers' demand for diversified products beyond a specific but unspecified threshold (Lamoreaux, Raff and Temin 2002). It explains also why the Lucas theory that predicted a general increase of average firm size in a growing income per capita economy has been disproved by ulterior, post 1970s, evolution.

Using industrial panel data on firm sizes on four countries – France, Germany, UK and USA – for the 1967 to 2004 period, we test our information growth hypothesis as a major determinant of firm size, also including other determinants found in the literature as normalizing variables.

Our findings give support to our quantity of information theory of the firm as expressed in a "Coase-Rybczinski theorem" of organizational choice and evolution. The higher quantity and dramatic fall of the cost of information resulting from the IT revolution increases the competitiveness of small firms relative to the larger established firms, leading to an expansion of the former's share in the economy's total employment.

Moreover, 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 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. This interpretation is further confirmed, particularly, by the Baumol et al. (2003) data on the changing distribution of firm sizes within the manufacturing sector. They show that the two categories of smaller firms, those enrolling 1-19 and 20-99 employees, have been upsizing from 1977 to 1992, while the largest size category of 10,000 employees or more has clearly been downsizing.

We therefore conclude that the overall degree of centralization of production, as well as the first (Visible Hand) and the second (Shrinking Hand) organizational revolutions, can be explained by the changing relative abundance of information.

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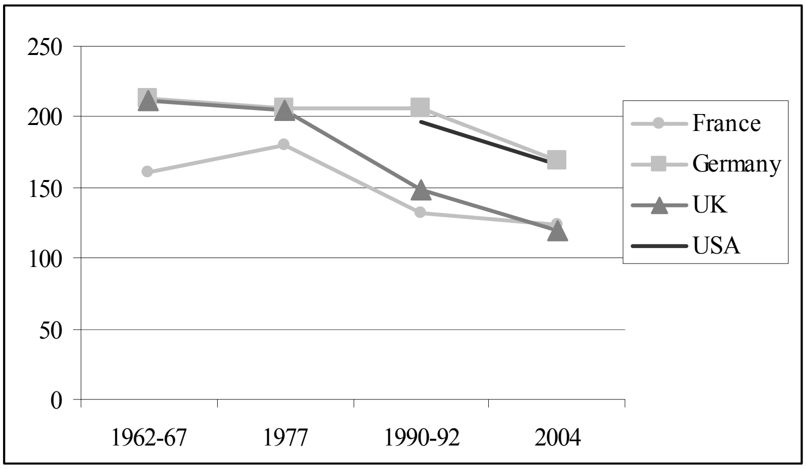
Figure 1. Average number of employees for firms with 20 employees or more

(All manufacturing industry)



Sources: Monnikhof and van Ark (1996), Eurostat and US Census of manufactures.

Figures 2a, 2b, 2c, 2d. Average number of employees (Firms with 20 employees or more)

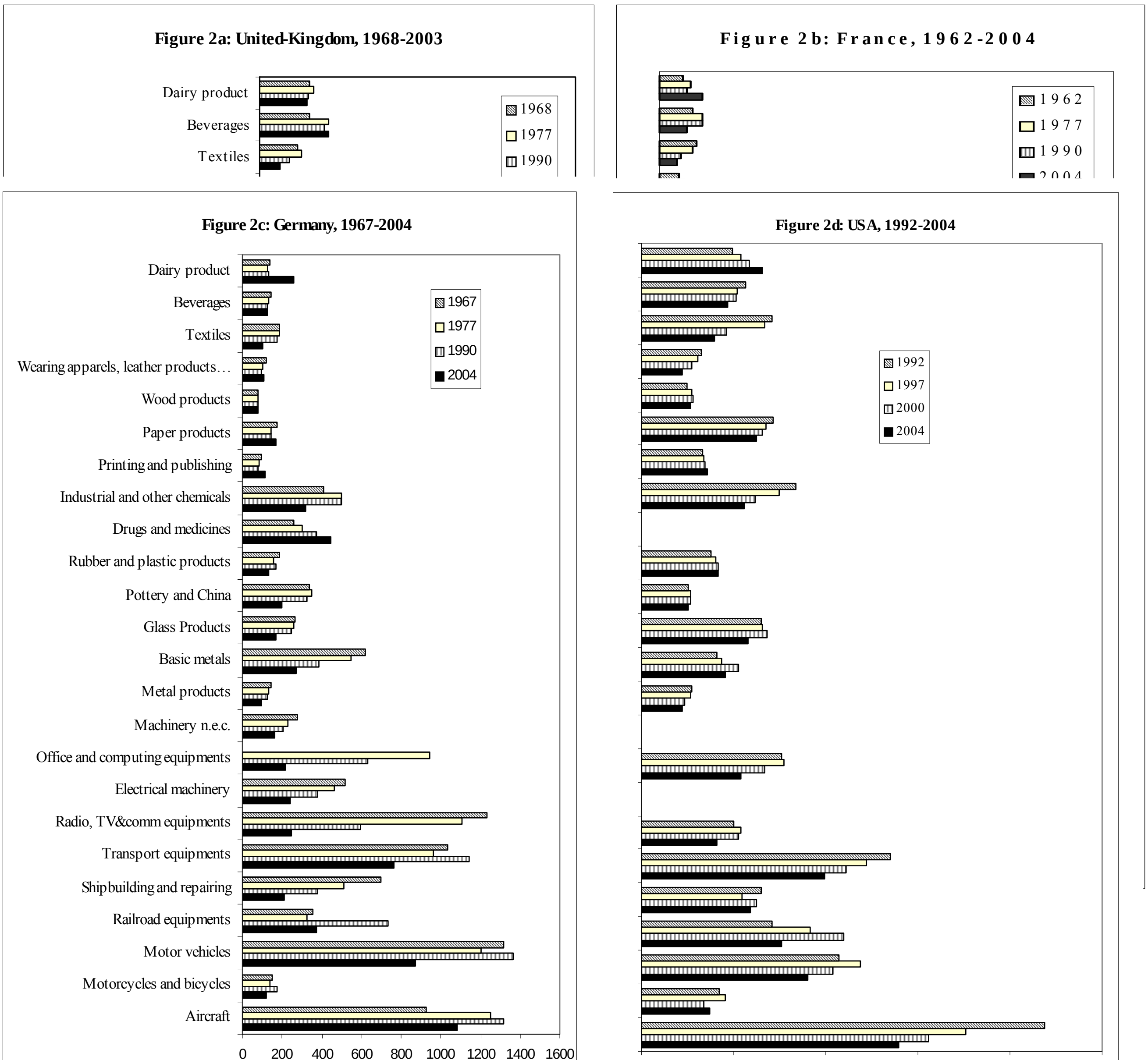
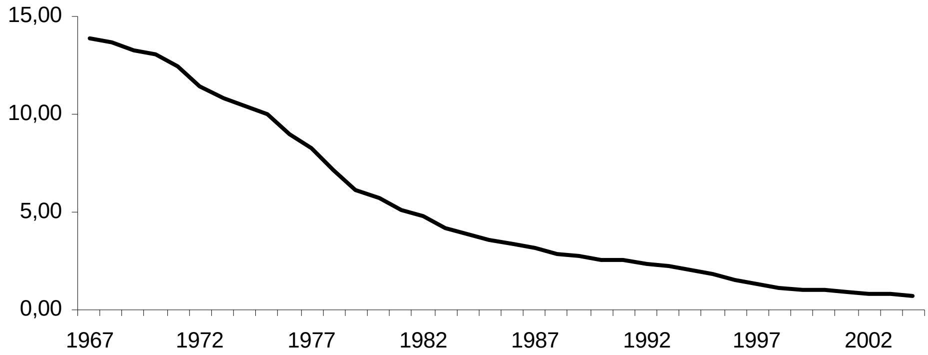


Figure 3. Relative price of ICT equipments 1967-2004, USA



Source: Jorgenson (2001)

Table 1. Test of differences in mean size, across periods, Fr, Ger, UK.

Period	Groups	Number of observations	Mean	Std. Err.
1990-2004	0	289	266.76	13.86
1962-1977	1	156	501.59	97.81
Difference			-234.83	98.79
diff = mean(0) - mean(1)		*t*-statistic	-2.3771	
Ho: diff = 0		Degree of freedom	161.252	
Ha: diff < 0		Ha: diff ≠ 0	Ha: diff > 0	
Pr(T < t) = 0.0093		Pr(T > t) = 0.0186	Pr(T > t) = 0.9907	

Table 2. Evolution 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 % change	Number of firms % change	Average size % change	Number of firms % change
United States 1992-2004	-21.70%	-11.88%	-0.31%	-10.67%
United Kingdom 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%

Table 3a. Correlation matrix. First sample: Fr, Ger, UK, 1967-2004

	Firm size	Number telephone lines in t [a]	Price of ICT equipments [a]	Computer price [a]	Market size [b]	Investment price [a]	Trade openness [a]
Firm size	1.000						
Number telephone lines in t [a]	-0.232*	1.000					
Price of ICT equipments [a]	0.089	-0.973*	1.000				
Computer price [a]	0.153*	-0.895*	0.819*	1.000			
Market size [b]	-0.009	-0.182*	0.194*	0.137*	1.000		
Investment price [a]	-0.068	0.388*	-0.547*	-0.655*	-0.084	1.000	
Trade openness [a]	-0.146*	0.720*	-0.582*	-0.723*	-0.037	0.113*	1.000
Human capital [a]	-0.155*	0.660*	-0.515*	-0.605*	-0.023	0.277*	0.804*

*Significant at 5% level.
[a] denotes variables measured country wide.
[b] denotes sector-level variables

Table 3b. Correlation matrix. Second sample: Fr, Ger, UK, USA, 1990-2004

	Firm size	Price of ICT equipments[a]	Computer price[a]	Market size[b]	Investment[a]	Trade openness[b]	Wage[b]
Firm size	1.000						
Price of ICT equipments[a]	0.119*	1.000					
Computer price[a]	0.118*	0.985*	1.000				
Market size[b]	0.025	0.022	0.016	1.000			
Investment[a]	0.065	0.011	0.031	-0.049	1.000		
Trade openness[b]	0.162*	-0.161*	-0.149*	-0.233*	-0.180*	1.000	
Wage[b]	0.356*	-0.232*	-0.217*	0.047	0.559*	0.119*	1.000
Corruption[a]	0.025	0.345*	0.367*	-0.008	-0.158*	0.043	-0.094

*Significant at 5% level.
[a] denotes variables measured country wide.
[b] denotes sector-level variables

Table 4. Effect of ICT equipments and prices on firm size – FR, UK, GER, 1967-2004, OLS estimates

Variable	Test	Industry fixed effect					Industry-country fixed effect					Correlated panel corrected standard errors regressions		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Number telephone lines in t [a]	-0.364	-0.261**					-0.254**					-0.363**		
	(0.137)	(0.028)					(0.036)					(0.049)		
Number telephone lines in t-1 [a]			-0.253**											
			(0.024)											
Number telephone lines in t-2 [a]				-0.249**										
				(0.029)										
Price of ICT equipments [a]					0.095***			0.101***		0.185*			0.281***	
					(0.005)			(0.001)		(0.063)			(0.000)	
Computer price [a]						0.033**			0.033**		0.093*			0.091***
						(0.018)			(0.019)		(0.054)			(0.000)
Market size [b]	0.598***	0.612***	0.608***	0.607***	0.463***	0.489***	0.637***	0.457***	0.495***	0.419***	0.471***	0.395***	-0.012	0.080
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		(0.927)	(0.499)
Investment price [a]	0.346***	0.298***	0.296***	0.295***	0.241**	0.253**	0.246***	0.249***	0.246***	0.244***	0.282***	0.572**	0.722***	0.728***
	(0.000)	(0.002)	(0.001)	(0.002)	(0.028)	(0.016)	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)	(0.030)	(0.000)	(0.001)
Trade openness [a]	0.156													
	(0.581)													
Human capital [a]	-0.075													
	(0.826)													
Trend										0.045	0.089			
										(0.338)	(0.227)			
Constant	-2.475***	-2.185***	-1.978***	-1.694***	-0.764	-1.131**	-2.197***	-0.772	-1.134*	-0.444	-1.191*	-1.239***	2.065***	0.933**
	(0.007)	(0.002)	(0.003)	(0.009)	(0.183)	(0.043)	(0.002)	(0.252)	(0.064)	(0.535)	(0.054)	(0.043)	(0.003)	(0.032)
Observations	389	389	389	389	415	415	389	389	389	415	415	389	415	415

Note: *p*-values are in brackets. (1)-(11): standard errors are multi-ways clustered following Cameron et al. (2006) and using their `cgmreg' routine in Stata.
[a] denotes variables measured country wide
[b] denotes sector-level variables
***Significant at 1% level.
**Significant at 5% level.
*Significant at 10% level.

Table 5. Effect of ICT equipments and prices on firm size, Fr, Ger, UK, 1967-2004, IV estimates.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number telephone lines in t [a]	-0.274*					-0.228***		
	(0.064)					(0.008)		
Number telephone lines in t-1 [a]		-0.263***						
		(0.053)						
Number telephone lines in t-2 [a]			-0.258**					
			(0.050)					
Price of ICT equipments [a]				0.074**			0.182***	
				(0.043)			(0.000)	
Computer price [a]	.		.		0.026*			0.052**
					(0.071)			(0.013)
Market size [b]	0.622***	0.616***	0.614***	0. 524***	0.544***	0.620***	0.425***	0.491***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Price of Investment [a]	0.278**	0.276**	0.274**	0.149	0.156	0.119	0.119	0.121
	(0.034)	(0.028)	(0.027)	(0.184)	(0.181)	(0.186)	(0.119)	(0.139)
Trend						0.054***	0.054***	0.043*
						(0.009)	(0.009)	(0.051)
Constant	-2.707***	-2.476***	-2.179***	-1.533***	-1.821***	-0.009	-0.554	-1.296***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.517)	(0.122)	(0.000)
Observations	389	389	389	415	415	389	415	415
First stage results. Excluded instruments:								
Real GDP	-1.737	-1.753	-1.754	-0.766	-0.572	-1.423	-0.702	-0.706
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population	3.427	3.4278	3.430	2.600	2.5586	3.252	2.620	2.822
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Anderson-Rubin Wald *F*-statistic (test of joint significance of endogenous regressors)	88.58	81.19	78.16	21.28	29.49	78.20	22.53	38.48
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Kleibergen-Paap *LM*-statistic (underidentification test)	24.85	24.81	24.80	25.71	25.89	26.03	25.72	25.76
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Kleibergen-Paap Wald *F*-statistic (weak identification test)	1823.06	1658.94	1608.44	6701.70	7201.00	2238.48	2986.85	2582.31
Hansen *J* test of overidentifying restriction, *p*-value	0.775	0.926	0.969	0.6948	0.845	0.606	0.442	0.0277

Notes: *p*-values are in brackets. Standard errors are industry cluster robust. Regressions are panel data-based and include an industry fixed effect. For the Kleibergen-Paap Wald F-statistic, the Stock and Yogo's (2005) critical values at 10% of maximal IV relative bias is 19.93.

[a] denotes variables measured country wide

[b] denotes sector-level variables

***Significant at 1% level., **Significant at 5% level., *Significant at 10% level.

Table 6. Effect of ICT and computer prices effect on firm size Fr, Ger, UK, USA 1990-2004

Variables	Tests	OLS regressions			IV regressions				Correlated panel corrected standard errors regressions	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Price of ICT equipments[a]	0.212**		0.738**		0.110**		0.449*		0.110***	
	(0.012)		(0.026)		(0.023)		(0.079)		(0.009)	
Computer price[a]		0.072**		0.1338		0. 039**		0.033		0.047***
		(0.05)		(0.376)		(0.031)		(0.508)		(0.006)
Market size[b]	0.217***	0.227***	0.179***	0.221***	0. 447***	0. 431***	0.369***	0.434***	0.282***	0.304***
	(0.001)	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Investment[a]	-0.32	-0.029	-0.038*	-0.029	0.091***	0.095***	0.092***	0.094***	0.053***	0.056***
	(0.114)	(0.167)	(0.088)	(0.159)	(0.004)	(0.004)	(0.005)	(0.005)	(0.000)	(0.000)
Trade openness[b]	0.154**	0.165**	0.106	0.162**	0.127	0.130	0.105	0.130	0.234***	0.25***
	(0.040)	(0.038)	(0.132)	(0.033)	(0.189)	(0.185)	(0.310)	(0.186)	(0.000)	(0.000)
Wage[b]	0.388***	0.384**	0.311*	0.373**	0.474	0.046	0.007	0.047		
	(0.008)	(0.013)	(0.100)	(0.023)	(0.70)	(0.708)	(0.956)	(0.707)		
Corruption[a]	-0.013	0.096	-0.323	0.062	-0.071	0.025	-0.194	0.026		
	(0.951)	(0.658)	(0.120)	(0.783)	(0.691)	(0.873)	(0.422)	(0.878)		
Trend			0.050	0.016			0.031	-0.001		
			(0.103)	(0.683)			(0.190)	(0.916)		
Constant	1.76***	1.432***	-96.904	-29.8257	-0.182	-0.188	-60.128*	2.554	1.865***	1.586***
	(0.000)	(0.001)	(0.109)	(0.697)	(0.863)	(0.847)	(0.081)	(0.933)	(0.000)	(0.000)
Observations	364	364	364	364	364	364	364	364	364	364
First stage results. Excluded instruments:										
Real GDP					0.826	0.739	0.846	0.730		
					(0.000)	(0.000)	(0.000)	(0.000)		
Population[a]					0.021	0.028	0.019	0.029		
					(0.000)	(0.000)	(0.000)	(0.000)		
Anderson-Rubin Wald *F*-statitic (test of joint significance of endogenous regressors)					12.21	11.30	10.42	11.59		
					(0.000)	(0.000)	(0.000)	(0.000)		
Kleibergen-Paap *LM*-statistic (underidentification test)					22.55	22.58	24.11	22.93		
					(0.000)	(0.000)	(0.000)	(0.000)		
Kleibergen-Paap Wald *F*-statistic (weak identification test)					455.30	475.55	426.70	483.18		
Hansen *J* test of overidentifying restriction, *p*-value					0.803	0. 808	0.355	0.796		

Notes: *p*-values are in brackets. Standard errors are industry cluster-robust. For the Kleibergen-Paap Wald F-statistic, the Stock and Yogo's (2005) critical values at 10% of maximal IV relative bias is 19.93.

[a] denotes variables measured country wide

[b] denotes sector-level variables

***Significant at 1% level.,

**Significant at 5% level.,

*Significant at 10% level

Table 7. Wooldridge test of autocorrelation in panel data

First sample: Fr, Ger, UK, 1967-2004

Variable	(1)	(2)	(3)	(4)
Number telephone lines in t [a]	-1.035***	-0.126		
	(0.000)	(0.128)		
Price of ICT equipments [a]			0.146***	
			(0.000)	
Computer price [a]				0.035***
				(0.000)
Market size [b]	0.444***	0.669***	0.434***	0.522***
	(0.000)	(0.000)	(0.000)	(0.000)
Investment price [a]	0.248***	0.088	0.256***	0.216***
	(0.001)	(0.192)	(0.000)	(0.000)
Trade openness [a]	0.586***			
	(0.000)			
Human capital [a]	0.586*			
	(0.091)			
Observations	283	283	308	308
Wooldridge test, *F*-statistic	106.458	66.316	66.045	64.343
	(0.000)	(0.000)	(0.000)	(0.000)

Second sample: Fr, Ger, UK, USA, 1990-2004

Variable	(5)	(6)
Price of ICT equipments[a]	0.154***	
	(0.000)	
Computer price[a]		.0486***
		(0.001)
Market size[b]	0.349***	0.387***
	(0.001)	(0.000)
Investment[a]	0.076**	0.075**
	(0.029)	(0.034)
Trade openness[b]	0.187**	0.184**
	(0.011)	(0.019)
Wage[b]	0.099	0.094
	(0.285)	(0.307)
Corruption[a]	-0.011	
	(0.948)	
Observations	263	263
Wooldridge test, *F*-statistic	63.791	65.329
	(0.000)	(0.000)

Notes: *p*-values are in brackets.
[a] denotes variables measured country wide
[b] denotes sector-level variables
***Significant at 1% level.
**Significant at 5% level.
*Significant at 10% level