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Technological revolutions and the evolution of industrial structures.

Assessing the impact of new technologies upon size, pattern of growth and boundaries of the firms

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Technological revolutions and the evolution of industrial structures. Assessing the impact of new technologies upon size and boundaries of the firms*

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Abstract

In this work we discuss the impact of the new ICT techno-economic paradigm upon the vertical and horizontal boundaries of the firm and ask whether the change in the sources of competitive advantage has resulted in changes in the size distribution of firms and also in the degree of concentration of industries. Drawing both on firm-level and national statistical data we assess the evolution of the overall balances between the activities which are integrated within organizations and those which occur through market interactions.

While the new paradigm entails "revolutionary" changes in the domain of technology, the modification in industrial structures has been somewhat more incremental. Certainly, the vertical and horizontal boundaries of firms have changed and together one is observing a turnover in the club of biggest world firms accounting also for a shift in the relative importance of industrial sectors. Nonetheless, we do not observe any abrupt fading away of the Chandlerian multidivisional corporation in favour of smaller less-integrated firms.

Keywords
New techno-economic paradigm; Organizational change; Vertical integration; Boundaries of the firm; Visible hand.

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1 Introduction

There is little doubt that over the last three decades the world economy has witnessed the emergence of a cluster of new technologies - that is a new broad techno-economic paradigm in the sense of Freeman and Perez (1988) - centered on electronic-based information and communication technologies. Such ICT technologies did not only give rise to new industries but, equally important, deeply transformed incumbent industries (and for that matter also service activities), their organizational patterns, and their drivers of competitive success.

Granted such "revolutionary" features of the emerging ICT-based (and possibly life science-based) technologies in manufacturing and services, what has been their impact upon the vertical and horizontal boundaries of the firms? What is the evidence supporting the view according to which the new techno-economic paradigm is conducive to a progressive fading away of the Chandlerian multidivisional corporation, which was at the center of the previous techno-economic paradigm, in favour of more specialized, less vertically integrated structures? Is it true that large firms are generally losing their advantage in favour of smaller ones? And more generally, how robust is the evidence, if any, of a "vanishing visible hand" (Langlois, 2003) in favour of a more market-centered organization of economic activities?

In this work we address these issues drawing both on several pieces of circumstantial evidence and on firm-level statistical data. In fact, if the sources of competitive advantage conditional on firm size had significantly changed, this should reflect also on changes in the size distribution of firms, on their growth profiles and on the degrees of concentration of industries. These are the variables we analyze in Section 2, together with some evidence on the relationship between size and innovation, on entry and exit, and on job creation in different size classes. Since, plausibly, the mark of a hypothetical "revolution" in the forms of economic organization should be found quite universally, when possible we try to disentangle those properties that are country- and industry-specific and others which robustly apply across national boarders and at different levels of aggregation.

In a nutshell, the evidence that we analyze does not support any notion of revolution: rather it hints at detectable but rather incremental changes in the size distribution in favour of smaller size classes, which might however have already stopped in some countries. Size distributions are, of course, a very rough indicator of underlying patterns of competitive advantage and of inter-organizational division of labour. In Section 3 we present a theoretical framework able to capture such underlying dynamics in terms of processes of market selection and of vertical integration (disintegration). Such an exercise allows also to identify different types of firms even when of a similar size.

Building on the foregoing statistical evidence and on an evolutionary conceptual framework on size dynamics, we turn to a "qualitative" discussion of the changes in the organization of industries associated with the new techno-economic paradigm, and focuses on the relationships between changing industrial structures, the dynamics of horizontal and vertical boundaries of firms, and the patterns of division of labour in general and of innovative labour in particular. The bottom line is that certainly the new paradigm has significantly influenced both the firm boundaries and the patterns of inter-organizational division of labour. However, there is hardly any sign of a "third Industrial Revolution", at least if by the latter one means a revolution in the role of the "visible hand" of organizations (as distinct from market exchanges) and in the relative competitive advantages of size such as compared to previous phases of capitalist development.

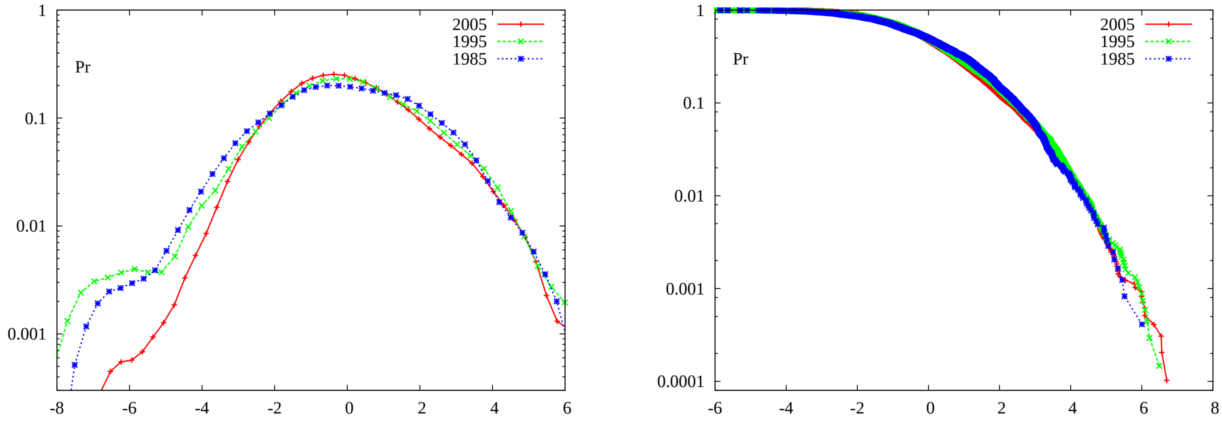

Figure 1: (Left) Size distribution of world's largest firms (in terms of sales). (Right) Right cumulated distribution. All publicly quoted firms with more than 500 employees from the Osiris (2005) databank. Observations are in log and normalized with the mean.

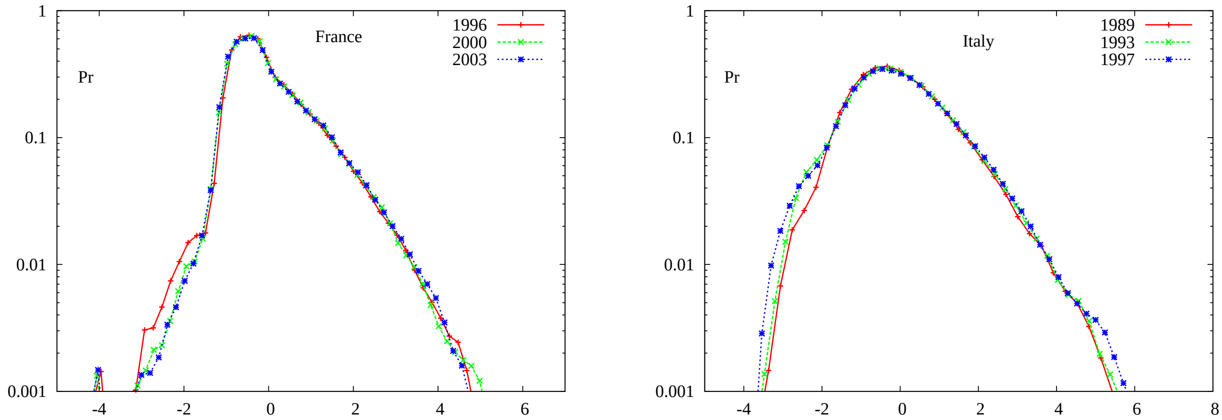

Figure 2: Size distribution (employment measures) of firms with more than 20 employees (logscale): France (left) and Italy (right).

2 Structure and dynamics of industries: some "stylized facts" and long-term trends

Let us begin by focusing on the invariances and changes in the structure of industries and growth processes,[1] trying to distinguish from the very beginning among those regularities which are common to all industrial sectors and those which reveal a high degree of sectoral or national specificities.

2.1 Size distributions

The skewness of size distributions, over an impressively wide support, is probably the most known "stylized facts" concerning industrial structures. Such a regularity holds true independently of the unit of observation (might it be the firm or the establishment) and of the chosen proxy for size (might it be sales, value added, or number of employees). In fact at a first approximation and at the *aggregate* manufacturing level the distribution of firms' size is

[1]Part of this section borrows from Dosi et al. (1995); Dosi (2007). See also the special issues of Industrial and Corporate Change, 1997 and International Journal of Industrial Organization, 1997.

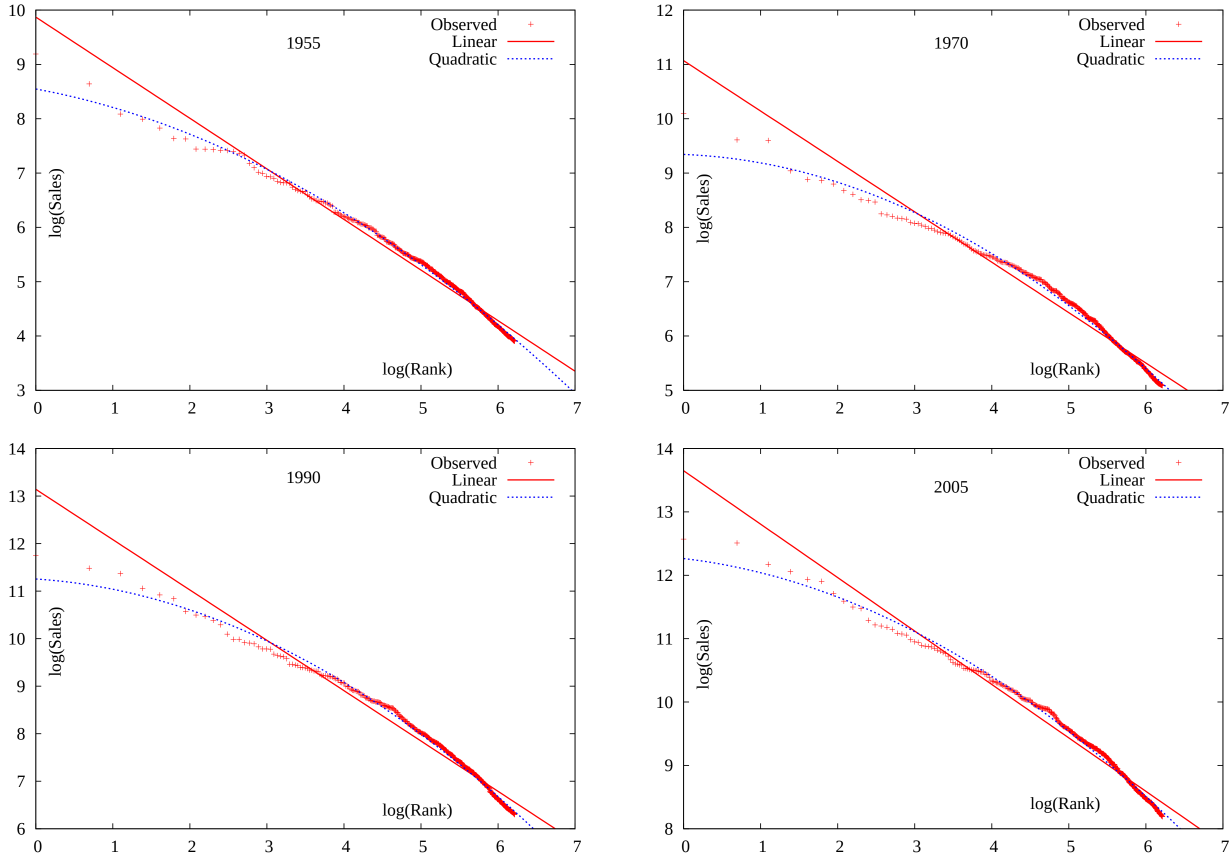

Figure 3: Zipf fit of Sales distribution for Fortune 500 firms, various years.

well described by a Pareto distribution.[2]

The (cumulative) probability density function, of Pareto distribution of discrete random variables is

$$Pr[s \geq s_i] = \left(\frac{s_0}{s_i}\right)^{\alpha} \tag{1}$$

where s_0 is the smallest firm size and $s_i \geq s_0$ is the size of the i-th firm, as increasingly ranked. In the following, one of the statistics that we will show is the right-cumulated function

$$F(s) = (as)^{-\alpha} \tag{2}$$

These statistics are a first way to characterize the density in populations of different size classes. Pareto law (Eq. 1) under the restriction that $\alpha = 1$, reduces to so-called Zipf law[3] linking the log of the rank and log of the variable being analyzed

$$sr^{\beta} = A \tag{3}$$

where r is the rank and s, in our case, is a proxy for size (choosing sales, value added, or employees does not significantly affect the analysis: cf. Bottazzi et al. (2007)). The largest

[2]For a classical discussion see Ijiri and Simon (1977). More recent evidence is in Axtell (2001) and Marsili (2005).

[3]The Zipf distribution is a discrete, one-parameter, univariate distribution that has been used to describe various physical and social phenomena that are highly skewed (Axtell, 2001; Newman, 2005).

Table 1: Fortune 500; Zipf fit. Linear and Quadratic Models.

Year	Linear Model		Quadratic Model		
	α	β	α	β	γ
1955	**9.871**	**-0.931**	**8.548**	**-0.263**	**-0.077**
	(0.083)	(0.015)	(0.204)	(0.089)	(0.009)
1970	**11.069**	**-0.928**	**9.342**	-0.056	**-0.100**
	(0.103)	(0.019)	(0.249)	(0.124)	(0.011)
1980	**12.506**	**-0.997**	**10.704**	-0.087	**-0.104**
	(0.106)	(0.019)	(0.499)	(0.149)	(0.010)
1990	**13.143**	**-1.059**	**11.254**	-0.105	**-0.109**
	(0.119)	(0.118)	(0.181)	(0.077)	(0.008)
2000	**13.254**	**-0.809**	**11.727**	-0.038	**-0.088**
	(0.096)	(0.017)	(0.185)	(0.078)	(0.008)
2005	**13.649**	**-0.843**	**12.264**	**-0.143**	**-0.080**
	(0.087)	(0.016)	(0.130)	(0.056)	(0.005)

5% statistically significant coefficients are in bold; standard errors in brackets.

firm is assigned rank 1. β and A are parameters, the former being an indicator of the degree of concentration of whatever measure in the population. Zipf plots are the other statistics that we shall use to characterize firm size distribution.

Figure 1 and 2 display the kernel estimate of the density of firm size for the world medium-large publicly quoted companies and for France and Italy.[4] The reader should not pay too much attention to the smaller-size densities which are affected by the truncation of the observations at a given threshold, in these samples at 20 employees.[5]

The evidence shows that the skewness in the distribution is very robust and quite invariant over time. Also note that skewness and the width of the support are not results of an *ad hoc* choice of the proxy for size (recall for example that Figure 1 is based on sales measures and Figure 2 on employment).[6]

The relative stability of the (nearly) Pareto upper tail of the distribution is confirmed by the evidence on Fortune 500 since 1955, over which we estimate both the linear and quadratic form of Eq. 3, which are, respectively

$$\log s_i = \alpha - \beta \log r_i + \varepsilon_i \qquad (4)$$

and

$$\log s_i = \alpha - \gamma (\log r_i)^2 + \varepsilon_i \qquad (5)$$

where $\alpha = \log A$. The estimates (see Figure 3 and Table 1) while highlighting the (rough) fit of the Zipf relation in its canonic (linear) form, also reveal that if anything has changed in the size distribution of the top firms, this has been far from dramatic: consider the coefficients β in the linear estimation.

To repeat, although the approximation of the distribution with Pareto (Zipf) ones are highly imperfect ones, as discussed at greater length in Dosi et al. (1995), the skewness property

[4]More detailed information on the database employed for the empirical analysis is provided in the Appendix.

[5]Plots are produced on the logarithms of normalized values, so that the distribution is centered to zero, with densities presented in 64 equispaced points using an Epanenchnikov kernel.

[6]On the stability over time of such asymmetric distributions, see also Armington (1986), Hall (1987), Storey (1994), Bottazzi and Secchi (2003a), among the others.

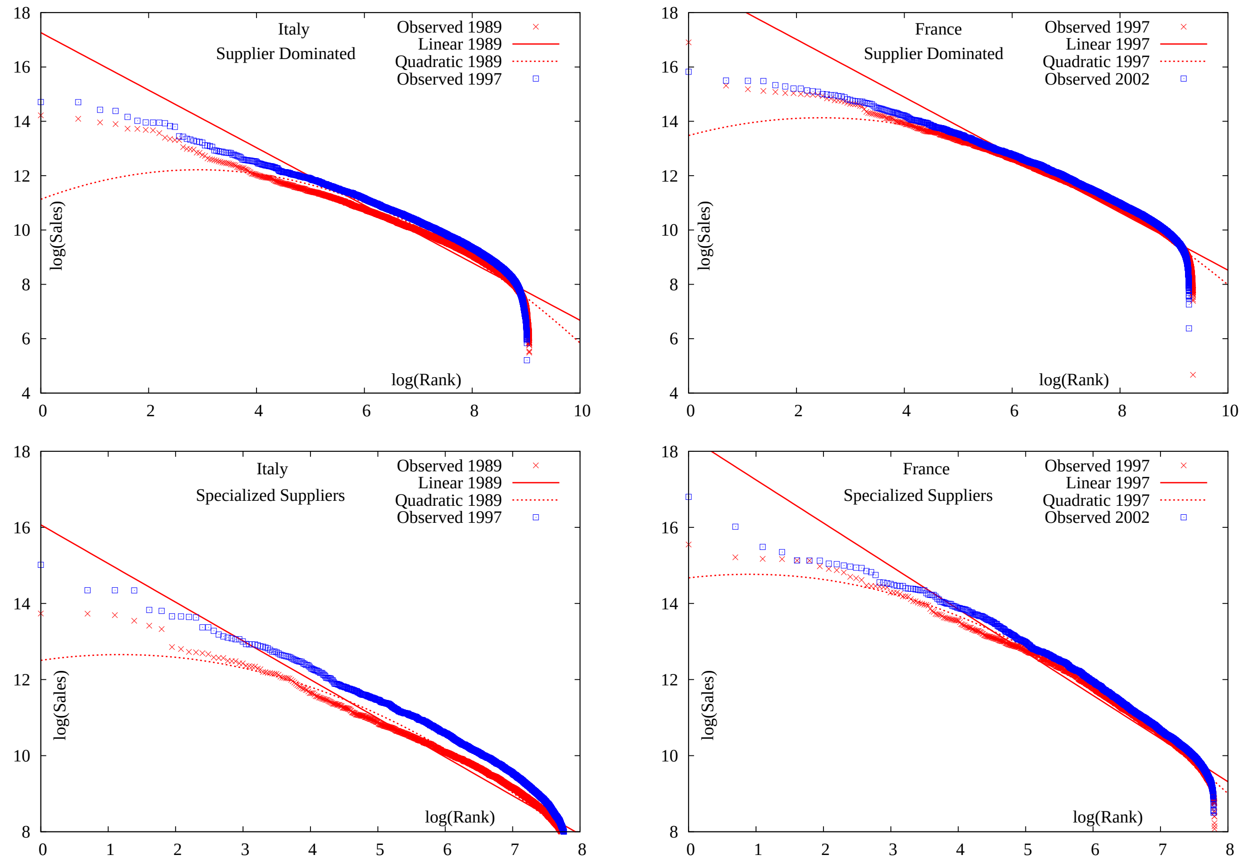

Figure 4: Zipf fit of sectors grouped according to Pavitt taxonomy, Italian and French manufacturing industry.

is extremely robust. Further, the coefficients of the Pareto (Zipf) estimates slightly differ across countries but the fit is quite robust at the level of broadly defined manufacturing aggregates.

2.2 Sectoral specificities

As conjectured on the ground of an evolutionary model in Dosi et al. (1995) and empirically shown in Bottazzi et al. (2007) on Italian data, disaggregated size distributions continue to display skewness and a wide support. That is, coexistence of firms with very different sizes is the norm, but the departures from a Pareto-shape are often very wide (sometimes the distributions are even bimodal or trimodal).

The structure of each industry, in turn, is the outcome of its evolutionary history, driven by the underlying patterns of technological and organizational learning and the competitive interactions (more on this in section 3, below). In particular industries differ in term of (a) intensity of innovative efforts and even more so in the modes through which they undertake them (e.g. through formal R&D, learning by doing, learning by using, etc.); (b) their revealed rates of innovation; (c) the rates of productivity growth; and (d) the patterns of inter-organizational division of labor.[7] Plausibly, such differences might also entail size-biased capabilities to innovate. Together, they certainly yield different potentials to grow conditional on the specific "regimes" of technological learning. One of the aims of the well-known taxonomy by Keith Pavitt (1984) is precisely to capture such relations and also try to map "industry types" (de-

[7]More on this issues in Dosi (1988) Malerba and Orsenigo (1995, 1997), Dosi et al. (2005).

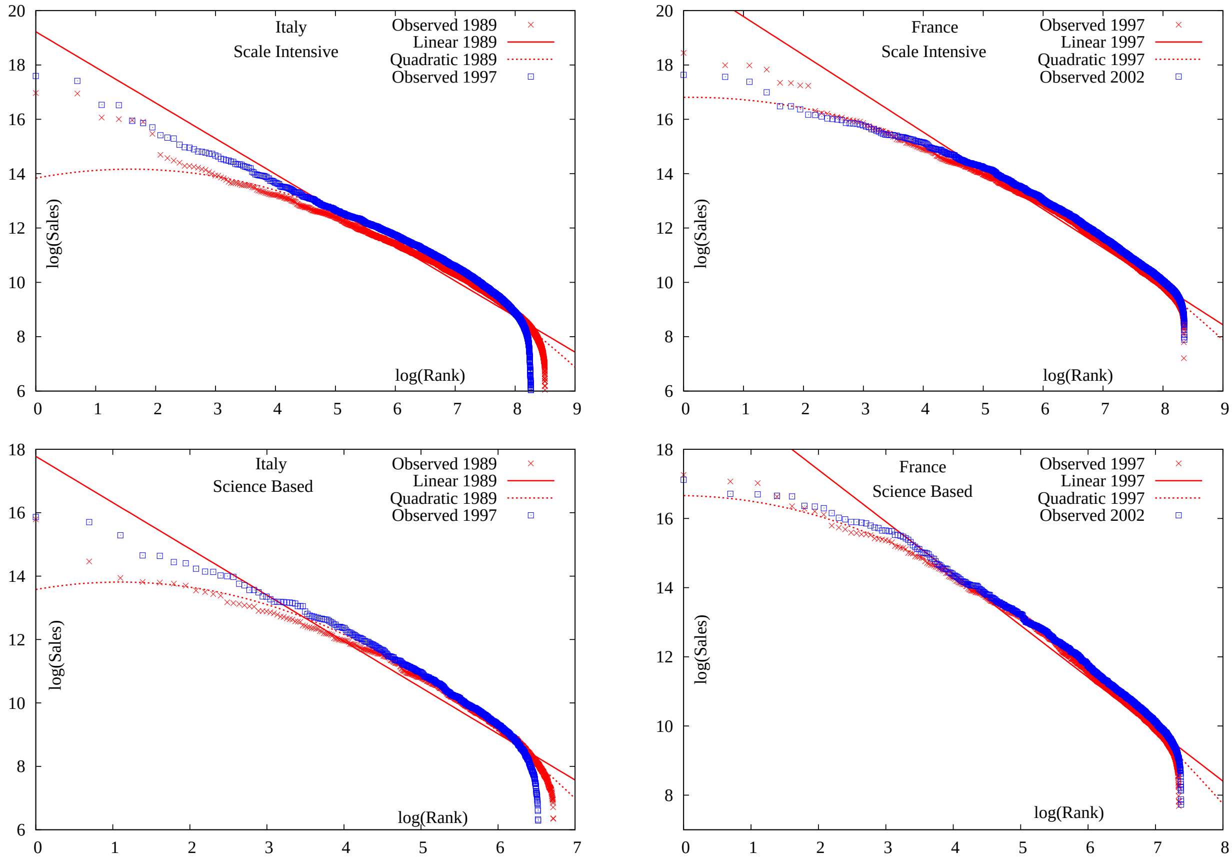

Figure 5: Zipf fit of sectors grouped according to Pavitt taxonomy, Italian and French manufacturing industry.

fined according to their learning modes) and firm size. To recall, Pavitt taxonomy comprises four groups of sectors, namely

(*i*) "supplier dominated" sectors, whose innovative opportunities, mostly come through the acquisition of new pieces of machinery and new intermediate inputs (textile, clothing, metal products belong to this category);

(*ii*) "specialized suppliers", including producers of industrial machinery and equipments;

(*iii*) "scale intensive" sectors, wherein the sheer scale of production influences the ability to exploit innovative opportunities partly endogenously generated and partly stemming from science-based inputs (see below);[8]

(*iv*) "science-based" industries, whose innovative opportunities co-evolve, especially in the early stage of their life with advances in pure and applied sciences (micro electronics, informatics, drugs and bioengineering in particular are good examples).

Pavitt's evidence was drawing upon the characteristics of a sample of British innovators. Do different family of industries display diverse size distribution profiles also over greater samples[9] including of course innovating and non-innovating firms?

[8]Here one should in fact distinguish between "discontinuous" complex-product industries such as automobiles, white goods and other consumer durables vs. "continuous" flow industries such as refining or steel making.

[9]In fact, in our case, the universe of all firms responding to the Central Statistical Office survey.

Table 2: Zipf fit. Linear and Quadratic Models. Our Elaboration on Micro.1 and EAE databank.

SECTOR	Year	Linear Model		Quadratic Model		
		α	β	α	β	γ
ITA - Supplier Dominated	1989	**17.263**	**-1.058**	**11.131**	**0.743**	**-0.127**
		(0.065)	(0.008)	(0.399)	(0.110)	(0.007)
ITA - Supplier Dominated	1997	**18.028**	**-1.122**	**11.264**	**0.878**	**-0.142**
		(0.074)	(0.009)	(0.447)	(0.124)	(0.008)
FRA - Supplier Dominated	1997	**19.134**	**-1.061**	**13.477**	**0.531**	**-0.108**
		(0.022)	(0.002)	(0.053)	(0.014)	(0.001)
FRA - Supplier Dominated	2002	**19.297**	**-1.064**	**13.714**	**0.524**	**-0.108**
		(0.023)	(0.003)	(0.053)	(0.014)	(0.001)
ITA - Scale Intensive	1989	**19.223**	**-1.310**	**13.833**	**0.418**	**-0.132**
		(0.080)	(0.010)	(0.499)	(0.149)	(0.010)
ITA - Scale Intensive	1997	**19.861**	**-1.370**	**14.313**	**0.479**	**-0.146**
		(0.092)	(0.012)	(0.551)	(0.170)	(0.012)
FRA - Scale Intensive	1997	**21.201**	**-1.418**	**16.807**	**0.026**	**-0.113**
		(0.027)	(0.003)	(0.040)	(0.012)	(0.001)
FRA - Scale Intensive	2002	**21.273**	**-1.402**	**16.234**	**0.252**	**-0.129**
		(0.030)	(0.004)	(0.039)	(0.012)	(0.001)
ITA - Specialized Suppliers	1989	**16.068**	**-1.017**	**12.505**	**0.254**	**-0.107**
		(0.081)	(0.011)	(0.271)	(0.088)	(0.007)
ITA - Specialized Suppliers	1997	**17.137**	**-1.120**	**13.048**	**0.353**	**-0.125**
		(0.095)	(0.013)	(0.364)	(0.121)	(0.009)
FRA - Specialized Suppliers	1997	**18.381**	**-1.133**	**14.673**	**0.207**	**-0.114**
		(0.033)	(0.004)	(0.045)	(0.015)	(0.001)
FRA - Specialized Suppliers	2002	**18.821**	**-1.177**	**15.376**	**0.071**	**-0.107**
		(0.031)	(0.004)	(0.042)	(0.014)	(0.001)
ITA - Science Based	1989	**17.777**	**-1.458**	**13.578**	0.428	**-0.195**
		(0.195)	(0.033)	(0.549)	(0.220)	(0.021)
ITA - Science Based	1997	**18.405**	**-1.547**	**14.745**	0.171	**-0.185**
		(0.195)	(0.035)	(0.360)	(0.151)	(0.015)
FRA - Science Based	1997	**20.406**	**-1.500**	**16.661**	-0.024	**-0.136**
		(0.046)	(0.007)	(0.059)	(0.021)	(0.002)
FRA - Science Based	2002	**20.500**	**-1.489**	**16.774**	-0.031	**-0.134**
		(0.047)	(0.007)	(0.070)	(0.026)	(0.002)
ITA - All Manufacturing	1989	**19.430**	**-1.188**	**12.683**	**0.604**	**-0.115**
		(0.047)	(0.005)	(0.393)	(0.099)	(0.006)
ITA - All Manufacturing	1997	**20.305**	**-1.267**	**12.915**	**0.732**	**-0.131**
		(0.054)	(0.006)	(0.444)	(0.114)	(0.007)
FRA - All Manufacturing	1997	**21.354**	**-1.219**	**15.788**	**0.232**	**-0.091**
		(0.015)	(0.002)	(0.040)	(0.010)	(0.001)
FRA - All Manufacturing	2002	**21.536**	**-1.222**	**15.718**	**0.299**	**-0.096**
		(0.018)	(0.002)	(0.039)	(0.010)	(0.006)

5 % statistically significant coefficients are in bold; standard errors in brackets.

Figure 4 and 5 and Table 2 presents Zipf estimates on Italian and French manufacturing sectors.[10]

The results do indeed vindicate the notion that technology-specific facts exert a significant influence on industry structures[11]. Consider again in particular the linear Zipf model (with all

[10]Table 7 in the Appendix reports an accurate description of the mapping we employed to relate a particular industrial activity, i.e. industrial classification code, into the corresponding "Pavitt's groups".

[11]Similar evidence on The Netherlands is discussed in Marsili (2005).

the foregoing *caveats* in mind) and recall that, roughly speaking, a higher absolute value of the β coefficient means a higher size advantage of the biggest firms. In fact, size advantages are relatively more important in scale intensive sectors (not surprising as such, but corroborating the soundness of the taxonomy) and in science-based ones, while they are least important in "supplier dominated" sectors.

A first account of the Italian and French cases interestingly lends support to the hypothesis of a significant role played by the specific technological regime in shaping the industry structure of different sectors which holds across countries. This is apparent comparing the coefficients for France and Italy in Table 2. Estimated β belonging to the same groups are indeed very similar for both France and Italy.

Note also that from the 80's to the 90's there is no evidence, so to speak, of a "shrinking top". On the contrary, even in a country like Italy, notoriously characterized by a small-firm bias, the β coefficient remains constant or slightly increase.

In fact, in order to study more generally the possible changes in industrial structures from the "fordist golden age" of the 50's and 60's to the current period, one would ideally require size distributions for the major OECD countries over the whole population of firms (at least above some threshold) going back over time. Unfortunately they are not available. Hence, in order to get some further hints of the dynamics of industrial structures let us look at the dynamics of the number of firms and of employment by broad size cohort and at the degree of industrial concentration.

2.3 Number of firms and employment by size classes

Tables 3 and 4 report the distribution fo the number of firms and of employment by size cohorts. The length of the footnotes to the tables, flagging differences in sources, coverage, cohort breakdown should warn the reader about making too strong inferences from such data. With that in mind, the data do not seem to reveal anything reminding a revolution either with respect to the percentage distribution of firms or their employment share. At a first look, Germany, France the U.S. and the U.K. (in terms of employment share, only) do appear to conform to the story of a growing hegemony of bigger firms up to the 70's with a turning point thereafter. However, in some countries like the U.K., Germany, and Italy the share of employment in the bigger size cohort continue to fall since (and less so in Japan, too, with a corresponding growth in the medium-large share[12]). Conversely, the U.S. evidence appear to suggest a *reversal* of such trend with a growing share in the number of big firms in manufacturing and a growing share in big-size employment in both manufacturing and overall economy.

2.4 Industrial concentration

Next let us consider in turn proxies for industrial concentration also in its dimension. Let us start from the former on the grounds of the Osiris (2005) databank which covers publicly quoted companies, in principle all over the world. Ideally, the measure ought to be calculated on the universe of firms in a given sector. Short of that, and given the biases associated with the lower size bound in the databank[13] we feel safer to consider concentration in the *upper tail* of the distribution.

[12]Firms in the 100-999 cohort.

[13]Note that the percentage of publicly quoted companies over the total of the size cohort tend to fall with the latter.

Table 3: Distribution of firms per size, percentages.

Country	Year	0-9	10-19	20-49	50-99	50-250	100-499	250+	500+
France	1962[a]	...	36.9[1]	34.1	13.6	...	12.8	...	2.7
	1977[a]	...	28.4[1]	38.3	14.6	...	15.1	...	3.6
	1990[a]	...	34.9[1]	37.8	13.4	...	11.5	...	2.5
	1996[b]	82.7	7.2	6.0	2.0	...	1.8	...	0.3
	1997[b]	82.4	7.3	6.2	2.0	...	1.8	...	0.3
	2000[b]	82.1	7.3	6.4	1.9	...	1.9	...	0.4
	2001[b]	81.8	7.5	6.4	2.0	...	1.9	...	0.4
	2003[b]	82.8	7.2	6.0	...	3.2	...	0.8	...
Germany	1967[a]	58.9[2]	...	17.9[3]	9.8	...	11.0	...	2.5
	1977[a]	56.6[2]	...	20.2[3]	10.2	...	10.3	...	2.6
	1990[a]	60.3[2]	...	17.7[3]	9.6	...	10.0	...	2.4
	2000[b]	67.3	16.3	7.4	4.1	...	4.1	...	0.8
	2001[b]	64.0	18.8	7.7	4.3	...	4.3	...	0.9
	2002[b]	62.1	18.4	8.9	...	8.4	...	2.2	...
	2004[b]	59.9	21.4	8.4	...	8.2	...	2.1	...
UK	1968[a]	62.5[2]	...	10.3[3]	10.4	...	13.4	...	3.4
	1977[a]	54.3	15.0	13.6	6.8	...	8.1	...	2.3
	1990[a]	66.2	13.3	10.2	4.5	...	4.8	...	1.0
	1996[b]	71.5	12.1	8.8	3.4	...	3.5	...	0.7
	1997[b]	72.0	12.1	8.4	3.3	...	3.5	...	0.7
	2000[b]	70.7	13.4	8.3	3.6	...	3.4	...	0.6
	2001[b]	71.7	12.2	8.8	3.5	...	3.2	...	0.6
	2002[b]	71.2	12.5	9.0	...	5.9	...	1.4	...
	2003[b]	72.9	11.8	8.5	...	5.5	...	1.3	...
Italy	1971[a]	...	48.0[1]	31.4	11.2	...	8.2	...	1.3
	1981[a]	...	57.3[1]	27.4	8.4	...	6.2	...	0.9
	1991[a]	...	59.0[1]	28.5	7.0	...	4.8	...	0.7
	1996[b]	83.7	9.5	4.8	1.1	...	0.8	...	0.1
	1997[b]	83.1	9.7	5.1	1.2	...	0.8	...	0.1
	1998[b]	83.5	9.6	4.8	1.2	...	0.8	...	0.1
	1999[b]	83.5	9.6	4.8	1.1	...	0.8	...	0.1
	2000[b]	83.5	9.6	4.7	1.2	...	0.8	...	0.1
	2001[b]	83.3	9.8	4.8	1.2	...	0.8	...	0.1
	2002[b]	83.4	9.7	4.7	...	1.9	...	0.3	...
	2004[b]	82.8	10.1	4.8	...	2.0	...	0.3	...
Japan	1967[a]	72.7	13.9	8.1	2.9	...	2.0	...	0.3
	1975[a]	76.2	12.3	7.0	2.5	...	1.7	...	0.3
	1990[a]	73.7	11.9	9.4	2.9	...	2.0	...	0.3
	1999[c]	71.6	13.5	9.2	3.0	...	2.5[8]	...	0.2[9]
	2001[c]	71.6	13.5	9.2	3.0	...	2.5[8]	...	0.2[9]
	2004[c]	72.1	13.2	9.0	3.0	...	2.5[8]	...	0.2[9]
USA	1972[d]	88.8	5.9	4.6[5]	...	...	0.6	...	0.1
	1977[d]	89.4	5.6	4.3[5]	...	...	0.6	...	0.1
	1982[d]	80.9	10.4	7.5[5]	...	...	1.0	...	0.2
	1988[e]	78.8	10.9	8.7[5]	...	...	1.3	...	0.3
	1992[e]	78.9	10.8	8.6[5]	...	...	1.4	...	0.3
	1997[e]	78.8	10.7	8.8[5]	...	...	1.4	...	0.3
	1999[e]	78.5	10.8	8.9[5]	...	...	1.5	...	0.3
	2000[e]	78.2	10.9	9.1[5]	...	...	1.5	...	0.3
	2003[e]	78.6	10.8	8.9[5]	...	...	1.5	...	0.3

(a) OECD (1995).
(b) EUROSTAT (2006).
(c) Japan Statistical Bureau (2006); Only Inc.
(d) U.S. Census of Bureau (1972, 1977, 1982a).
(e) U.S. Census of Bureau (2006b); Only Inc.
(o) OECD (2006); Manufact. only.
(1) Bigger than 10 employees.
(2) The smallest cohort is 0-24.
(3) Cohort of range 25-49.
(4) Plants, rather than firms.
(5) 20-99.
(6) 100-249.
(7) 250-499.
(8) 100-999.
(9) 1000+.

Table 4: Employment share per size cohort, percentages.

Country	Year	0-9	10-19	20-49	50-99	50-250	100-499	250+	500+
France	1962[a]	...	4.7[1]	10.0	8.8	...	24.5	...	51.9
	1977[a]	...	3.1[1]	9.3	7.9	...	24.4	...	55.3
	1990[a]	...	5.7[1]	13.4	10.4	...	25.7	...	44.7
	1996[b]	13.0	6.3	13.1	8.4	...	23.5	...	35.7
	1997[b]	13.1	6.2	13.4	8.4	...	23.7	...	35.2
	2000[b]	12.2	6.2	12.9	8.5	...	24.3	...	35.9
	2001[b]	11.8	6.3	12.7	8.5	...	24.5	...	36.2
	2003	12.1	6.5	12.5	...	22.1	...	46.9	...
Germany	1967[a]	3.9[2]	...	6.2[3]	7.5	...	25.2	...	57.2
	1977[a]	3.9[2]	...	6.9[3]	7.7	...	23.5	...	58.0
	1990[a]	4.7[2]	...	6.8[3]	7.8	...	24.1	...	56.6
	2000[b]	7.2	7.1	7.5	8.8	...	25.8	...	43.6
	2001[b]	7.0	7.7	7.4	8.7	...	25.8	...	43.4
	2002[b]	6.7	6.7	7.8	...	23.7	.	55.1	...
	2004[b]	6.6	8.5	7.7	...	23.6	...	53.6	...
UK	1968[a]	6.8[2]	...	4.2[3]	8.0	...	31.6	...	49.5
	1977[a]	3.8	3.2	6.2	7.1	...	25.6	...	54.3
	1990[a]	5.8	4.4	9.6	9.3	...	30.0	...	40.9
	1996[b]	11.4	6.8	11.2	9.7	...	28.1	...	32.8
	1997[b]	9.4	7.1	10.9	9.5	...	29.5	...	33.6
	2000[b]	10.0	7.6	10.5	10.0	...	28.3	...	33.6
	2001[b]	10.1	7.2	11.7	10.4	...	28.0	...	32.6
	2002[b]	10.5	7.5	12.1	...	26.0	...	43.9	...
	2003[b]	10.9	7.4	12.0	...	25.4	...	44.3	...
Italy	1971[a]	...	9.8[1]	14.6	11.8		24.1	...	39.7
	1981[a]	...	15.1[1]	16.2	11.6		23.8	...	33.4
	1991[a]	...	19.5[1]	20.2	11.8		22.3	...	26.2
	1995[a]	24.1	14.7	25.5[5]	...	10.0[6]	6.2[7]	...	19.4
	1996[b]	24.7	15.1	16.3	9.2	...	16.8	...	17.9
	1997[b]	24.4	15.1	16.6	9.7	...	17.1	...	17.1
	1999[b]	25.3	15.1	16.6	9.5	...	17.1	...	16.4
	2000[b]	25.1	15.1	16.2	9.6	...	17.5	...	16.5
	2001[b]	25.1	15.2	16.0	9.9	...	17.4	...	16.4
	2002[b]	25.5	15.1	15.9	...	20.7	...	22.8	16.4
	2004[b]	25.5	15.3	16.1	...	21.0	...	22.1	...
Japan	1967[a]	16.4	11.2	14.3	11.3	...	22.1	...	24.8
	1975[a]	19.1	11.3	14.1	11.1	...	21.2	...	23.1
	1990[a]	17.6	10.1	17.0	12.2	...	23.1	...	20.0
	1999[c]	10.6	8.6	13.2	9.8	...	28.4[8]	...	29.5[9]
	2001[c]	10.8	8.7	13.1	9.7	...	28.3[8]	...	29.4[9]
	2004[c]	11.0	8.6	13.0	9.9	...	29.3[8]	...	28.2[9]
USA	1972[d]	13.4	8.6	19.3[5]	...	...	12.2	...	46.5
	1977[d]	13.2	8.4	18.5[5]	...	...	12.4	...	47.5
	1982[d]	16.5	9.5	19.8[5]	...	...	13.0	...	41.3
	1988[e]	12.6	8.3	19.2[5]	...	...	14.5	...	45.5
	1992[e]	12.3	8.0	18.4[5]	...	...	14.3	...	47.0
	1997[e]	11.6	7.6	18.1[5]	...	...	14.5	...	48.2
	1999[e]	11.1	7.3	17.8[5]	...	...	14.1	...	49.7
	2000[e]	10.8	7.3	17.8[5]	...	...	14.3	...	49.9
	2003[e]	11.0	7.3	17.8[5]	...	...	14.5	...	49.3

(a) OECD (1995).
(b) EUROSTAT (2006).
(c) Japan Statistical Bureau (2006); Only Inc.
(d) U.S. Census of Bureau (1972, 1977, 1982a).
(e) U.S. Census of Bureau (2006b); Only Inc.
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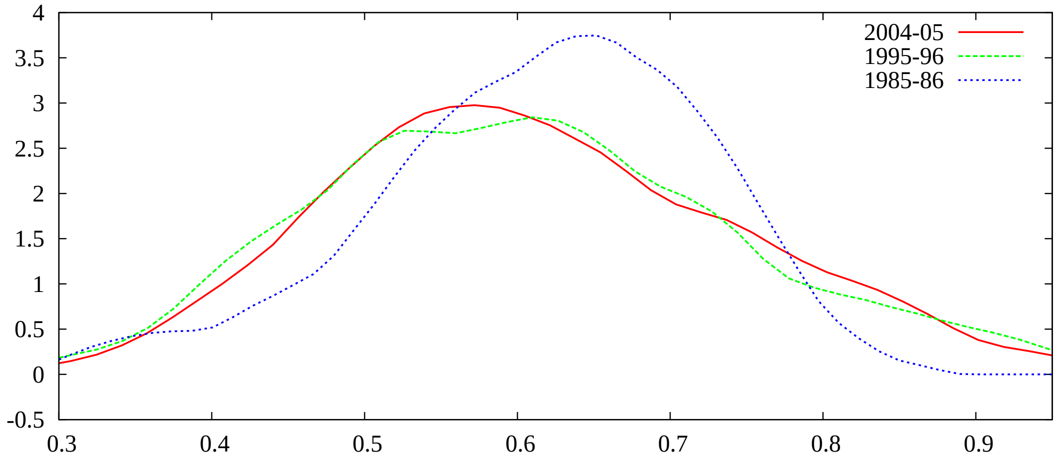

Figure 6: Probability densities of the sectoral concentration index D^4_{20} in terms of total sales, different years (kernel estimates). The support of these densities is [0.3 0.95]. World's largest firms Osiris (2005) database.

$$D^4_{20}(t) = \frac{C_4}{C_{20}} \qquad t = 1982, ..., 2005 \tag{6}$$

where C_4 and C_{20} are the sums of the market shares of the top 4 and top 20 firms in each sector, respectively. If a sector is highly concentrated, D^4_{20} would be near to 1, while it would be 1/5 if all firms were identical.

Figure 6 displays the densities of the concentration measure over the last two decades for all 3 digit sectors with more than 45 observations. Interestingly, the *shapes* of the distributions change a good deal, while the *means* of the distributions vary much less. The modal value of the concentration rates falls from the mid-80's to the mid-90's, remaining roughly stable thereafter. At the same time the upper tail gets fatter. An increasing number of sectors displays $D^4_{20}(t)$ statistics above 0.7, meaning that the first four firms in the "world", as defined in the Osiris dataset, in a particular sector, accounts for more than 70% of the top 20 firms in the same sectoral data record.

Note also that the lower tail seems to be remarkably stable over the last two decades.

This body of evidence in principle is not at all in conflict with the evidence put forward by Ghemawat and Ghadar (2006) suggesting that market globalization *has not in general* carried along an increasing industrial concentration (under all the ambiguities of measurement of corporate sales as distinct from the actual production, etc.). Our somewhat symmetric point is that the new techno-economic paradigm has neither brought along flattening and shrinking size distributions or a generalized fall in the measures of industrial concentration across sectors and across countries.

A quite distinct issue concerns the geographical concentration of industrial activities across countries or regions. Of course, the original legal location of any one firm is a very noisy indication for the location of the overall activities of each large firm (most likely MNCs). Still the national origin of world top-size firms is informative in its own right. Moreover, it continues to hold true that core activities such as strategic management and R&D are mostly performed in country of origin (Cantwell and Iammarino, 2001).

At this level of analysis, *first*, the evidence from the (Fortune 500) upper tail of the size distribution displays a persistent dominance of US-based firms: see Table 5. However, *second*,

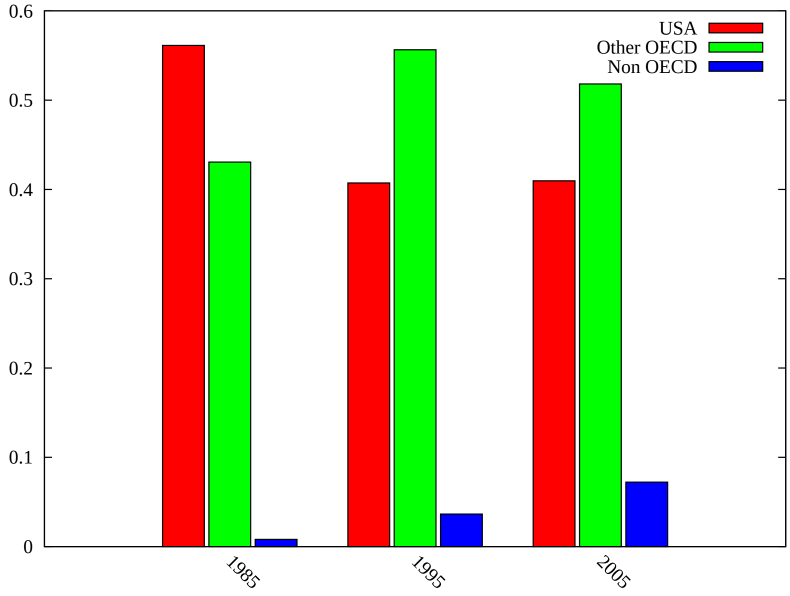

Figure 7: Histogram of the distribution of sales for biggest firms worldwide per geographic origin. Our elaboration on Osiris (2005)

the relative balance amongst big firms[14] has shifted from the '80s to the '90s in favour of non-US firms (cf. Figure 7). It is a decline which operated mostly in favour of Japan and to a less extent of European firms in the last part of the 20^{th} century. It arrested over the latest period, statistically highlighting a European and Japanese slowdown vis-á-vis non-OECD countries, together with the emergence of newer players (e.g. Korean and Chinese oligopolists).

2.5 The dynamics of corporate growth

Clearly, the observed industrial structures - including size distributions and degrees of concentration - are the outcome of the underlying processes of growth of incumbent firms, together with the processes of entry and exit.

Concerning the former, a common starting point in the literature, and also a handy instrument to assess if and how size influences growth, is the so-called *Gibrat's law*.[15]

Let

$$s_i(t+1) = \alpha + \theta_i s_i(t) + \varepsilon_i(t) \tag{7}$$

where $s_i(.)$ are the log-sizes of firm i at times t and $t+1$, and α is the sector-wide (both nominal and real) component of growth.

Gibrat law in its strong form suggests that

(a) $\theta_i = 1$ for every i

(b) $\varepsilon_i(t)$ is an independent identically and normally distributed random variable with zero mean.

[14] With 'bigness' defined on the much larger meter of Osiris firms.

[15] For discussions and reviews of the evidence, see Dosi (2007), Sutton (1997) and Lotti et al. (2003).

Table 5: Total Sales and Number of firms in Fortune Global 500 (2003) for each country. Sales are in billions of U.S. dollars.

Country	Total Sales	Number of firms	Country	Total Sales	Number of firms
United States	5841	189	Russia	62	3
Japan	2181	82	Brazil	61	3
Germany	1363	34	Belgium	60	3
France	1246	37	Norway	60	2
United Kingdom	1079	35	India	60	4
The Netherlands	388	12	Belgium/The Netherlands	57	1
Switzerland	382	12	Mexico	49	1
China	358	15	Venezuela	46	1
Italy	300	8	Denmark	35	2
South Korea	266	11	Luxembourg	29	1
United Kingdom/ The Netherlands	250	2	Malaysia	26	1
Canada	185	13	Singapore	15	1
Spain	162	7	Taiwan	14	1
Australia	107	7	Ireland	12	1
Sweden	96	6	Thailand	12	1
Finland	71	4			
			Total	14,873	500

Hypothesis (a) states the "law of proportionate effect": growth is a *multiplicative* process independent of initial conditions. In other words there are no systematical scale effects.

Note that were one to find $\theta_i > 1$, we ought to observe a persistent tendency toward monopoly. Conversely $\theta_i < 1$ would be evidence corroborating regression-to-the-mean, and, indirectly, witness of some underlying "optimal size" attractor.

Overall, hypothesis (a) which is indeed the object of most inquiries gets a mixed support:

(i) most often, smaller firms - on average - grow faster (under the *caveat* that one generally considers small *surviving* firms);

(ii) otherwise, no strikingly robust relationship appears between size and average rates of growth (see, among the others, Mansfield, 1962; Hall, 1987; Kumar, 1985; Bottazzi et al., 2002; Bottazzi and Secchi, 2003b), but the coefficient θ_i is generally quite close to one;

(iii) the relationship between size and growth is modulated by the age of firms themselves - broadly speaking, with age exerting *negative* effects on growth rates, but *positive* effects on survival probabilities, at least after some post-infancy threshold (Evans, 1987b,a).[16]

(iv) Recent works have also highlighted a rich, non-Gaussian structure in the shocks $\varepsilon_i(t)$: cf. Bottazzi and Secchi (2006a) on US firms and Bottazzi et al. (2007) on Italy (the discussion of this property would however take us too far away from the thrust of this work).

[16]Moreover, the relationship between size and growth appears to be influenced by the stage of development of particular industries along their life cycles (Geroski and Mazzucato, 2002).

For our purposes here let us retain the idea that corporate growth is (and has always been, as far back as our statistics go) a multiplicative process driven by factors that on average have little to do with size either way: that is, size does not seem, now as well as 40 years ago, either to foster or to hinder growth, at least above a certain threshold, with faster growth and higher mortality rates in the smaller cohorts.

2.6 Size, innovativeness and efficiency

As known, the influence of size upon innovative capabilities and/or revealed rates of innovation has long been debated in the literature, often under the misplaced heading of the so-called "Schumpeterian hypothesis" according to which size as such would confer an innovative advantage (for discussions, see Kamien and Schwartz, 1982; Baldwin and Scott, 1987; Cohen and Levin, 1989; Cohen, 1995; Symeonidis, 1996).

The evidence, again, does not seem to support any strong relation between size and innovativeness. So, for example, Scherer (1965), well before the current technological revolution, analyzes the relation between sales, R&D employment, and patents over a few hundred big firms and finds an inverted U-shaped relation between sales and R&D intensities. However, on quite similar data, Soete (1979) identifies strong intersectoral differences, with several sectors displaying "increasing returns" in the relation size-innovativeness. Yet later, Bound et al. (1984), on a larger sample, find again the inverted U, with the peak of innovativeness in the medium size cohorts. The sectoral specificities of the revealed correlation between innovativeness and size is explicitly addressed in Acs and Audretsch (1987) and Acs and Audretsch (1990), which find a positive correlation in 156 industrial sectors, a negative one in 122, and negligible rates of innovation – as they measure them – irrespectively of size in 170 sectors. Pavitt et al. (1987) analyzes innovativeness using a discrete innovation count from the SPRU database and find a U relation (not an inverted one !) with small-medium and very big firms displaying the highest propensity to innovate. Such a relation, however, shows strong sectoral specificities (cfr. the already mentioned taxonomy in Pavitt, 1984). So, for instance, innovative firms are likely to be rather small in industrial machinery; big firms prevail in chemicals, metal working, aerospace and electrical equipment, while many "science-based" sectors (such as electronics and pharmaceuticals) tend to display a bimodal distribution with high rates of innovation of small and very large firms.

The bottom line here, in agreement with Cohen and Levin (1989), is that the results on the relation between size and innovativeness are "inconclusive" and "fragile". And, in fact, a good deal of the evidence on such relationship is further weakened, first, by endemic sample selection biases: quite often one compares the universe of medium-big firms with a biased sample of small ones, indeed, those which innovate. Second, even when one finds size-innovativeness correlations, one should be extremely careful in offering any causal interpretation. It could well be, for example, that in some circumstances being bigger is conducive to innovation (aerospace is a good example), but the opposite direction of causation is generally at work too: a firm is big today precisely because it has been innovative in the past (for example this is a bit the story of Intel).

What about the relationship between size and production efficiency as measured by inputs productivity? We discuss the issue at greater length in Dosi and Grazzi (2006) where we explore such a relation at disaggregated levels in the Italian case. Again, the data seem to suggest either, roughly, *constant returns to scale*, or, a mild evidence of a continuing role of *economies of scale*, plausibly associated with scale-biased forms of mechanization/automation of production.

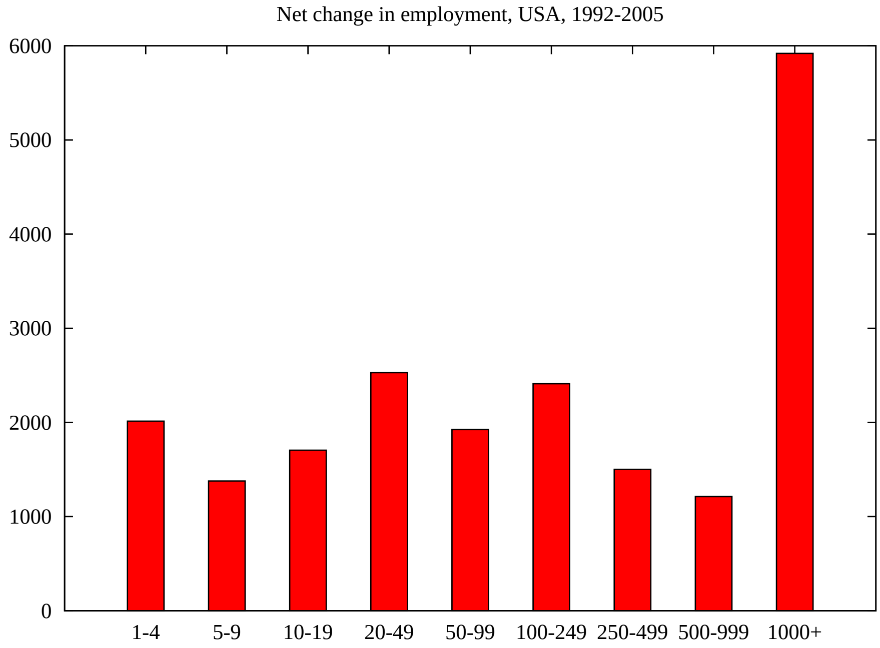

Figure 8: Net change (thousands) in employment per size class, 3^{rd} 1992 - 1^{st} quarter 2005, seasonally adjusted. Source Business Employment Dynamics, BLS (2005).

2.7 Entry, exit and market turbulence

The evidence discussed so far lends support to the existence of some powerful invariances in industrial structures (concerning for example size distribution and growth processes) which appear to hold throughout the current technological revolution. These persistent properties, however, should not be taken as evidence of "business as usual" and even less of any sort of long-term equilibrium.

On the contrary, underlying the foregoing statistical regularities one observes indeed the turbulent microeconomics which Metcalfe (2001) calls "restless capitalism". In fact, an extremely robust stylized fact which seems to apply irrespectively of periods of observation, of countries and sectors, is the persistent turbulence in the profile of industrial evolution, due to persistent entry and exit flows and changes in the incumbents' market shares: for more details see, among the others, Acs and Audretsch (1990), Beesley and Hamilton (1984), Baldwin (1998), Bartelsman and Doms (2000) and the comprehensive comparative analysis on the patterns of entry and exit in Bartelsman et al. (2005). Figure 8 and Table 6 offer a broad picture of the gross and net changes in employment in the U.S. by firms size classes since the early '90's.

Note that relatively high rates of entry are pervasive phenomena even in high capital intensity industries (Acs and Audretsch, 1989, 1991). The overwhelming majority of entrants begins with a small size, with the partial exception of those "entrants" which are actually new subsidiaries of incumbent, sometimes, MNC, firms. Exit rates are quite high too, of the same order of magnitude of entry flows. Roughly, around half of the entrants is dead after seven years in all OECD countries (Bartelsman et al., 2005). The evidence on churning ("rubbish in, rubbish out" dynamics) is quite robust and apparently uncorrelated with the appearance of a new techno-economic paradigm.

Certainly, a phenomenon which distinguishes the last three decades from the previous

Table 6: Average percent shares[a] of gross job gain and gross job losses by firm size, 3^{rd} 1992 - 1^{st} quarter 2005, in thousands, seasonally adjusted. Source Business Employment Dynamics, BLS (2005).

	Firm size class (number of employees)								
CATEGORY	1 - 4	5-9	10 - 19	20 - 49	50 - 99	100 - 249	250 - 499	500 - 999	1000^+
Gross job gains	14.3	11.5	11.9	14.2	9.1	9.8	5.9	4.9	18.4
Expanding firms	7.0	10.6	12.0	15.1	10.0	11.1	6.8	5.7	21.7
Opening firms	51.8	16.0	11.6	9.8	4.3	3.1	1.3	0.9	1.2
Gross job losses	14.6	11.8	12.2	14.4	9.1	9.7	5.8	4.8	17.6
Contracting firms	7.5	11.1	12.3	15.2	10.0	10.8	6.7	5.5	20.9
Closing firms	49.2	15.5	11.7	10.3	4.8	3.9	1.8	1.2	1.6
Net Change	9.9	6.6	8.1	12.1	9.2	11.5	7.3	6.0	29.3

[a] Share measures the percent of the category represented by each firm size class.

period is the apparent increase in the rates of entry of new firms, generally small startups. So, for example, *gross* entry flows in the USA were around 50,000 per year in the early '50 and are around 500,000 in the last decade (with a peak of 700,000 in 1988). It is hard to disentangle the drivers of such a phenomenon. Circumstantial evidence suggests that a significant share of new firms are in fact spin-offs from incumbent firms (on the characteristics of entrants see Bhidé, 2000). Indeed, the emergence of a new technological paradigm is likely to have influenced entry dynamics. One should however avoid any strict identification of entry with "innovative entrepreneurship", the latter being a small subset of the former (see also below).

Less effort has gone into the investigation of the degree of turbulence *in the oligopolistic core of individual industries*. Rather old studies (e.g. Kaplan, 1954; Collins and Preston, 1961; Mermelstein, 1969; Bond, 1975) suggest a relatively high stability in the membership and rankings within such core itself. Broadly in the same vein, Chandler (1990) notes that 96% of the top 200 firms in year 1924 were still present, albeit sometimes under different denominations in 1958. Louçã and Mendonça (2002) resort to Fortune 500 to extend the work of Chandler. They emphasize the long-term turn over of the membership of the largest firms group which is probably attributable to change in the dominant techno-economic paradigm. Come as it may, whatever chosen measure of "turbulence" - including of course death rates - it appears to be much higher among small firms as compared to bigger cohorts (cf. Acs and Audretsch, 1991; Geroski and Toker, 1996).

In any case, one has to carefully distinguish the relative stability of the oligopolistic core in many industries from the dynamics in the relative size rankings of top firms over the whole economy (see Section 3, below, for an interpretative framework). Anecdotal evidence goes both ways: examples that come to mind are, on the "erosion of the oligopolistic leadership" side, General Motors or Westinghouse, and, on the "oligopolistic emergence" side Microsoft or Nokia. But note that the emergence of new oligopolists, like in the latter case does not occur in incumbent sectors but in new lines of business associated with the emergence of new technological paradigms. No doubt, more than two thirds of the first Fortune 500 firms (year 1954) do not appear in current statistics (at least under the original name). However, it does not look to be a sign of an "organizational revolution" specific to the currently emerging new techno-economic paradigms but rather a long-term feature of "restless capitalism" with its persistent emergence of new industrial activities and its changing weights among them.

A complementary angle from which to look at the organizational changes in contemporary industry is in terms of gross and net job flows conditional on firm size classes. In the "Fordist golden age" a good deal of employment creation occurred in medium-large companies. Over the last three decades the contribution of small firms to job creation seems to have increased; for much more detailed analyses on the '80s and early '90s, cf. Boeri and Cramer (1992) and Davis et al. (1996). This applies to different degrees to all OECD countries (OECD, 1994). So for example in the period 1990-95 new production units accounted in the USA for 69% of the total job creation (and 22% of the total was due to new start-ups).

Interestingly, however, the bias toward small firms in employment creation seems to have become less pronounced or even reversed in the most recent years, at least in the USA: bigger firms (with more than 1,000 employees) in the new century are by far the biggest net source of employment (cf. Table 6 and Figure 8). Small firms (especially start-ups) continue to be a major source of *gross* employment creation, but this is matched by impressive rates of employment *destruction*, too (cf. again Table 6). This is in fact the employment facet of the "churning" discussed earlier in terms of entry and death of new firms. Italy - a country characterized by high rates of new firms formation - is a good case to the point: new firms are born mainly in rather traditional industries and often display very low degrees of innovativeness and, as everywhere, many die young.

Note also that widespread entry is not a new phenomenon. As Chandler (1990) himself noted, large integrated firms were mostly concentrated in capital-intensive and technology-intensive industries, and in a handful of countries. Smaller firms have been the norm in labor-intensive activities and in many regions of the world. Moreover, as already remarked, note that in both labor-intensive and capital-intensive industries a good deal of entry and exit has always occurred. The novelty, if any, is the apparent relative increase in turbulence – with higher rates of both entry and exit – at the lower end of the size distribution.

2.8 Some Conclusion: the Major Stylized Facts

Let us summarize the relevant stylized facts so far:

a) A few OECD countries, especially European ones, display a decline in average firm size starting in the late 70's early 80's. Yet, the decline has not been dramatic. Large firms still play an important role in terms of output and employment. And in fact the importance of the largest firms seems to have increased in the US over the most recent period.

b) At the aggregate level the size distribution of firms is still considerably skewed. In this respect, a well established and persistent fact, which is robust across countries, is that the overall firm size distribution is close to a Pareto one. The picture is more blurred at more disaggregate sectoral levels, but the skewness of the distribution remains a robust property.

c) The science-based industries and the scale-intensive ones, according to the classification by Pavitt (1984), exhibit a more asymmetric distribution. Circumstantial evidence confirms Pavitt's findings that science-based industries display a higher share of both very large and quite small firms.

d) The most important change compared to the earlier decades has been the notable increase in the number of new firm entries, especially in the US and partly in the UK, made of both new start-ups and on many occasions spin-offs from existing firms. The new firms account for a significant share of the increase in employment as measured by gross job flows and a positive but much lower share of net job gains.

e) Since the new entries are accompanied by corresponding high exit rates, the recent decades have exhibited an increase in industrial turbulence at least at the lower end of the size distribution.

f) Finally, while there has been a trend towards globalization, this has not implied greater oligopolistic concentration worldwide, and certainly not a greater concentration of international production in the US. However our elaborations show that sectoral degrees of concentration have not fallen systematically either, with the mode of concentration measures falling from the '80s to the '90s (and remaining stable thereafter), but also with an increase in the number of highly concentrated sectors.

What does this evidence tell us about the possible emergence of a "new regime" of industrial organization possibly based on a different balance between small and big firms? In order to answer the question, let us first spell out some elements of a theory of the processes of competition and division of labor underlying the continuing co-existence of firms of different sizes and different organizational and technological characteristics. To do that we ask the reader to bear with us through some formalism which will help highlighting the main processes at work.

3 Theoretical models and observational implications: learning, competition and industrial organisation

3.1 Firms size: some introductory remarks

As a starting point for our discussion, it might be useful to begin from some simple identities. Let us consider an economy composed by m productive activities, which - in a first approximation - we assume to correspond to specific markets (M_j , $j = 1, ..., m$). If the assumption is added that each firm i ($i = 1, ..., n$) is active exclusively in a single activity / market, its size in terms of output, S_i, is obviously equal to the total size of the market multiplied by its market share, f_{ij}

$$S_i \equiv f_{ij} M_j \tag{8}$$

In the more empirically plausible case of firms characterized by varying degrees of diversification, among final products, and of vertical integration (abstracting for sake of simplicity from considering the input-output relations of the economy), the firm's size is:

$$S_i \equiv \sum_j f_{ij} M_j \tag{9}$$

Given these identities, each observed distribution in the S_i needs an interpretation of the distribution of the shares within each market and among markets, as well as, over time, of the dynamics of the shares themselves and of the total sizes of the markets.

3.2 Product differentiation, vertical integration and diversification: the boundaries of firms

Start by noting that rarely any one "market" can be simply identified as corresponding to a product and a univocal set of "productive activities". A necessary condition is obviously a perfectly homogeneous good. Yet in reality each market usually involves a collection - changing over time - of imperfectly substitutable goods, even abstracting from the unavoidable statistical arbitrariness and the resulting aggregation problems. This applies to products that are a) horizontally differentiated in their characteristics for the final consumer (in line with Lancaster, 1979 and its predecessor Hotelling, 1929; Chamberlin, 1962 and Robinson, 1933), b) vertically differentiated in term of some ordering of quality (Shaked and Sutton, 1978) or c) intermediate products and capital goods with different technical characteristic and performances (see, among others, Freeman, 1982; Dosi, 1988).

A straightforward implication of such differences in otherwise similar products is the likely possibility that many firms having a non-null measure coexist occupying different market niches. However, the simple observation of product differentiation or monopolistic competition as such does not suffice to support any prediction on the form of the firms' size distributions. Even (incorrectly) postulating a direct correlation between firm's size and the size of the market, it could well be – and in fact is – the case that large firms are large also because they horizontally diversify in many markets.

Consider next "vertical measure" of firms. So far, we have been assuming that to each product / market was associated a characteristic set of "productive activities". But ever since Adam Smith, it is well known that such activities are subject to varying degrees of "decomposition", along the chain from the raw materials to the final products. In turn, "decomposition" of different activities may or may not be associated with patterns of division of labor among different firms, as a function of the size of the markets and of technical change. When this is the case, it also associated to the emergence of a corresponding "market" of the intermediate product. Thus, different technical decompositions and different degrees of vertical integration or specialization of productive processes may correspond to different sets of markets. In turn, this determines, *ceteris paribus*, different firms' size distributions. So for example, it is of course possible to think of a firm which is large in absolute terms because it is highly vertically integrated, but it is small with respect to the size of the final market in which it is active (i.e. with a small f_{ij} over a large M_j), or viceversa a firm with a large f notwithstanding low degrees of vertical integration.

In a fundamental sense, the "thickness" of each market is endogenous to the dynamics of technologies and institutions. Thus, in the old Soviet Union the number of "markets" corresponded at the most to the number of final markets. Conversely, the Italian industrial districts is the example that matches more closely the ideal archetype in which to each technical task corresponds different firms and different markets, like in the Smithian parable of pin making.

In an extreme synthesis, size distributions depend tautologically – given the size of the markets – on a) the distribution of market shares in each market; b) the degree of integration among vertically related activities / markets; c) the degree of horizontal diversification on different markets.

The question then becomes what are the processes that generate those distributions. Ultimately, they concern (i) the dynamics of market shares in each market and (ii) the determinants of the vertical and horizontal boundaries of firms (and their dynamics). In other works (Dosi and Marengo, 1994; Dosi et al., 1995, 1997; Teece et al., 1994) one discusses the comparative merits of competing theories offering an interpretation of such patterns. For the purposes of this paper, we shall only propose succinctly some interpretations and conjectures.

Let us start with the second set of issues concerning the vertical and horizontal boundaries of firms. This is a particularly delicate question because ultimately it has to do with the very problem of "what is a firm" jointly with an interpretation of its structure and behavior. Heroically reducing a particularly complicated subject to a telegraphic discussion, let us suggest that each firm can be thought of as a relatively coherent behavioural entity which embodies a) specific problem-solving procedures (that is to say, competences concerning technologies, manufacturing, marketing, relationships with customers and suppliers, etc..); b) specific mechanisms governing potentially conflicting interests within the organization itself and with the interacting entities; and c) specific strategic orientations, concerning for example pricing policies, investments, R&D, diversification, etc., i.e. its "dynamic capabilities" (more on all this in Dosi and Marengo, 1994; Teece et al., 1994; Dosi et al., 2000; Teece et al., 1997; Dosi and Coriat, 1998).

Coherent with this definition, our hypothesis is that the potential boundaries of the firms are approximately determined by its knowledge bases jointly with the complementary assets controlled by the firm itself (Teece et al., 1994). The word potential is crucial: a firm - or even entire systems of firms - can plausibly choose to explore a very small subset of this potential. On the contrary, one can historically observe firms which try to overstretch these boundaries in the attempt of compensating factors of backwardness upstream and downstream, especially in technologically lagging countries.

These potential boundaries are highly conditioned by the sectors of principal activity of the firms. Various works have begun to provide taxonomies of these patterns (Patell and Pavitt, 1998; Piscitello, 2000). The basic intuitive idea is almost trivial for non economists (the competences needed for producing a car are useless for producing biscuits) but its operationalization is much more complex, also because it is not easy to find non tautological proxies of the very notion of "organisational capabilities").

Within these potential boundaries - we suggest - the actual patterns of vertical integration and diversification are modulated by factors pertaining to a) alternative governance mechanisms of transactions, as in the Williamsonian tradition, and b) (*lato sensu*, "Smithian") processes of technical and organisational division of labour.

At the end, firms with different sizes tend to undertake a number of activities which empirically appears to be monotonic in the size itself, with a relation hinting at a possible underlying dynamics of diversification driven by the incremental exploitation and expansion of the idiosyncratic capabilities of the firm[17].

In synthesis: a first restriction on the "measure of firms" comes from the technological and organisational conditions that influence the values of the variables of summation in identity (9), even though these restrictions still leave ample degrees of behavioural freedom, as the comparative evidence e.g. between Italy, the USA or Japan shows (cf. Table 3 and 4).

[17]The scaling coefficient linking number of markets / activities and size appears to be robustly close to .35. That is at each doubling of size the number of activities increases by one third (Bottazzi and Secchi, 2006b; Castaldi et al., 2006). In turn such relation is consistent with a process of diversification formally represented as a branching process (Bottazzi and Secchi, 2006b), well in tune with a notion of incremental addition of lines of activities building on the incumbent capabilities.

3.3 Learning and selection

Given whatever notion of "market" as the domain of competitive interactions, a fundamental question, which straightforwardly concerns size, regards the dynamics in the shares in production and sales of individual firms in each market in which they operate, that is the dynamics of the f_{ij} in eq. 8.

Following a large body of evolutionary inspired works, let us assume that a set of variables which approximate the specific capabilities of firms map - directly and indirectly - into their competitive performances (often, evolutionary models refer to a "fitness" variable, using a metaphor perhaps too close to the biological archetype). These variables include obviously the prices and the performance of products, but also other organisational and spatial dimensions, like localisation of production, distribution channels, etc. Moreover, these characteristics of individual firms influence performance through their behavioural patterns: for example, price-cost margins, localisation strategies, product positioning in niche vs. mass markets, diversification vs. specialisation, etc.

Come as it may, by heroically simplifying, it is possible to represent "reduced forms" of the competitive interactions, in which vectors of firm-specific characteristics, **a**, influence the dynamics of their shares. Let us assume

$$\Delta f = g(f, \mathbf{a}) \tag{10}$$

where f is the vector of the firms' shares and the function $g(.,.)$ summarises the interactions mapping the firms' technological, organisational, behavioural specific characteristics on the dynamics of the shares. (In the jargon of many evolutionary models, function $g(.,.)$ defines the *fitness landscape* on which firms survive, grow, die.). Even more parsimoniously, dynamic models sharing this inspiration often collapse all the factors influencing the interactive dynamics into a "synthetic variable" - "competitiveness" $e(.)$ - , and under further simplifications they study the properties of markets in which shares monotonically evolve in the differences between "average competitiveness" $\overline{\mathbf{e}} = \sum_i f_i e_i$ and the specific competitiveness of each firm[18]

$$\Delta f = A[e_i(t) - \overline{\mathbf{e}}(t)]f_i(t) \tag{11}$$

Let us offer just some quite general considerations.

First, notice that "space" – both literally defined in terms of 'where the markets are' and metaphorically referred to product characteristics – contributes to define the shape of the fitness landscape: *ceteris paribus*, a perfectly homogenous market will tend to generate smooth, single peaked, landscapes (e.g. lower prices always attract more customers) while product differentiation will tend to produce many peaks, corresponding to market niches, etc.

Second, the function $g(.,.)$ – when it is applied to economic domains – is inevitably influenced by behavioural factors. The variables in the vector **a**, eq. 10, determine how much a firm's competitiveness can allow it to grow, but actual growth depends also on how much the firm *wants* to grow; that is to say its expansion strategies, propensities to invest, etc. (the point is emphasized also by Metcalfe, 2001).

Third, notice that the function $g(.,.)$ captures then the "strength" of selection. In the linear form of equation 11, the parameter A determines the reactivity of shares to competitiveness

[18]Such "replicator type" dynamics concerning the competitive process in economics are discussed in Silverberg (1988) and Metcalfe (2001) and enter explicitly in evolutionary models such as Dosi et al. (1995). However, most models of evolutionary inspiration, including Nelson and Winter (1982), implicitly entail a similar selection dynamics.

differentials: the higher is A, the higher are the prizes and the punishments that the market attributes to more or less competitive firms.

Fourth, technological and organisational innovation determines the dynamics of the $\mathbf{a}_i$ for each firm. This is the essential link between the theory of industrial evolution and firm growth on the one hand and the analysis of technological and organisational change on the other. Ultimately, the dynamics of the $\mathbf{a}_i$ and their evolving distributions capture the processes of *learning* of whatever kind by each firm. Conversely, the $g(.,.)$ accounts for competitive *selection* processes amongst firms carrying different technological, organizational and behavioural traits.

How do different dynamics over $\mathbf{a}_i$ and different market processes influence firm growth, industrial evolution and the boundaries between what is internalized within firms and what is exchanged through markets? Work has begun to explore both empirically and formally different learning regimes and their implications on industrial dynamics, but admittedly one is still far from any thorough answer.[19]

Recall eq. 7, with its "Gibrat" representation of the stochastic process of firm growth. Even abstracting for a moment from the role of entry and from the fact that growth occurs also through diversification and vertical integration / disintegration, if one believes that the "true" dynamics is some stochastic version of eq. 10, then the "true drivers" of change, namely the distributions of the $\mathbf{a}_i$ and the forms of the $g()$ function, should affect the observed statistical paths. In the "Gibrat representation", they should do it by affecting the $\theta_i(t)$ and $\varepsilon_i(t)$ terms in eq. 7. So for example, the more competition bites, the more should the $\varepsilon_i(t)$ terms be correlated across firms (i.e. the "most competitive" firms ought to quickly eat out the possibilities of growth of other firms). And the more "success breeds success", the more the positive shocks on the $\varepsilon_i(t)$ ought to be serially correlated over time. We still know little on statistical grounds about the mapping between different *regimes of learning and selection* and different patterns of corporate growth, and, more so, we are still far from discriminating from a formal point of view the implications of different learning / selection regimes in terms of different industrial structures, firm size distributions, etc. Short of that, one has begun to explore the robustness of phenomenological taxonomies and their implications in terms of patterns of industrial evolution. So, for example, in other works (Dosi et al., 1995; Winter et al., 2000; Malerba et al., 1999; Malerba and Orsenigo, 2002), one has started to analyse the properties of alternative sectoral learning regimes, comparing the "Schumpeter I" archetype, where innovation is essentially driven by new entrants, to the opposite "Schumpeter II" regime, where incumbents learn in a cumulative way.

More recent attempts include efforts to model industry evolution and firms growth considering also diversification and vertical integration / disintegration (Malerba et al., 2008). Here, the vertical structure of firms is critically affected by the actual distribution of capabilities across firms in upstream and downstream industries. For example, the decision to specialize is elicited by and critically depends on the actual existence of upstream suppliers at least as competent as the integrated firm itself. Moreover, when products are systems with various components and subsystems, the ability to coordinate and integrate the design of such systems and components may constitute an important competence in its own right and a significant source of competitive advantage.

In fact, in other works one shows that if: i) learning is not too biased against incumbence, ii)

[19] For empirical analyses, see among others, Malerba and Orsenigo (1997) and Breschi et al. (2000); for formal models, see Winter (1984), Dosi et al. (1995), Winter et al. (2000), Malerba et al. (1999) and Malerba and Orsenigo (2002).

the vertical boundaries of firms do not dramatically change and iii) there are no "revolutions" in the balance between "Schumpeter" I and "Schumpeter" II regimes of industrial change then the distribution of firm sizes in the aggregate turns out to be relatively close to a Pareto one as it does in the real world (cf. Dosi and Salvatore, 1992; Dosi et al., 1995).

3.4 Typologies of (small) firms

Up to this point, our discussion of industry structures and their dynamics has been conducted at a rather abstract level, attempting to identify some robust properties of the underlying evolutionary processes and their relations with the patterns of learning, market selection, diversification and vertical integration. In the next Section we shall try to use this simplified conceptual apparatus to discuss the implications of current technological and organizational changes in terms of firm sizes and boundaries. However, in order to begin linking the foregoing conceptual framework to the following more qualitative discussion of the changing role of small and large companies, let us distinguish between different types of small firms and different reasons why they are small. In particular, one may roughly identify five types:

- "Marginal" firms, who manage to survive in local markets, whose existence is often allowed by the exercise of monopolistic power by larger and more efficient competitors or simply by the slowness and imperfections of market selection (early precisions insights on the process are in Steindl, 1945);

- "Chamberlin - Robinson - Hotelling" firms, i.e. small companies that survive and prosper into particular niches of differentiated product markets;

- "Smithian" firms, i.e. firms based on processes of division of labour and specialised in the supply of intermediate products and components to other, often larger, companies, sometimes on the basis of organised sub-contracting relations;

- "Marshallian" firms, i.e. companies that are active in a specific geographical area (a "district") often specialised in some stage of the value chain and/or in a product niche (in that they largely overlap with the former two categories);

- "Schumpeterian" firms, i.e. companies which are born to develop an innovation of whatever kind. In some cases, these firms grow or are acquired by larger companies. In most cases, these firms fail. However, these firms are small essentially because they are young.

These distinctions are of course overly simplified. For example, a new biotechnology firm may well be categorized as both a Schumpeterian and a Smithian firm. And sometimes it may also belong to a particular geographical cluster. However, the distinction remains useful as long as it forces us to distinguish among different processes and causes of the changes in the organisation of productive activities.

4 Continuity and changes in organizational forms, learning patterns, and competitive processes

With the foregoing conceptual framework in mind, let us try to better understand the reasons behind the evidence on the significant increase in the importance of smaller firms in the last part of the 20^{th} century and its more recent interruption, discussed in Section 2 above.

In the following, first we argue that the role of smaller firms can be explained, in part, by the growth of product differentiation and variety. Following the argument in Section 3.2, as the number of submarkets increases it might be more difficult for one firm to dominate a larger, but more fragmented market. The point is straightforward. If a market of size 100 is homogeneous, the assets that are necessary to gain market shares in that market are undifferentiated. Economies of scale and learning processes then may well enable one firm to obtain an overall competitive advantage. By contrast, if the same market is divided into 10 markets of size 10, with differentiated assets necessary to operate in each market, learning across submarkets might be more difficult: hence a higher probability that different firms dominate different niches.

The second issue that we address is vertical specialization, the changing division of "innovative" labor (Arora et al., 2004), and the associated patterns of specialization and comparative advantages of firms of different size. We point out the growing importance of these processes in some high-tech industries and suggest that some of the observed changes in the size distribution of firms that took place in the 80's and the 90's may be grounded in these phenomena. As a related point, we discuss the emergence of agglomeration of technology-based industries in geographical clusters. Silicon Valley is a prototypical example. At the same time, the Silicon Valley model, based on high rates of entry and exit has diffused in a few industries to other countries, including newly rising economies like Ireland, Israel, or India (Bresnahan and Gambardella, 2004; Arora and Gambardella, 2005). The Silicon Valley model rests on a flow of relatively smaller firms associated with the processes of innovative exploration. Yet, it also produces a new role for the larger firms as the latter preserve a comparative advantage in the exploitation of innovative advances and in incremental innovation, which can even be enhanced by a more productive exploration process. Moreover, while Silicon Valley type environments are the locus of smaller innovative firms, they are also the province of some rather large firms, often "Schumpeterian firms" which have grown big.

Third, we discuss the existing trends towards product modularity and their organizational implication. Once again, the separability in product components can give rise to specialization and smaller size, because individual firms can master a single module and do not need to control the entire production process. Yet, modularity requires coordination, and this calls for the role of larger firms as system integrators.

4.1 Product variety and differentiation: the horizontal boundaries of firms

A first reason of decreasing average firm sizes can be found in the opportunities for product differentiation. In some cases, differentiation is intrinsic to the diversity of applications of a basic technology. Laser is one example. As discussed by Klepper and Thompson (2007), laser products are differentiated. This is associated with several market niches. In turn, no firm has been able to cover a large set of such niches, which has kept the industry from consolidating into a tight oligopoly. Interestingly, this is the same process suggested by Sutton (1998) with his flowmeter example. In flowmeters, like in laser, the lack of consolidation does not stem from the fragmented nature of the technology, whose basic features are common to the application sectors, but on the fragmentation of the industry downstream. That is, applications of the same technology are differentiated by the specific uses and requirements by customers. When an industry is not fragmented, economies of scale induce the more efficient firms to cover larger shares of the market. But when a market of identical equal size is fragmented, such economies of scale are less prominent because the fixed costs have to be born for each market niche and also learning is likely to be niche-specific. As a result, companies can dominate only if they are better in each and every submarket or in a large number of them. This is unlikely in so far as different companies develop specific capabilities in different sub-markets. As a result, a structure in which one firm covers a large share of sub-markets is less likely than in the case of more homogenous final products.

In a more dynamic, evolutionary perspective, this argument can be recast in terms of learning and capabilities. Take the example of pharmaceuticals. Here, research capabilities developed for one product – e.g. a drug for the treatment of hypertension – might be of limited use for the search of say, Parkinson treatments. In fact, capabilities are likely to be accumulated incrementally and this is reflected also by the pace of diversification across submarkets.[20] That is to say, the horizontal boundaries of firms are defined by the span of their capabilities over differentiated products and markets.

Circumstantial evidence suggests that the application of ICT technologies to a wide ensemble of production processes and the associated transition to post-Fordist patterns of production and demand have increased the scope for product differentiation. Hence a possible first driver of an increased share of smaller firms over the total of the manufacturing population.

4.2 Smith, Marshall, and Schumpeter: the vertical boundaries of firms

A second category of processes driving changes in firm sizes and firm boundaries involves changing patterns of division of labour. There is little question that increasing division of labour and specialisation constitute a fundamental secular tendency in economic activities. From Adam Smith to Allyn Young to Herbert Simon, the notion that division of labour is a crucial "natural" engine of productivity growth is probably one of the less disputed propositions in economics. Indeed, it is a major stylized fact in the history of industries, technologies and business enterprises that progress occurs also through significant processes of specialisation. The history of the mechanical and electro-mechanical industries are typical examples. In this respect, the birth and diffusion of specialised firms - what we have labeled as the "Smithian firms" - is by no means a new phenomenon (Pavitt, 1998). And, other things being equal, one would expect such processes to be favoured by growing and more integrated markets (in line with the Smithian adagio that the division of labour is limited by the extent of the market).

However, it is important to distinguish between different drivers of the processes of division of labour. One process concerns the "natural" tendency towards increasing specialisation that occurs along an industry life cycle / a technological trajectory whereby as a technological paradigm matures, intermediate inputs tend to become more standardized, economies of scale in production become more relevant and the emergence of specialized producers of intermediate inputs and machinery gets easier. A significantly different question regards the extent to which specific new technologies based on ICT tend *intrinsically* to favour more decentralized forms of organisation as compared to more vertically integrated structures. In this respect, it has been suggested that the ICT revolution systematically favors vertical disintegration and arm-length form of coordination of what were previously integrated units.[21]

[20] In the case of the pharmaceutical industry Bottazzi and Secchi (2006b) show that the diversification patterns, as already mentioned, can be well described by a branching process.

[21] This is also part of Langlois' argument on the "vanishing hand" of big integrated corporations Langlois (2003).

Certainly, in both scale-intensive and science-based sectors the application of information technologies to design and production has fostered concepts and practices like product modularity (since IBM's system 360), which has in turn affected organizational modularity (Sanchez and Mahoney, 1996; Brusoni and Prencipe, 2001, see also below).

Together vertical specialization has become more prominent also in some high-tech industries (e.g. semiconductors, and even pharmaceuticals). In particular, as suggested by Arora et al. (2004), one observes a tendency towards an increasing division of "innovative" labour. The process is particularly evident in sectors like software, semiconductors – with the development of the fabless firms – and in the bio-pharmaceutical industry.

More generally, the advent of the ICT revolution has offered not only opportunities for the discovery and development of new products and processes, but has often entailed major organizational innovations. There is no need to emphasize how the diffusion of information technologies has made it possible major organisational transformations, ranging from so-called "flexible automation", all the way to modularization, to e-commerce, all involving the possibility of decentralization of activities previously carried out within the boundaries of individual firms.

The acknowledgment of the foregoing "Smithian" tendencies is sometimes complemented by a "Marshallian" argument. Not only the large, vertically integrated corporation, it is argued, has become less efficient than more decentralized and specialised structures interacting in the production process, but such collections of specialised firms have also specific spatial connotations, i.e. spatial concentration of economic activities confers "externality" advantages to those firms. Despite their enormous differences, the emphasis on both "Smithian" and "Marshallian" tendencies is an ingredient of the argument suggesting that a "Third Industrial Revolution" did occur or is occurring involving the demise of the vertically and horizontally integrated corporation in favour of networks of small(er), highly specialised firms interacting together in the invention, development, production and marketing of products. While both the Smithian (vertical specialization) and the Marshallian (Silicon Valley) type processes would seem to have become more prominent than in the "Fordist" past, these points have to be qualified.

First, as noted by our data, the trend towards smaller firm size is perceptible but not so dramatic to call for a revolution in the distribution of firm sizes. This observation is more consistent with secular Smithian processes of division of labour, rather than with the thesis of a drastic revolution giving a systematic advantage to smaller size firms.

Second, Marshallian clusters of small firms are again certainly not a new phenomenon. Even assuming that Marshallian clusters have actually become increasingly important as compared to the "First" and "Second" Industrial Revolutions, it must be recognised that Silicon Valley itself is not simply the paradise of small entrepreneurs and small companies. It is also the locus of some of the largest firms worldwide in addition of course to many smaller ones.

A related but distinct question concerns whether a new model of organisation of large corporations – loosely definable as the "network" form – is supplanting the Chandlerian-Fordist one.

The statistical evidence discussed in section 2 above on the relative stickiness of size distributions throughout the current technological revolution throw doubts on such an hypothesis. If anything, as the data on the distribution of firms' size show, the ratio of what is produced within the boundaries of firms and what is exchanged via market transactions would appear to have remained fairly constant or only slightly decreasing.

Yet, there is certainly ample evidence, both anecdotal and based on rigorous case studies of firms and industries, indicating that vertical disintegration, outsourcing and de-conglomeration are actually very important tendencies in the organisation of innovative and productive activities in many industries hinting at some discontinuity *vis á vis* the Chandlerian/ Fordist past. Our interpretative suggestion is indeed that such discontinuity regards more the ways large firms are internally organized, managed, and interact with the environment that surrounds them than the fact that they have been replaced by systems of smaller firms.

Once again, it can be reasonably argued that none of these processes is entirely new.

As Langlois (2003) notes the rise of the multidivisional firm was itself at one level a Smithian process, i.e. an attempt at decoupling and separating vertically – and horizontally – related activities, through the professionalization of management and through the separation of strategy from day-to-day operations.

With regards to the distribution of innovative labor Mueller (1962) noted that well inside the "Chandlerian era" many of the important innovations by DuPont originated outside DuPont: ideas or early prototypes were often generated by others, typically smaller concerns. Likewise, Lamoreaux and Sokoloff (2007) have shown that vibrant markets for technology existed and prospered in the second half of the 19*th* century in the USA. Yet, these patterns have become more widespread than in the "Fordist" past, involving a greater reliance on outsourcing, a greater importance of markets for technology and greater degrees of organizational decentralization. Let us start from the former.

Outsourcing is an increasingly important phenomenon, as epitomized by the growing fears of countries like the US or even Europe for the movement of jobs outside their own national boundaries towards new locations in China, India or Asia more generally. In fact, the concerns go beyond outsourcing in traditional sectors – experiencing "natural" industrial life cycles –, and regard outsourcing of jobs in more advanced industries in which the US or other advanced countries could still retain comparative advantages when judged by the lens of the life cycle story. Of course outsourcing as such might not affect the "size" of firms when measured in terms of sales but should do so when measured in terms of value added: still there is no systematic evidence, to our knowledge, of a trend in this direction. At the same time, there is good evidence that licensing deals have increased significantly worldwide since 1990, and that markets for technology are rising (Athreye and Cantwell, 2007; Arora et al., 2004). Yet, our point is that these very same processes have not pushed unilaterally towards a greater importance of smaller firms and decentralized networks as opposed to larger integrated firms.

4.3 The dynamics of exploration and exploitation

A particularly important issue regards the relationship between specialized (small) firms and integrated (plausibly bigger) ones with respect to the division of innovative labor. The tricky issues here concern the possible trade offs between exploration of new innovative knowledge and its exploitation on the one hand and between decentralization and coordination, on the other. Start by noting that whenever the innovative process does not require significant complementary assets such as, for instance, manufacturing facilities (Teece, 1986), then "Smithian" vertical disintegration, "Schumpeterian" technology markets, and the "Marshallian" Silicon Valleys, are likely to enhance the degree of *exploration*. If the development of an innovation requires integration with downstream manufacturing or commercialization assets, only the firms owning these assets can innovate. In turn, this sets an upper bound to the number of innovators. By contrast, as Arora et al. (2004) point out, if vertical specialization, and related separation, in different organizations are possible between activities for producing innovations and activities for developing them, there can be more innovation "trials". This is because "ideas" can be tried out at low fixed costs. Put simply, without separability, innovation producers have to have the downstream assets, and innovation manufacturers have to have the ability to produce innovations. Separation between these stages of the innovation process makes it possible for the "explorers" to pursue innovative search even if they do not have the costly downstream assets. It is of course not at all clear ex ante whether new ideas will become profitable for someone else to buy and exploit it. But the failure rates are only limited to the research assets and not to the downstream production or commercialization networks. In some cases - e.g. new software programs - these innovation trial costs can be rather small. All this, other things being equal, leads to more innovation trials, because it is less costly to do so, and hence there are lower barriers to entry in the exploration activities.

The obvious consequence of the higher degree of exploration and of the higher number of potential innovations is that technological opportunities are tapped more intensively. Under this scenario the very process of vertical specialization means that the firms with the capabilities to develop new products downstream can access a wider set of the innovation input more productively. This reinforces their comparative advantage and consequently their role in the vertical division of labour. In short, the very success of smaller decentralized firms "upstream", and the very fact that these firms are part of a broader process that involves larger more integrated companies "downstream" makes also the latter more effective. Thus, we ought to observe that larger firms become key agents "downstream" and in R&D activities that require large scale.

Clearly under this scenario vertical disintegration of innovative labour does not necessarily involves a changing balance between small and big firms but just a different pattern of division of labour among them.

There is however a downside to this set-up. In the vertically disintegrated structure we have described, even if more "ideas" are explored, one is bound to bear the costs of having a fragmented structure for innovation with possibly a lower potential for learning. More integrated structures may improve learning processes, which under vertical disintegration are harder to pursue because knowledge is dispersed in many different uncoordinated avenues, across many smaller independent firms. The point is made by Pisano (2006) with respect to biotech firms but we think that such trade-off – i.e. greater exploration at the expense of better more consolidated learning processes along fewer but well defined trajectories – is an important one, which goes beyond the confines of the drug industry.

Indeed, the current technological revolution (as other ones in the past: see Perez, 2007) has been associated with a surge of entry of small innovative companies which ultimately has led to the dotcom bubble. There are signs of an increasing appreciation of the potential advantages from greater integration in the most recent years. For example, the nanotechnology business seems to be the province of firms that are still small compared to the larger established oligopolists of the world, but are also larger and more integrated than many biotech entities. To the extent that these tendencies are there to stay, they suggests that we ought to observe some reintegration in the near future. Our hanch is that again this will not make a revolution in the pattern of division of innovative labour. But "disintegrated exploration" may cyclically leave room to a greater degree of exploitation, increasing the role of "exploitative" vis-á-vis "explorative" firms. Once again, the trends of the past two decades are not likely to be the beginning of a secular dynamics but rather part of repeated historical swings from "excessive" fragmentation – often associated with the decentralized activities of exploration typical of the emergence of new technological paradigms –, to integration – and thus the dominance of "exploitation" and incremental innovation, often characteristics of more mature technological paradigm.

4.4 Modularisation and the division of innovative labour: integration and the Visible Hand

Another side of trade-off specialisation/ integration has to do with the need for coordination, even in the presence of processes of modularization and of division of innovative labour. In this respect, it is often argued that, by adopting modular design strategies, firms can take responsibility for the design and development of separate modules. Thus, they can develop new products at a faster pace, as the integration of the final product is a matter of mix and match of 'black boxes' (Baldwin and Clark, 2001, 2000; Sanchez and Mahoney, 1996). This is supposedly made possible by codified technological knowledge about component interactions that can be used to fully specify and standardize component interfaces and, therefore, to decouple the design of the product architecture (i.e. the arrangement of functional elements) from the design of each module. Modularity, by simplifying design and development processes, would thus allow a greater division of labour across firms.

However, modularity implies a trade-off between the 'speed' of search (enabled by modularity) and the 'breadth' of search (made easier by non-modular search strategies). Apparently, modular search strategies are indeed highly efficient in the short term enabling fast searches within a predefined search space. However, these gains might disappear in the long term, as 'slower' (i.e., less modular) search strategies reach better solutions as they can explore wider search spaces, exactly because they rely on less tightly defined 'design rules'. Thus, in dynamic terms, modularity may entail some risks: firms may miss value-generating alternatives because they cannot escape the boundaries set by the existing modular design strategies (Brusoni et al., 2001).[22]

In this respect, modularization, while it simplifies the problem of searching for better design and it fosters division of labour, it calls at the same time for an increasing role played by system integrators, who remain involved in exploratory research that looks beyond the boundaries set by current architectures in order to be able to lead the process of development of successive generations of systems. Put it another way, increasing specialisation generated by modularity requires the development of more centralized agents who "coordinate" the integration of different modules and - even more important - the development of new systems.

We noted in the previous section that the greater opportunity to separate research from development and production, and the possibility to define specific intermediate research outputs to be transferred across organizations, imply that the rate at which individuals can experiment their innovations in the economy has increased. In turn, this explains some of the factors discussed earlier, viz. high-tech entrepreneurship and market turbulence.

However, in other respects, large corporations do not simply specialize in the development of innovations created by others. They perform at the same time the crucial role of integrators of fragments of specialised knowledge, building up architectures or frames which organize and structure the knowledge required to develop, produce and sell new products. Even in the case of biotechnology, large firms appear as central nodes in a hierarchically structured network of relationships (Orsenigo et al., 2001), whose density remains basically stable. Division of labour and decentralization associated with the expansion of the network require at the same time stronger integration and coordination within the nodes of the network. As some activities are outsourced, their coordination implies the development of highly structured functions dedicated to their management and to the achievement of coherence and integration. In other words, division of labour does not simply reduce the need for managerial control, but shifts

[22]Some of these properties are formally explored and corroborated in Marengo and Dosi (2005)

it at different levels. Thus, the management of supply chains does not eliminate the need for hierarchical control. If anything, it changes its nature and its practices. But one could legitimately argue that the management of supply chains is a more organisationally complex activity than straightforward vertical integration.

In this perspective, the Visible Hand is not disappearing. Perhaps the grip of its fist is relaxing. But its strength is not weakened: its grip is perhaps smoother but firmer.

4.5 Innovation, entrepreneurial firms and the life cycle of industries

Last but not least it is important to remark that the balance between exploration and exploitation, and of decentralization and coordination, often depends on the stage of the industry life cycles, with the early stages favoring exploration and the production of many new technologies and products (Klepper, 1996, 2002). As shown by Klepper (2002), even an industry as concentrated as automobiles was highly fragmented when it started, with a great deal of entry and exit. A shake-out then gradually reduced the number of suppliers. The internet boom of the 1990s involved a similar process. Out of the many newly created firms, the shake-out of the early 2000's weeded out most and correspondingly re-shaped the industry structure. Even if the Industry Life Cycle model should not be taken as a model applicable to all industries or products (as Klepper (1997) himself easily acknowledges), technological revolutions open up new rich technological opportunities to be explored and exploited by both small and large firms. The space of opportunities is often so wide and complex, that no single organisation can hope to be able to explore it extensively. Competing (and complementary) directions of search have to be tested and developed before, but to a lesser extent also after, the establishment of specific paradigms and trajectories (Dosi, 1982). Thus, even without assuming any intrinsic advantage of size or age, periods of technological transitions are typically marked by entry of new firms and turbulence (cf. Orsenigo et al., 2001 and the model in Dosi and Salvatore, 1992). In many cases, new companies are the carriers of new technologies, precisely because incumbents embody old knowledge bases which makes it harder for them to grasp and master the new ones (Christensen and Rosenbloom, 1995). Thus, some of the new firms are able to displace old leaders. The advantages of the new companies are not linked to their small size, though: rather they are small because they are young and successful ones will grow larger. Thus, some of the large firms that have become prominent worldwide are new firms in a long-term perspective. This is especially true of information technology firms, such as Microsoft, Cisco, Sun Microsystem.

Moreover, it is not always the case that new firms inevitably end up dominating the industry. In many instances, incumbents are able to survive technological disruptions and maintain their leadership: for example, to a significant extent this is the case of pharmaceuticals after the biotechnology revolution (Galambos and Sturchio, 1998; Henderson and Cockburn, 1994; Henderson et al., 1999).

A final remark. In general, we have just argued, a surge of new "Schumpeterian" firms is associated with the early stages of introduction of a new techno-economic paradigm, like over the last three decades, it is the case of ICT and life sciences. However, specifically with reference to the contemporary "technological revolution" this phenomenon is also likely to be linked to institutional changes which have little to do with technological change as such. For example, the diffusion of a tight IPR regime especially in the USA has certainly favored the development of the biotechnology industry as an organisational solution alternative to more direct use of the knowledge created in universities by large corporations.[23] And, this outcome is not obviously and necessarily more efficient (Pisano, 2006).

5 Conclusion

Long ago, Herbert Simon (Simon, 1991, pp. 27-28) suggested the following thought experiment. Suppose that each intra-organizational interaction is flagged with a green color and each market transaction with a red one. Allow some visitor from outer space to approach the earth. What will he see? Simon answer was: a lot of continents and islands with the green color interlinked with many, thick and thin, red lines.

Has the picture changed since Simon's original answer? Our bird-eye statistical answer is: not too much, if at all. Hence, if the question of whether there has been a "Third Industrial Revolution" is posed in terms of overall balances between the activities which are integrated within organizations and those which occur through market interactions, the answer is largely negative. Of course, we do not know how to precisely measure the number of intra-organizational interactions. However, if we reasonably assume that the bigger a firm is the higher the number of intra-organizational interactions it contains, than the evidence on the relative stability of size distributions offers a strong support to the point.

At closer look, however, many things have changed, both as "normal" outcomes of the processes of creative destruction / creative accumulation, and as specific features of the new techno-economic paradigm.

In the foregoing image, some continents have shrunk or even disappeared while some (old and new) islands have grown to the size of continents.

Hence, first, not too surprisingly, "life cycle" phenomena imply that the seemingly dominant firms in 1900 (including in the U.S. some associated with the distribution of ice bars in New England!) are almost entirely different from those one observes in say, Fortune 500 today. At the same time, one observes the emergence of the Intel, Microsoft (and also Boeing and Airbus, etc.) of the current world.

Second, at an even closer look, our outer-space observer will notice significant, persistent, fluctuations in the location of innovative activities among "continents" and "islands" of different sizes and ages.

Enough to corroborate the notion of a "Third Industrial Revolution"? Certainly, the technological breakthroughs militates in favour of the "revolutionary" hypothesis. However, the organization picture is rather more blurred. Within the co-evolutionary dynamics of technologies, sectors and firms, a "revolution" can hardly be seen from the angle of the distribution of activities left respectively to the "visible hand" of organizations and the "invisible hand" of market interactions.

[23]Likewise, entrepreneurship has been buttressed by a host of supporting policies including programs like the SBIR financial support to small firms in the USA.

Technical Appendix and data description

The analysis on Italian firms has been performed on Micro.1 database.[24] MICRO.1 contains longitudinal data on a panel of several thousands of Italian firms with employment of 20 units or more and it covers the years 1989-97.

As reported in Bartelsman et al. (2004) the percentage of manufacturing firms with more than 20 employees is the 12% of the total population. However, these relative larger companies account for almost 70% in terms of employment. The empirical analysis performed in Figures 2, 4 and 4 draws upon firms in manufacturing sectors only.

Table 2 and Figures 4 and 5 report the Zipf fit of sectors grouped according to Pavitt taxonomy (Pavitt, 1984). The mapping of industrial activity to the corresponding "Pavitt sectors" has been adapted to the Italian standard ATECO, of whom NACE is an almost perfectly overlapping classification[25]. Table 7 reports such correspondence, which has been applied also to French data, since their standard (Nomenclature d'Activités Française - NAF) perfectly maps the ATECO one at the 3 digit level.

Results presented on French firms make use of the EAE databank collected by SESSI and provided by the French Statistical Office (INSEE). This database contains longitudinal data on a virtually exhaustive panel of French firms with 20 employees or more over the period 1989-2002. We restrict our analysis to the manufacturing sectors. For statistical consistency, we only utilize the period 1996-2003 and we consider only continuing firms over this period. Database characteristics are described in greater detail in Bottazzi et al. (2008).

The analysis of size distribution and concentration ratio of world largest firms (see, Figures 1 and 6) have employed data collected in the database Osiris (2005).[26]

Table 3 and 4 report data on firm and employee distribution per size class as one might recover from publicly available statistics published by OECD, Eurostat and some National Statistical Offices. Figures on earlier years for European countries and Japan have been retrieved from OECD sources (OECD, 1994, 1995). Data on more recent years have been collected for Europe from the "Industry, trade and services" statistics released yearly by Eurostat (EUROSTAT, 2006) and for Japan from the "Establishments and Enterprise Census" (Japan Statistical Bureau, 2006).

For USA it has been possible to access the "Enterprise statistics" of the Bureau of Census starting from 1958 onward thanks to the access granted to their archives. After 1988 data are recovered from Statistics of U.S. Businesses (U.S. Census of Bureau, 2006b).

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[24]The database has been made available to our team under the mandatory condition of censorship of any individual information. Two authors (G.D. and M.G.) gratefully acknowledge the Italian Statistical Office (Istat), and the French one (INSEE) for their invaluable support.

[25]International comparisons among various classification standard are available at the United Nations Statistics Division *http://unstats.un.org/unsd/*

[26]Access to this database was kindly granted to one of the authors (M.G.) while visiting at the University of Pennsylvania.

Table 7: Mapping of industrial activities to the corresponding “Pavitt sectors”.

ISIC	SECTOR	Supply Dominated	Scale Intensive	Special Suppliers	Science Based
151	Production, processing & preserving of meat		√		
155	Dairy products		√		
158	Production of other foodstuffs		√		
159	Production of beverages (alcoholic and not)		√		
171	Preparation and spinning of textiles	√			
172	Textiles weaving	√			
173	Finishing of textiles	√			
175	Carpets, rugs and other textiles	√			
177	Knitted and crocheted articles	√			
182	Wearing apparel	√			
191	Tanning and dressing of leather	√			
193	Footwear	√			
202	Production of plywood and panels	√			
203	Wood products for construction	√			
205	Production of other wood products	√			
211	Pulp, paper and paperboard		√		
212	Articles of paper and paperboard	√			
221	Publishing	√			
222	Printing	√			
241	Production of basic chemicals		√		
243	Paints, varnishes, printing inks and mastics		√		
244	Pharmaceut. & medicinal chemicals				√
245	Soap, detergents, cleaning & toilet preparations		√		
246	Other chemical products		√		
251	Rubber products	√			
252	Plastic products	√			
261	Glass and glass products		√		
262	Ceramic goods not for construction		√		
263	Ceramic goods for construction		√		
264	Bricks, tiles and construction products		√		
266	Articles in concrete, plaster and cement	√			
267	Cutting, shaping and finishing of stone	√			
273	First processing of iron and steel		√		
275	Casting of metals		√		
281	Structural metal products	√			
284	Forging, pressing, stamping of metal		√		
285	Treatment and coating of metals	√			
286	Cutlery, tools and general hardware	√			
287	Other fabricated metal products				
291	Machinery for production & use of mech. power			√	
292	Other general purpose machinery			√	
293	Agricultural and forestry machinery		√		
294	Machine tools			√	
295	Other special purpose machinery			√	
297	Domestic appliances not elsewhere classified		√		
311	Electric motors, generators and transformers			√	
312	Manufacture of electricity distr., control equip.			√	
316	Electrical equipment not elsewhere classified			√	
322	TV, radio transmitters, lines for telephony				√
332	Measure, control and navigation instruments				√
342	Production of bodies for cars & trailers		√		
343	Production of spare parts & accessories for cars		√		
361	Furniture	√			

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