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# LEM

## Working Paper Series

**Statistical Regularities  
in the Evolution of Industries.  
A Guide through some Evidence  
and Challenges for the Theory**

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Statistical Regularities in  
the Evolution of Industries. A guide  
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## 1. INTRODUCTION

Fundamental drivers of the evolution of contemporary economies are the activities of search, discovery and economic exploitation of new products, new production processes, new organizational arrangements within and amongst business firms. Such processes ultimately entail the emergence and development of novel bodies of technological knowledge, novel “ways of doing things” and novel organizational set-ups. Indeed the identification of the sources of change and the “political economy” of their economic selection continues to be a major challenge for all analysts of socio-economic change. Knitted together, however, comes also the understanding of the statistical properties that such processes might possibly display. This work focuses on the latter, concerning specifically the patterns of industrial evolution.

Three basic questions in particular are addressed here:

First, are there distinct characteristics of the microentities (*in primis*, business firms) and their distributions which systematically persist over time?

Second, how do such characteristics within the population of competing firms affect their relative evolutionary success over time? And in particular what are the ultimate outcomes in terms of growth and profitability performances?

Third, amongst the foregoing statistical properties and relations between them, which ones are invariant across industries, and, conversely, which ones depend on the technological and market characteristics of particular sectors?

Note that the answer to these questions has also major implications with respect to the empirical validation of evolutionary theories of industrial change. After all, such theories focus on the twin processes of technological and organizational learning, on the one hand, and market selection, on the other, as the central drivers of industrial change.

If this is so, one ought to be able to robustly detect also in the empirical data the marks of variables and processes which are so crucial for the theory – including e.g. the footprints of firm-specific knowledge accumulation, competition-based selection, and industry-specific *regimes* of learning. Hence the discussion of the evidence which follows can also be read as an assessment of the elements of empirical corroboration of evolutionary interpretations of economic change, together with a series of challenges which the theory still faces.

At the same time, the increasing availability of longitudinal panel of firm-level data is likely to shed new light also on old questions raised in the old “structuralist” and “structure-conduct-performance” perspectives in industrial economics concerning e.g. the relationships between firm size, industrial concentration and the ability to exercise “monopoly power” and thus extract “super-normal” profits.

In order to address these questions we proceed in a sort of “inductive” manner. We start by examining some basic features of the distributions of firms sizes, growth rates and profitability (Section 2). Next, Section 3 considers some evidence on the underlying inter-firm heterogeneity - particularly with regards to technological innovativeness and productivity - and their relationships with corporate performances.

Finally, Section 4 recalls the basic elements of an evolutionary interpretation of the evidence. Together with important points of corroboration of such a view - including those regarding a profound heterogeneity of firms at all levels of observation -, one also facing standing challenges - *in primis*, concerning the purported role of markets as effective selection devices -.

Some *caveats*. Concerning the sources of evidence, while this work draws on multiple secondary sources, it heavily relies upon the data banks analyzed by the research groups of which I am or have recently been part. These data regard (i) longitudinal micro-evidence on the Italian manufacturing (the MICRO.1 data from the Italian Statistical Office, ISTAT), (ii) US manufacturing (COMPUSTAT data), and (iii) the world pharmaceutical industry (the PHID data bank organized by Fabio Pammolli at EPRIS, Florence).

Moreover the discussion which follows largely neglects most phenomena concerning “life cycle” properties of industries, which would require a much greater disaggregation and much longer time spans (for a thorough discussion on the subject, Klepper, 1997). Neither do I address explicitly the “stylized facts” on entry and exit dynamics (cf. the recent survey by Bartelsman, Scarpetta and Schivardi, 2005). Rather, this work is restricted to the distributions of sizes and performances of incumbents, their dynamics and their relations with their underlying technological characteristics.

## **2. FIRM SIZES, GROWTH RATES AND PROFITABILITIES**

Let me begin by considering the old and new evidence concerning industrial structures together with two common performance variables, namely corporate growth and profitabilities.

### **2.1 Size distributions**

A first, extremely robust, “stylized fact” regards the quite wide variability in firm sizes. More precisely, one observes – throughout industrial history and across all countries – right-skewed distributions of firm sizes<sup>1</sup>: within a large literature see Steindl (1965), Hart and Prais (1956), Ijiri and Simon (1977), all the way to Bottazzi et al. (2003), and Bottazzi and Secchi (2005).

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<sup>1</sup> This property as well as few other ones that we shall discuss below apply also to plant distributions. However, in this essay we shall mostly focus on firms which as such may well be composed of several plants.

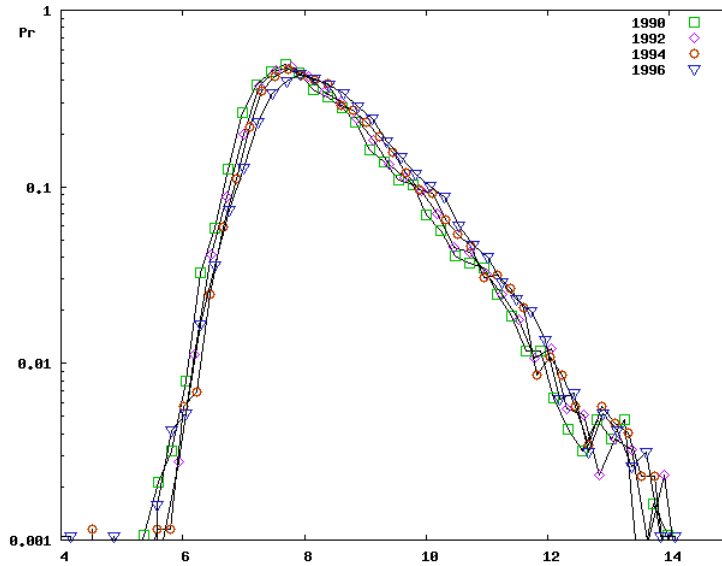


Figure 1: Empirical Densities of  $\log(VA_i)$  in different years (size measured in terms of Value Added)  
 Source: Bottazzi G., Cefis E., Dosi G., Secchi A. (2003)

Figure 1 presents the distribution of Italian firms with more than 20 employees. Here, *size* is measured in terms of value added but alternative proxies such as sales and number of employees yield a very similar picture. Irrespectively of the precise form of the density function, the intuitive message is the coexistence of many relatively small firms with quite a few large and very large ones – indeed in a number much higher than the one would predict on the ground of any Gaussian shape. In turn, all this militates against any naive notion of some “optimal size” around which empirical distributions should be expected to fluctuate. Notice that, as a consequence, also any theory of production centered around invariant U-shaped cost curves, familiar in microeconomic theory, loose a lot of plausibility. Were they the rule, one ought to reasonably expect also a tendency to converge to such a technologically optimal equilibrium sizes.<sup>2</sup>

Plausible candidates to the representation of the empirical size distributions are the log-normal, Pareto and Yule ones. Certainly, the full account of the distributions suffers form serious problems in offering also an exhaustive coverage for the smallest firms. Recent attempts to do that, such as Axtell (2001) on the population of US firms, lend support to a “power-law” distribution linking firm sizes probability densities with the size ranking of firms themselves: cf. figure 2.<sup>3</sup>

<sup>2</sup> The literature does present interpretations which try to reconcile standard production theory with such an evidence. My personal view is that they tend to range between the implausible and the incredible – the latter including Lucas (1978), suggesting that the observed distributions are the outcome of an optimal allocation of managerial skills -.

<sup>3</sup> The (cumulative) probability density function, of Pareto distribution of discrete random variables is

$$({S}) \Pr[S \geq S_i] = \left( \frac{S_0}{S_i} \right)^\alpha \quad S_i \geq S_0 \quad (1)$$

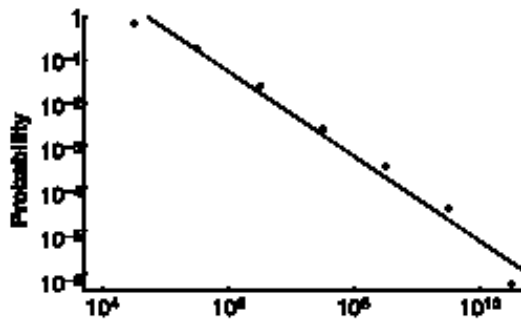


Figure 2: Cumulative Distribution of U.S. Firms by Receipts (logs, 1997 \$)  
 Source: Axtell (2001)

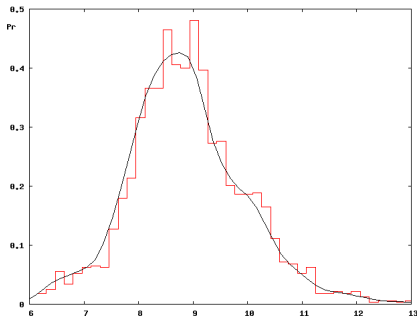
The evidence discussed so far concerns *aggregate manufacturing* firm size distributions. Are these properties *robust to disaggregation*? An increasing body of finer sectoral data suggest that in fact *they are not*.

Corroborating a conjecture put forward in Dosi et al (1995) and further explored in Marsili (2001), aggregate “well-behaved” Pareto-type distributions may well be a *puzzling outcome of sheer aggregation* among diverse manufacturing sectors, characterized by diverse regimes of technological learning and market interactions which do *not* display Paretian size distributions. While some sectors present distributions rather similar to the aggregate ones, others are unimodal symmetric and almost log-normal and yet others are bi-modal or even multi-modal. Figures 3 and 4, taken from Bottazzi et al. (2003) on three Italian manufacturing sectors, vividly illustrate such inter-sectoral diversity.

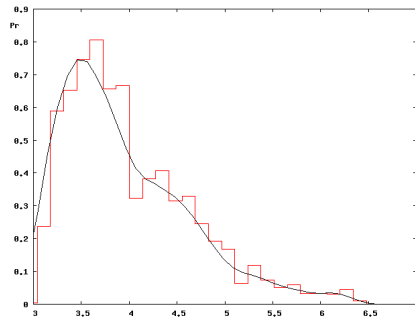
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where  $S_0$  is the smallest firm size and  $S_i$  is the size of the  $i$ - firm, as increasingly ranked. Under the restriction that  $\alpha \cong 1$ , this is known as *Zipf Law*. Note that, generally, the Pareto description is generally restricted to the upper tail of the distribution (for which one also finds more reliable data).

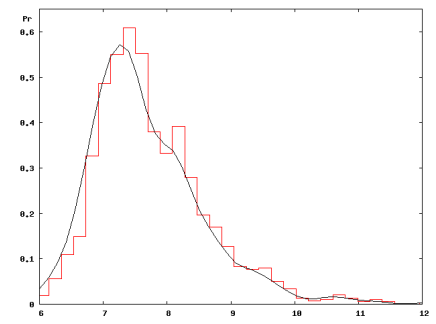
### Footwear



Total sales

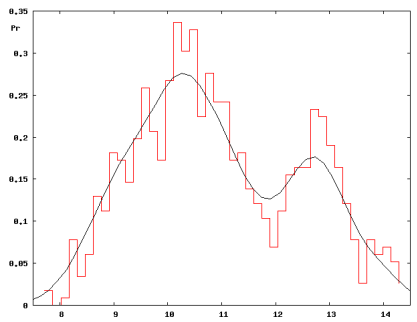


Employees

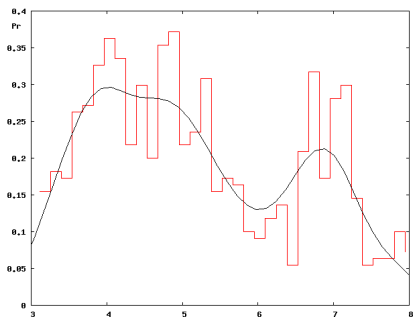


Value Added

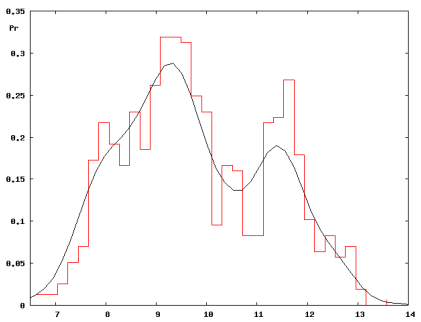
### Pharmaceuticals



Total sales

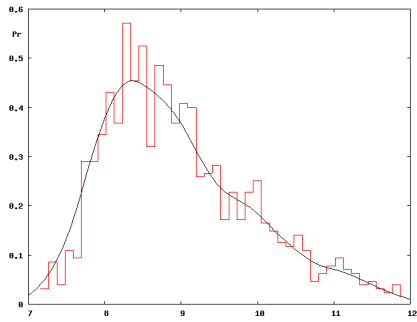


Employees

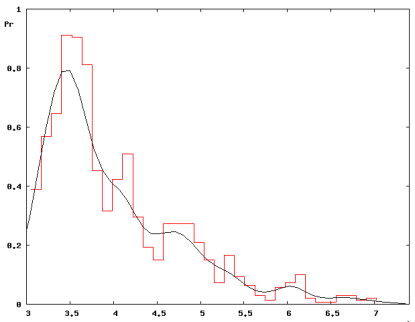


Value Added

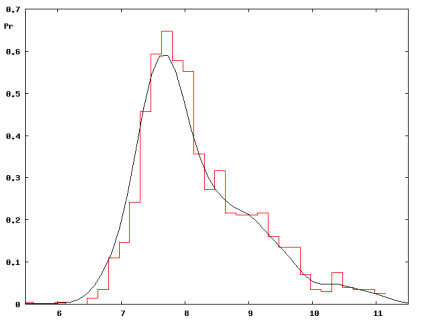
### Cutlery, tools and general hardware



Total sales



Employees



Value Added

Figure 3: Densities of  $\log(S_i)$ ,  $\log(L_i)$ , and  $\log(Va_i)$  in different Italian manufacturing sectors  
Source: Bottazzi G., Cefis E., Dosi G., Secchi A. (2003)

The more recent evidence (e.g. on Italy, see Bottazzi et al. (2003)) based on extensive micro panels does robustly confirm an older “stylized fact” regarding the remarkable inter-sectoral differences in concentration ratios (cf. the thorough overview in Schmalensee (1989a), and also the inter-country comparison in Pryor (1972)).

Together, however, the same evidence appear to go against the conventional wisdom according to which sectoral concentration should go together with (sectoral) average firm sizes: in fact the data analyzed by Bottazzi et al. (2003) suggest the lack of any correlation whatsoever.

Finally, admittedly circumstantial evidence hints at a plausible oligopolistic core vs. fringe firms separation in several sectors – indirectly supported by the mentioned bimodality of size distributions.<sup>4</sup>

Come as it may, industrial structures – in this case proxied by size distributions – are the outcomes of the growth dynamics undergone by every entity in the industrial population (jointly, of course, with birth and death processes).

What about such growth processes?

## 2.2 Corporate growth rates

It is handy to start the analysis of firm growth processes by setting a sort of “strawman” which also happens to be a classic in the literature, namely the so called *Gibrat Law* (cf. Gibrat (1931), Simon and Bonini (1958), Steindl (1965), Ijiri and Simon (1977) and Sutton (1997)).

Let

$$s_i(t+1) = \alpha + \theta_i s_i(t) + \varepsilon_i(t) \tag{2}$$

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

Gibrat law in its strong form suggests that

$$(a) \quad \theta_i = 1 \quad \text{for every } i,$$

and,

$$(b) \quad \varepsilon_i(t) \quad \text{is an independent identically and normally distributed random variable with zero mean}$$

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

Note that were one to find  $\theta_i > 1$  one ought to observe a persistent tendency toward monopoly. Conversely  $\theta_i < 1$  would be evidence corroborating regression-to-the-mean, and, indirectly, witness for some underlying “optimal size” attractor.<sup>5</sup>

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<sup>4</sup> Indeed, an important research task ahead concerns the transition probabilities between “core” and “fringe”.



A good deal of evidence is summarized in Table 1, borrowed from Lotti, Santarelli and Vivarelli (1999).

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 (cf. Mansfield (1962), Hall (1987), Kumar (1985), Bottazzi et al. (2003) and Bottazzi and Secchi (2004), among others).

**Table 1 Selected empirical studies on Gibrat's Law**

STUDY	METHODOLOGY	CONTROLS	DATA	RESULTS
<i>Mansfield, 1962</i>	Logarithmic specification	None	About 1,000 US firms in steel, petroleum and tires over 1916-57.	Gibrat's law fails to hold in about 50% of cases: smaller firms grow faster.
<i>Brusco - Giovannetti - Malagoli, 1979</i>	Logarithmic specification	None	1,250 Italian firms in ceramics, mechanical and textiles over 1966-77.	Gibrat's law fails to hold in most cases when only survived firms are included: smaller firms grow faster.
<i>Kumar, 1985</i>	Logarithmic specification	Persistence	1,747 UK quoted firms in manufact. and services over 1960-76.	Smaller firms grow faster.
<i>Hall, 1987</i>	Growth rate regression	Sample selection, heteroskedasticity	1,778 US manufact. firms over 1972-79 and 1976-83 (only incumbents)	Smaller firms grow faster.
<i>Evans, 1987a and 1987b</i>	Growth rate regression	Sample selection, heteroskedasticity	42,339 US manufacturing firms, subdivided in 100 sectors.	Smaller firms grow faster in 89 industries out of 100.
<i>Contini - Revelli, 1989</i>	Growth rate regression	Persistence	1,170 Italian firms over 1980-86 (only incumbents).	Moderate evidence that smaller firms grow faster.
<i>Dunne - Roberts - Samuelson, 1989</i>	Growth rate regression with grouping procedure	None	219,754 US manufacturing plants over 1967-82 (only entrants).	Smaller firms grow faster.
<i>Wagner, 1992</i>	Logarithmic specification	Persistence	About 7,000 West German manufact. plants over 1978-89; (only incumbents).	Gibrat's law fails to hold, but no evidence that smaller firms grow faster.
<i>Dunne - Hughes, 1994</i>	Logarithmic specification	Sample selection, heteroskedasticity, persistence	2,149 UK companies over 1980-85 (only incumbents).	Smaller firms grow faster.
<i>Mata, 1994</i>	Growth rate regression	Sample selection, heteroskedasticity	3,308 Portuguese manufacturing firms over 1983-87 (only entrants).	Smaller firms grow faster.
<i>Solinas, 1995</i>	Logarithmic specification	None	5,128 Italian firms over 1983-88 (only entrants).	Once the sample is limited to companies with at least one employee, smaller firms grow faster.
<i>Hart - Cullton, 1996</i>	Logarithmic specification	Heteroskedasticity, persistence	87,109 UK companies over 1989-93 (only incumbents).	Smaller firms grow faster.
<i>Tschoegl, 1996</i>	Logarithmic specification, growth rate regression	Heteroskedasticity, persistence	66 Japanese regional banks over 1954-93 (only incumbents).	Moderate evidence that smaller firms grow faster.
<i>Weiss, 1998</i>	Logarithmic specification	Sample selection, heteroskedasticity, persistence	43,685 Austrian farms over 1986-90 (only incumbents).	Smaller firms grow faster.
<i>Harhoff - Stahl - Woywode, 1998</i>	Growth rate regression	Sample selection, heteroskedasticity	10,902 West German firms over 1989-94 (only incumbents).	Smaller firms grow faster.
<i>Almus - Nerlinger, 1999</i>	Logarithmic specification	Persistence	39,355 West German manufacturing firms over 1989-96 (only entrants).	Smaller firms grow faster.

Source: Lotti F., Santarelli E., Vivarelli M., "Does Gibrat's Law Hold in the Case of Small, Young Firms?", (1999)

<sup>5</sup> More rigorously, with  $\theta < 1$  there exist a limit distribution with finite variance (if  $\varepsilon$  has a finite variance). In turn, any properly instructed economist would conjecture that such a distribution should display a good part of its mass around the "optimal size" value. That is, intuitively even under the persistent arrival of "disturbances" of several origins and several magnitudes, with  $\theta < 1$  one may still easily conjecture some "fundamental" driving tendency toward some underlying "optimal structure" – whatever that means.

- (iii) The relationship between size and growth is modulated by the age of firms themselves – broadly speaking, with age exerting *negative* effects of growth rates, but *positive* effects on survival probabilities, at least after some post-infancy threshold (cf. Evans (1987))<sup>6</sup>.

Note that such pieces of evidence are easily consistent with evolutionary theories of industrial change. Indeed an evolutionary interpretation would be rather at odds with a notion of convergence to some invariant “optimal” size, with decreasing returns above it. Conversely, it is rather agnostic on the precise specification of *non-decreasing* returns. In particular, it does not have any difficulty in accepting a world characterized by *nearly constant returns to scale*, (i.e. by values of  $\theta_i$  in eq. 2 on average not too far from one) jointly with drivers of firm growth on average uncorrelated with size itself.

Conversely, precious clues on the basic characteristics of the processes of market competition and corporate growth are offered by the statistical properties of the “error term” ( $\varepsilon_i(t)$  in eq. 2). Note in this respect that the absence of any structure in the growth processes would be very damaging indeed to evolutionary theories of industrial change. In fact, if one were to find corroboration to hypothesis (b) according to which – to recall – growth would be driven by a multiple, small “atomless” uncorrelated shocks, this would come as bad news to evolutionary interpretations whose basic building blocks comprise the twin notions of (i) persistent heterogeneity among agents, and (ii) systematic processes of competitive selection among them.

What properties in fact the statistics on firm growth display?

#### *Growth variability*

Since the early insights from Hymer and Pashigian (1962), a quite robust (albeit not unanimous) evidence suggests that the *variance* of firms growth rates *falls* as firms sizes increase (cf. table 2 for a concise summary). Interestingly, however, it falls less than proportionally.

Why is that?

An interpretation is that the variance-scale relation depends on the *diversification-size* relation. In fact, firms grow by both expanding within their incumbent lines of business and by diversifying into new ones. In turn, if market dynamics across activities are not perfectly correlated and if size goes together with an increasing number of lines of business in which a firm operates, then one should indeed expect

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<sup>6</sup> Moreover, the relationship between size and growth appears to be influenced by the stage of development of particular industries along their life cycles: cf. Geroski and Mazzucato (2002)

<b>Table 2</b>	
<b>Growth Variability / Firm Size Relations:</b>	
<b>“Scaling Law”: <math>\sigma(g s) \approx S^\beta</math></b>	
→	<u>Aggregate Manufacturing, U.S. data</u> <ul style="list-style-type: none"> <li>• Amaral et al. (1997): <math>\beta \approx -.2 \pm .03</math></li> <li>• Bottazzi and Secchi (2004): <math>\beta \approx -.19 \pm .01</math></li> </ul>
→	<u>International Pharmaceutical Industry</u> <ul style="list-style-type: none"> <li>• Bottazzi et al. (2001): <math>\beta \approx -.2 \pm .02</math></li> </ul>
→	<u>Aggregate and Sectoral Manufacturing, Italian data</u> <ul style="list-style-type: none"> <li>• Bottazzi et al. (2004): <math>\beta \approx .0</math></li> </ul>

a lower variance for bigger firm sizes.<sup>7</sup> In absence of any correlation in market dynamics across lines of business and with a number of lines of business proportional to size, one should expect to see the variance fall with the square root of size (that is, to observe a coefficient  $\beta$  in table 2 of around -.5). However, most of the evidence suggests a coefficient of around -.2, as such suggesting either non-proportionality in the relation diversification-size or correlation between markets or a mixture of both. In fact, in Bottazzi et al. (2001) and Bottazzi and Secchi (2004), one begins to disentangle the issue on the grounds of disaggregate data on the pharmaceutical industry, showing, at least in this case, that the scaling coefficient is entirely due to a less than proportional increase in the number of markets in which firms are active as a function of their size. Moreover, Bottazzi (2001) offers an explanation of such diversification patterns in terms of a *branching process* which is intuitively consistent with *capability-driven patterns of diversification*. As capability-based theories of the firm would predict, the expansion into new activities builds incrementally upon the knowledge and the complementary assets accumulated within existing ones (see also the remarks in Teece et al. (1994) on the ensuing “coherence” in the diversification profiles).

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<sup>7</sup> The relationship between diversification and growth variance might also explain the absence of such a scaling in the Italian evidence (Bottazzi et al. (2004)), probably due to low degrees of diversification of Italian firms, *as they appear in the statistics*. Anecdotal evidence suggests in fact that diversification events often entail the formation of a new legal entity (also due to fiscal reasons) rather than the development of new lines of business within the original company.

### *Growth rates distributions*

One of the most important pieces of evidence able to throw some light on the underlying drivers of corporate growth regards the distribution of growth rates themselves.

For convenience consider the normalized (log) size

$$s_i = \log S_i(t) - \langle \log S(t) \rangle$$

where  $\langle \log S(t) \rangle (\equiv 1/N \sum_i \log S_i(t))$  is the mean log size. The variable of interest is thus the normalized growth  $g_i(t) = s_i(t+1) - s_i(t)$

The evidence suggest an extremely robust stylized fact: growth rates display distributions which are *at least exponential (Laplace) or even fatter in their tails* (see Stanley et al. (1996) and Bottazzi and Secchi (2003) on US data; Bottazzi et al. (2001) on the international pharmaceutical industry; Bottazzi, Cefis and Dosi (2002) and Bottazzi et al. (2003) on the Italian industry).

Figures 4 and 5 present some examples from Italian data.

This property holds across (i) levels of aggregation; (ii) countries; (iii) different measures of size (e.g. sales, employees, value added, assets), even if (iv) one observes some (moderate) variations across sectors with respect to the distribution parameters.

Note that such statistical properties of growth rates are indeed good news for an evolutionary analyst. The generalized presence of fat tails in the distribution implies much more structure in the growth dynamics than generally assumed. More specifically, ubiquitous fat tails are a sign of some underlying correlating mechanism which one would rule out if growth events were normally distributed, small, and independent. In Bottazzi et al. (2003) we conjecture that such mechanisms are likely to be of two types. First, the very process of competition induces correlation. Market shares must obviously add up to one: someone's gain is someone else's loss. Second, in an evolutionary world one should indeed expect "lumpy" growth events (of both positive and negative sign) such as the introduction of new products, the construction/closure of plants, entry to and exit from particular markets.<sup>8</sup>

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<sup>8</sup> A suggestive attempt to model increasing-return dynamics yielding the observed fat-tailed distribution is in Bottazzi and Secchi (2005)

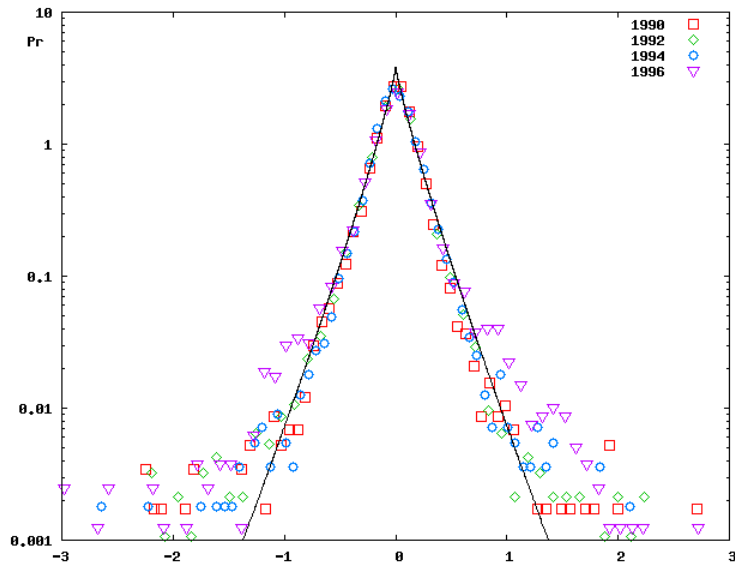


Figure 4: Growth rates distributions in different years. Size measured in terms of Value Added. Italian aggregate manufacturing

Source: Bottazzi G., Cefis E., Dosi G., Secchi A. (2003)

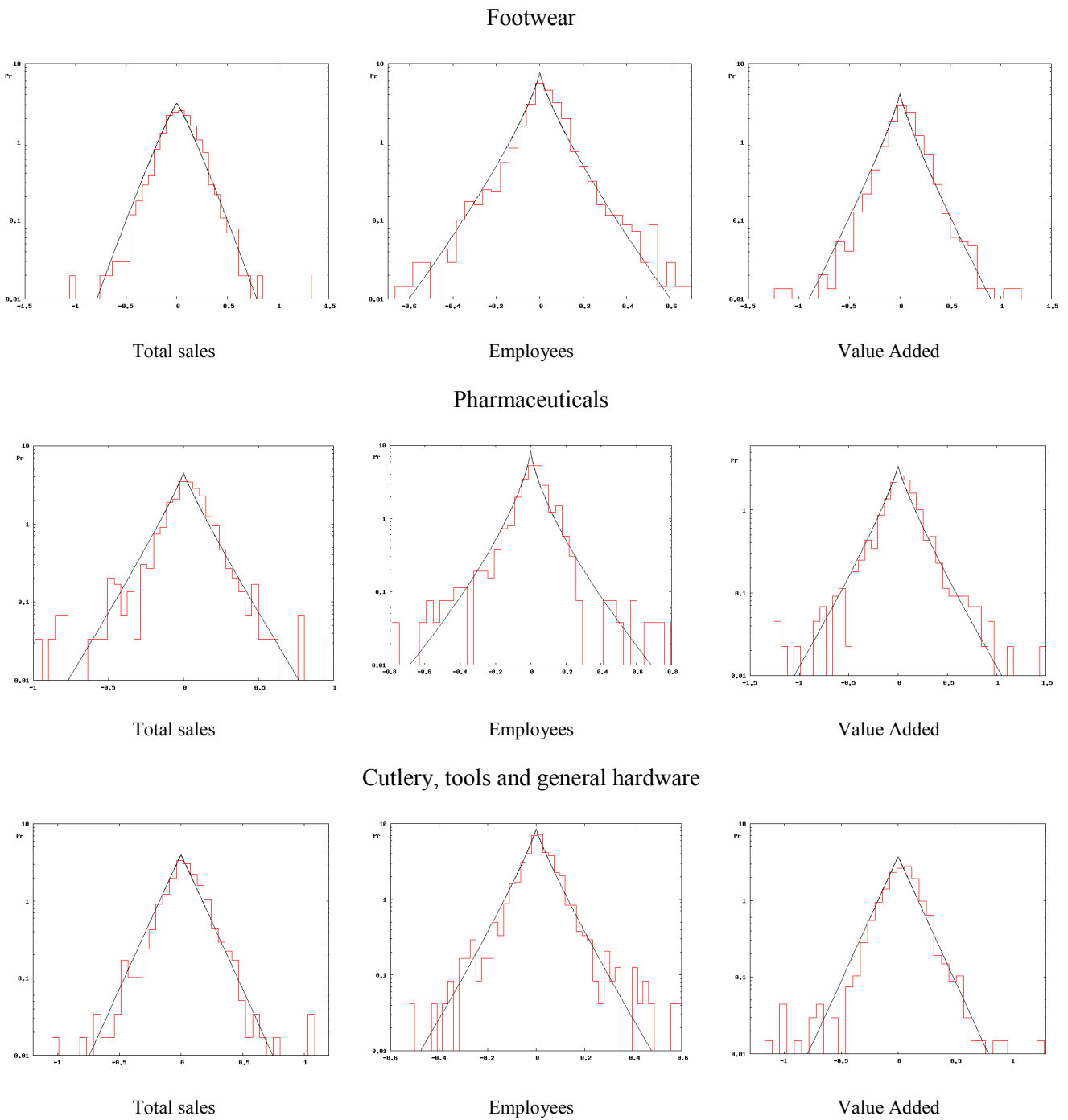


Figure 5: Probability densities and maximum likelihood estimation of firm growth rates  $g$  in three different Italian sectors.

Source: Bottazzi G., Cefis E., Dosi G., Secchi A. (2003)

### *Autocorrelation in growth rates*

Another piece of evidence on the structure of growth processes concerns the possible autocorrelations over time. Here the variable under study is in the first difference  $g_i(t+\tau) - g_i(t)$ , where, as above, the  $g_i(\cdot)$  are the (normalized) growth rates of each firm  $i$ . Begin by noting that ideally one would like to have time series long enough to describe the properties of the sample path of each firm on the grounds of the conjecture that the evolutionary pattern of each firm ought to be specific to each entity in its interactions with the population of other firms which happen to compete in that particular market in those particular times – all bearing distinctly different technological, organizational and strategic features –.

Well short of that, one generally has to be content with *sectoral averages* in the differences  $\langle g_i(t+\tau) - g_i(t) \rangle$ , under different autoregressive lags.

Interestingly, in an industry for which one has reasonable longitudinal panel data at different levels of disaggregation – namely the international drugs industry – one does find a robust autocorrelation structure. For example, firm-level growth rates exhibit a long-lasting positive autocorrelation, statistically significant up to the 7<sup>th</sup> lag (cf. Bottazzi et al. (2001)).

Broader, inevitably coarser, evidence typically on 3-digit sectors (as such already aggregates of a quite large number of lines of business) like that in Bottazzi and Secchi (2003) on US manufacturing displays (i) only a relatively short autoregressive structure (typically with one-lag only significance); and, (ii) a good deal of inter-sectoral variability.

At similar levels of aggregation, the Italian panel of manufacturing firms often displays average autocorrelations which are quite small (around  $|.1|$ ), and significant if at all only at the first lag (cf. Bottazzi et al. (2003)). Even in this case, however, the data suggest *highly heterogeneous firm-specific autocorrelation profiles* within each sector. This is confirmed by “bootstrapping” exercises involving the comparison between the distribution of *actual* firm-specific coefficients with any “virtual” one obtained by randomly scrambling actual growth rates over the same (but randomly drawn) firms. The two distributions turn out to be significantly different, meaning that there are *systematic but idiosyncratic differences* in autocorrelation structures, which are not captured by sectoral average autocorrelation coefficients (cf. Bottazzi, Cefis, and Dosi (2002)).<sup>9</sup>

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<sup>9</sup> Revealing complementary evidence to the same effect suggests that even growth paths, *conditioned on size*, tend to be significantly *firm-specific*: cf. Cefis, Ciccarelli, and Orsenigo (2002)

### 2.3 Profitabilities and their Dynamics

Together with corporate growth, profitability is another crucial measure of revealed corporate performances. There are three major intertwined issues here, namely (i) the revealed *inter-firm differences* in profitability proxies; (ii) their persistence over time; and (iii) the properties of their patterns of change.

Some due premises. I strongly believe that simpler measures are better measures because they reduce theory-driven biases. So, for example, derivations of profitability measures from purported technological relations which nobody has actually seen such as Cobb-Douglas and alike are likely to lead to blind alleys.

Given that, let me stick to the simplest possible measure of profitability, aiming at the same time at the highest possible degree of sectoral disaggregation.

Consider the variables

$$gom_i(t) = \log(GOM_i(t)) - \langle \log(GOM(t)) \rangle$$

$$GOM_i(t) = VA_i(t) - W_i(t)$$

where

$GOM_i$  = gross operating margins

$VA_i$  = value added

$W_i$  = total wage costs

and, as above,  $\langle \dots \rangle$  stands for the sectoral averages.

If capital/output ratios are not too different across firms - as they should not be the more one refines the sectoral disaggregation -, then the simple *MOL* measure should not be too biased a proxy for “true” profitabilities. Fig. 6 offers some impressive evidence drawn from the Italian sample on inter-firm profitability asymmetries: the reader is indeed invited to appreciate the width of the support of the density distributions going well beyond, say, ten to one ratios in profitability margins between the best and the worse performers.

Given that, a crucial property regards the persistence of such differentials. After all, evidence on low persistence could simply suggest that capitalism involves daring and heroic efforts by multitudes of firms which happen to make many mistakes as well as reap huge rewards, but markets are there to help and quickly redress individual mistakes and wash away abnormal rents. It turns out that this view does not quite match the evidence.

There is indeed a robust literature on the *persistence of profitability differences across firms*: see, among others, Müller (1986) and (1990), Cubbin and Geroski (1987), Geroski and Jacquemin (1988), Goddard and Wilson (1999), Cefis (2003a), Gschwandter (2004). The Italian evidence strongly supports the point.



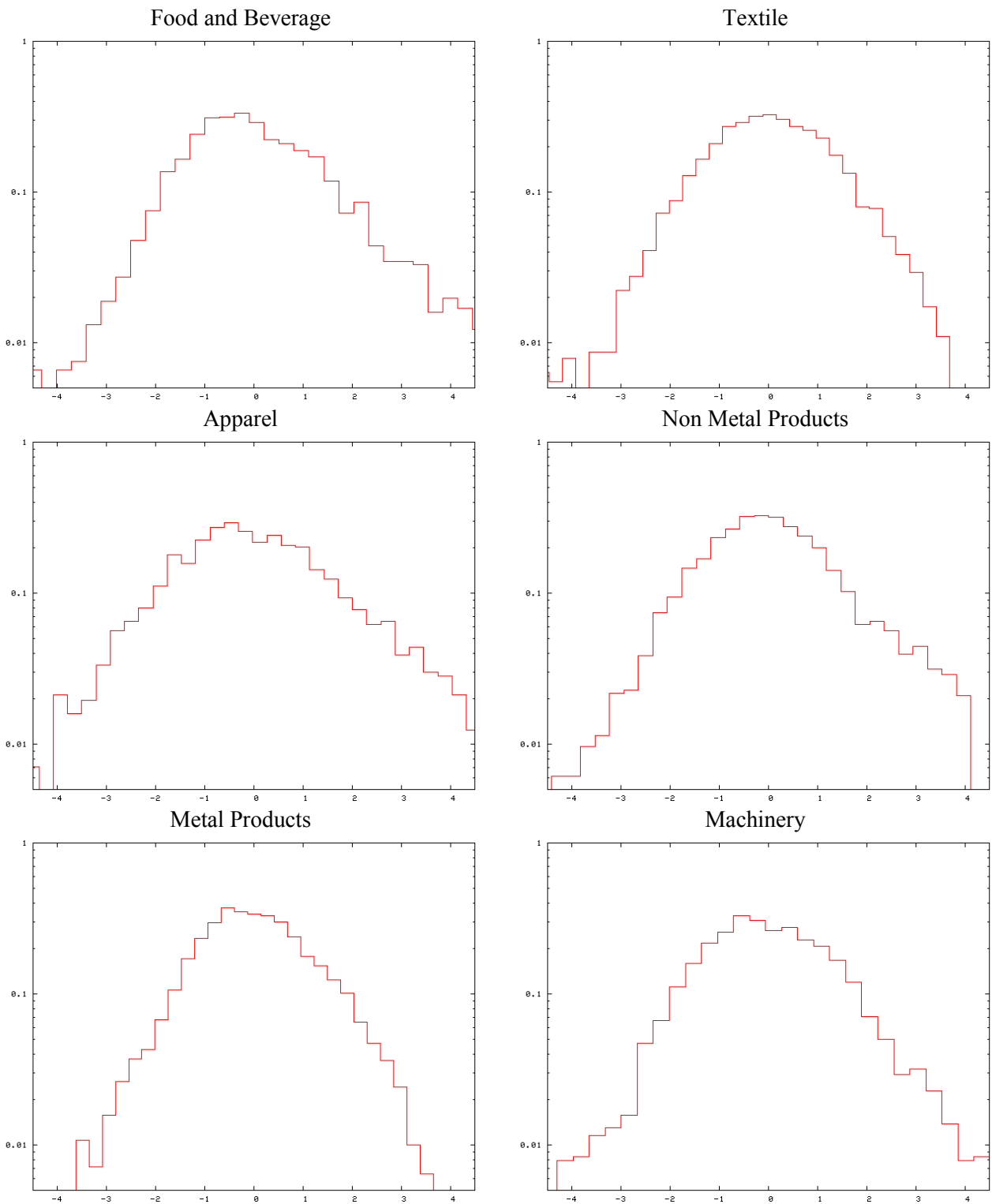


Figure 6: Distribution of Gross Margins by sectors  
 Source: our elaboration of Italian (ISTAT MICRO.1) data: cf. text on the data description

	ISIC CODES	LEVELS		DIFFERENCES	
		AR (1) coeff	Std dev	AR (1) coeff	Std dev
FOOD PRODUCTS AND BEVERAGES	15	0,9516	0,0060	-0,3424	0,0190
TEXTILES	17	0,9117	0,0067	-0,2953	0,0163
WEARING APPAREL, DRESSING AND DYEING OF FUR	18	0,9328	0,0087	-0,3992	0,0254
TANNING AND DRESSING OF LEATHER; LUGGAGE; FOOTWEAR	19	0,8781	0,0144	-0,2984	0,0307
MANUFACTURING OF WOODS AND RELATED PRODUCTS	20	0,9430	0,0115	-0,3658	0,0332
PAPER AND ALLIED PRODUCTS	21	0,9432	0,0104	-0,2935	0,0298
PRINTING AND PUBLISHING	22	0,9471	0,0098	-0,3917	0,0293
CHEMICALS AND ALLIED PRODUCTS	24	0,9370	0,0081	-0,3315	0,0216
RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS	25	0,9203	0,0085	-0,2917	0,0208
OTHER NON-METALLIC MINERAL PRODUCTS	26	0,9430	0,0067	0,3337	0,0190
BASIC METALS	27	0,9149	0,0101	-0,3245	0,0248
FABRICATED METAL PRODUCTS, EXCEPT MACHINERY	28	0,9213	0,0064	-0,2957	0,0155
INDUSTRIAL MACHINERY AND EQUIPMENT	29	0,9207	0,0055	-0,3215	0,0137
ELECTRICAL MACHINERY AND APPARATUS	31	0,9649	0,0086	-0,2382	0,0265
FURNITURE AND OTHER N.E.C. MANUFACTURING INDUSTRIES	36	0,9210	0,0080	-0,3349	0,0185

Source: Our elaborations on Italian (STAT MICRO. 1) data. The selected sectors are those which include more than 200 firms

As shown in Table 3, the autocorrelation over time in profit margins is extremely high in all manufacturing sectors, with just a relatively mild tendency of mean-reversion, revealed by both negative coefficient on the first differences and the value of the autoregressive coefficient on the *levels* slightly lower than unity.

Finally note that, interestingly, the rates of change in profit margins display distributions which are again fat-tailed, at least exponential, or even fatter-tailed. See Figure 7, displaying the growth rates of the normalized margins,  $g_{gomi}(t) = gom_i(t+1) - gom_i(t)$ . The sectors shown in the figure are chosen simply to illustrate the point that the property holds across activities that are very different in terms of technologies and forms of corporate organizations.

For the interpretation of such an evidence let me refer the reader back to the discussion of a similar evidence in the case of growth rates of companies as such. Again we find here the mark of powerful underlying correlation mechanisms which tend to induce “coarse grained” shocks upon profitabilities.

Recalling our previous argument, consider – as a term of comparison – a process of variation in profitabilities of individual firms driven by little idiosyncratic shocks occurring all the time, independent from each other. A caricatural way of illustrating it is by depicting a multitude of producers which all survive near equilibrium (i.e. in the conventional definitions, near a zero-profit steady state), while being nonetheless continuously hit by small and uncorrelated profit opportunities (e.g. one or few unexpected or uniformed customers; some small advances on products characteristics, etc.) If such shocks are uncorrelated, again for the law of large numbers, summing up over, say, years, one should expect normally distributed changes. Not getting it as such is a striking evidence on “drivers of change” which are more “lumpy” and more powerfully correlated with each other.

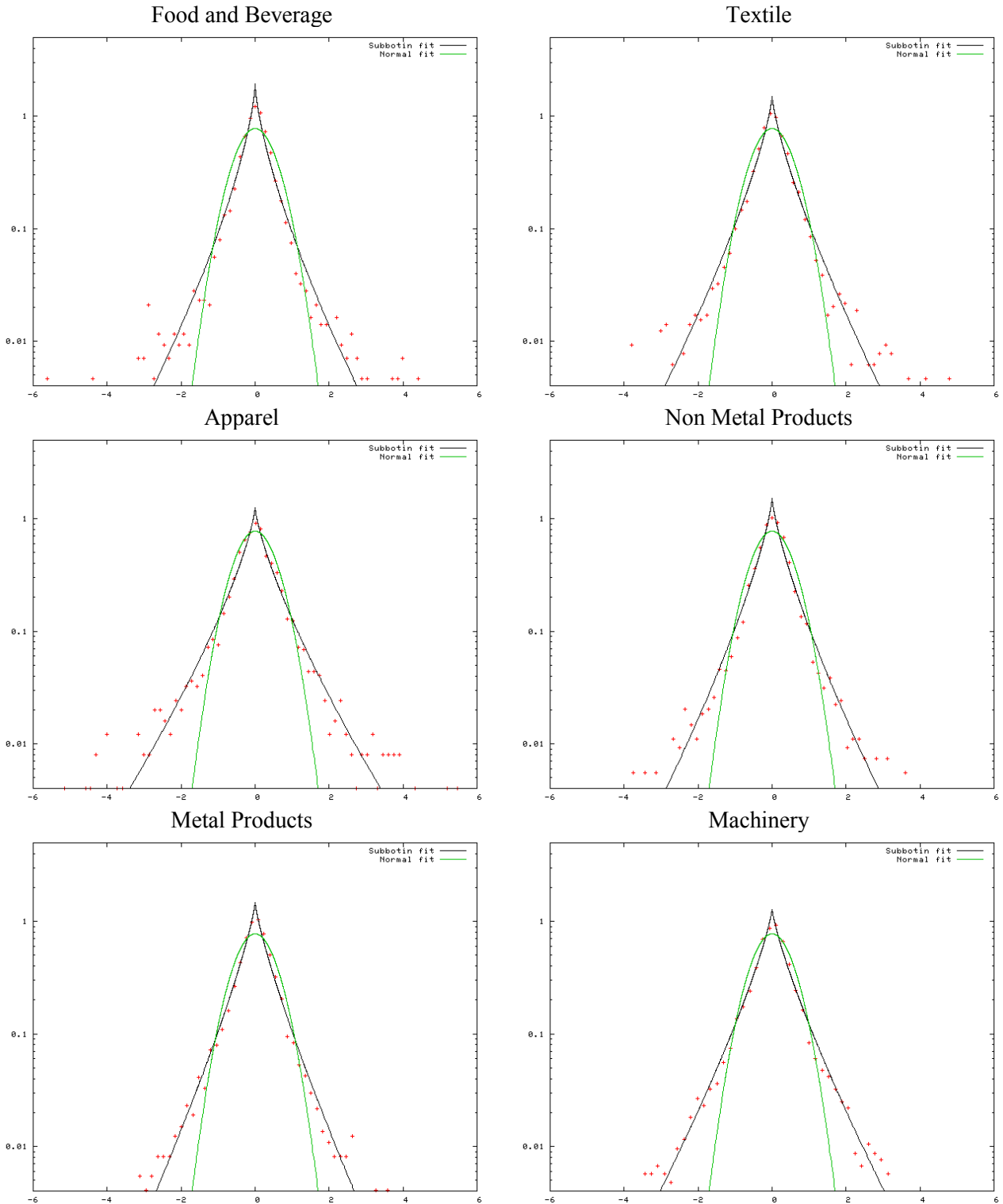


Figure 7: Distribution of Gross Margins Growth Rates by sectors, Italian data. Each figure displays the maximum likelihood estimates of Subbotin distributions (cf. Bottazzi and Secchi (2005)) whereby “tent” shapes witness for exponential distributions. The figure also displays as a term of comparison the (bad) fit of a normal distribution (the dotted line)

Source: our elaborations on ISTAT MICRO.1 data

## 2.4 The statistical structure of industrial evolution: some concluding remarks

There are possibly two major messages that come from the whole discussion so far.

The first, more methodological one, is that there is a rich statistical structure in the dynamics of industries which has remained largely neglected until recently, as long as most analysis simply focused on *average* relations between corporate performances and corporate characteristics, and more often between firm sizes and firm rates of growth. Indeed, the revealed structure in the stochastic processes describing industrial evolution bear the familiar signs of all *complex system dynamics*, including the fat-tailed distributions in the rates of changes of all variables of interest. That, in turn, is likely to witness for the existence of some underlying correlation mechanism, which makes the system (in our case, each industry) “self-organizing” in its growth process. In most respects, the statistical evidence on industrial change corroborates the exciting conjecture that evolutionary phenomena tend to generically undergo “non-gaussian” lives – influenced by persistent (positive or negative) interactions amongst agents within and across relevant populations.

Second, but relatedly, the core indicators of corporate performances discussed in this section – i.e. growth and profitability – reveal a widespread and profound *heterogeneity* across firms that persist over time notwithstanding the competition process. Given all that, a natural question concerns the sources of such heterogeneities themselves.

## 3. BEHIND HETEROGENEOUS PERFORMANCES: INNOVATION AND PRODUCTION EFFICIENCY

Straightforward candidates for the explanation of the differences in corporate performances are in fact (i) differences in the ability to innovate and/or adopt innovation developed elsewhere regarding product characteristics and production processes; (ii) different organizational arrangements; (iii) different production efficiencies.

Needless to say, the three sets of variables are profoundly related. Technological innovations typically involve also changes in the organization of production. Different ways of searching for innovations imply distinct organizational arrangements regarding the relationships amongst different corporate tasks (e.g. R&D, production, sales, etc.). And, most obviously, technological and organizational innovations ultimately shape the degrees of efficiency in which inputs happens to generate outputs. With that in mind, let me offer some telegraphic overview of the evidence concerning the patterns of technological innovation, on the one hand, and production efficiencies on the other. (I am forced to neglect here the role of organizational variables. In fact, *organizational capabilities* are intimately linked with the very process of technological innovation and with production efficiencies: cf. the discussions to which I have contributed in Dosi, Nelson, and Winter (2000) and Dosi, Marengo, and Faillo (2005)).

### 3.1 Technological Innovativeness

A rich and wide literature in the field of economics of innovation does indeed suggest that firms deeply differ also in their ability to innovate: for detailed surveys and discussions see Freeman (1994), Freeman and Soete (1997) Nelson (1981) and (1991), Pavitt (1999), Dosi, Orsenigo and Sylos Labini (2005), Dosi (1988).

- (i) Innovative capabilities appear to be highly asymmetric, with a rather small number of firms in each sector responsible for a good deal of innovation output.
- (ii) Somewhat similar considerations apply to the *adoption* of innovations (in the form of new production inputs, machinery, etc.) revealing asymmetric capabilities of learning and “creative adaptation”.
- (iii) Differential degrees of innovativeness are generally persistent over time and often reveal a small “core” of systematic innovators (together with the foregoing broad critical surveys, c. specifically Cefis (2003)).
- (iv) Relatedly, while the arrivals of major innovations are rare events, they are not independently distributed across firms. Rather, recent evidence suggests that they tend to arrive in firm-specific “packets” of different sizes.<sup>10</sup>

In terms of intuitive comparisons of such evidence with the predictions of evolutionary theorizing, heterogeneity in innovative/initiative abilities is indeed a robust piece of corroborating evidence. And so is the evidence on micro-correlation of innovative events, well in tune with an evolutionary notion of few, high-capability, persistent innovators.

On a much larger scale, the persistent asymmetries across countries, even within the same lines of business, cry out in favour of profound heterogeneities in learning and searching capabilities.

### 3.2 Production efficiencies

As well known, there are two straightforward measures of production efficiency, namely labour and total factor productivity (TFP).

It should come as no surprise at this point of the discussion that, despite its obvious limitations, I tend to prefer a measure based on the net output (that is the “real” value added) per employee or, even better, per worked hours. The reason for this preference lies in the dubious elements which make up conventional production functions, in turn the instrument necessary to yield the TFP measure. This is not the place to discuss the issue. Suffice to mention, first, that technologies as we know them essentially involve *complementarities* among inputs –so that it makes little sense to separate the “contribution” of each “factor”

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<sup>10</sup> On the statistical properties of the discrete innovations, *in general*, cf. Silverberg (2003) showing a secular Poisson-type process. However, at a much finer level of observation the firm-specific patterns of innovation are not likely to be Poisson-distributed. Rather, as one shows in Bottazzi et al. (2001) in the case of the pharmaceutical industry, few firms “draw” relatively large “packets” of innovations well described by Bose-Einstein (rather than Poisson) statistics.

to the final output. To paraphrase on a suggestive metaphor suggested by Dick Nelson it makes as much sense as trying to disentangle the separate contributions of butter, sugar, eggs, etc. to the taste of a cake.

Second, but relatedly, one typically lives in a technological world characterized by micro coefficients which are fixed in the short-term (i.e. each firm basically masters the technique actually in use), while in the longer-term techniques change essentially due to learning and technical progress. Conversely, if this is the case, it does not make much sense to distinguish changes *along* any purported production function vs. changes of the function itself.

Come as it may, on overwhelming evidence *concerning both labour productivity and TFP* and at all levels of disaggregation suggest widespread differences in production efficiency *across firms and across plants* which tend to be persistent *over time*: see, among others, Nelson (1981), Baily et al. (1992), Baldwin (1995), Bartelsman and Doms (2000), Jensen and McGuckin (1997), Power (1998), Rumelt (1991).

Our Italian data are well in tune with such stylised facts. Figure 8 presents the distribution of (normalized) value added per employee, that is

$$\pi_i(t) = \log \Pi_i(t) - \langle \log \Pi_i(t) \rangle$$

whereby

$$\Pi_i(t) = VA_i/N_i;$$

and,

$\langle \log \Pi_i(t) \rangle \equiv$  mean (log) value added (VA) per employee (N) averaged over all firms in any particular sector.

Moreover, as shown in Table 4, productivity differentials are quite stable over time with some mild regression-to-the-mean tendency.

Also at the level of input efficiencies the broad picture is characterized by general and profound heterogeneity across firms.

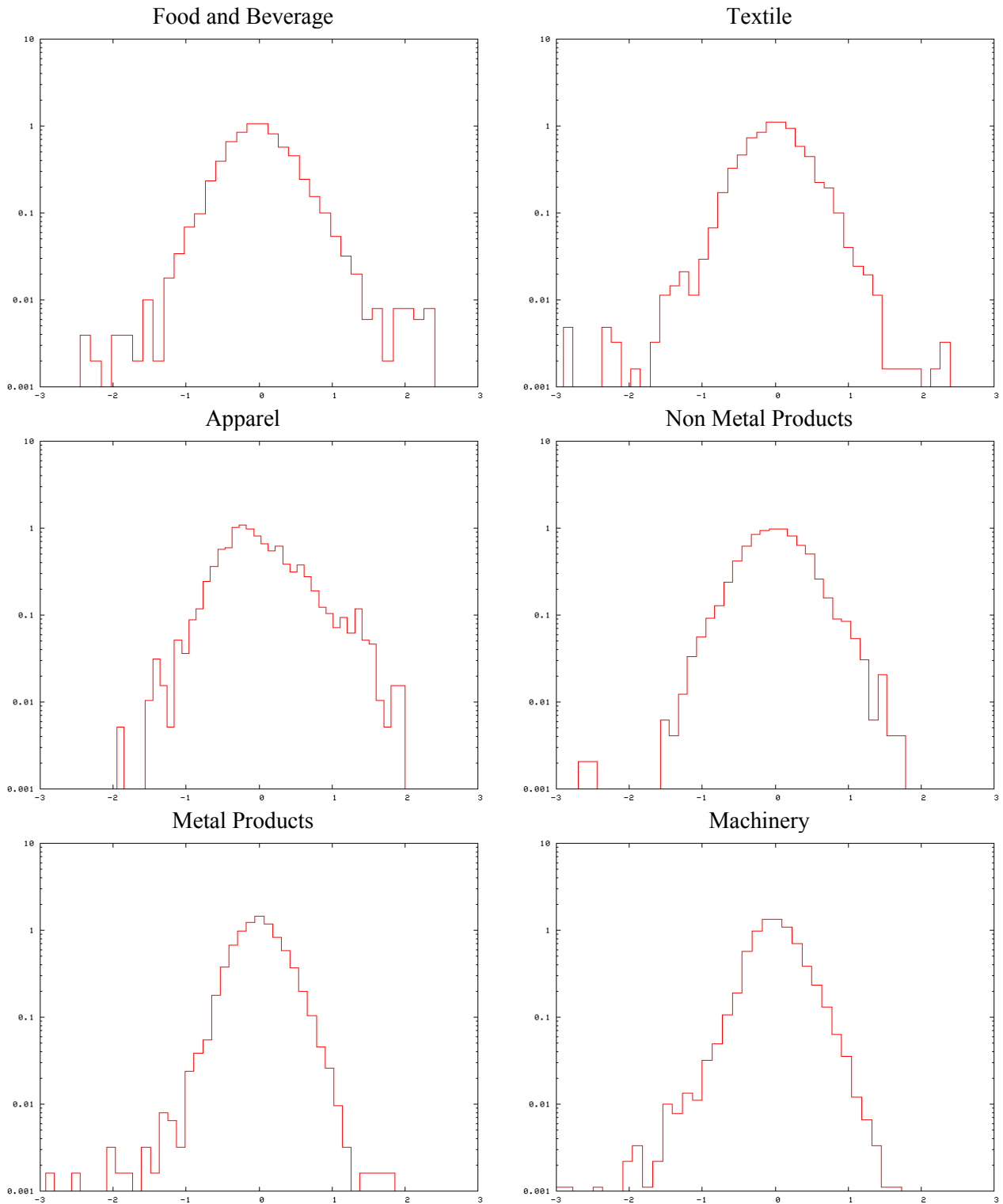


Figure 8: Distribution of Labour Productivity by sectors  
 Source: our elaboration of Italian (ISTAT MICRO.1) data



Table 4: Autocorrelation of Labour Productivity levels and growth rates (Labour Productivity = VA / # employees)		LEVELS		DIFFERENCES	
	ISIC CODES	AR (1) coeff	Std dev	AR (1) coeff	Std dev
	FOOD PRODUCTS AND BEVERAGES	0,8619	0,0092	-0,2641	0,0208
	TEXTILES	0,8699	0,0076	-0,2770	0,0171
	WEARING APPAREL, DRESSING AND DYEING OF FUR	0,9285	0,0087	-0,3428	0,0250
	TANNING AND DRESSING OF LEATHER; LUGGAGE, FOOTWEAR	0,8932	0,0158	-0,3123	0,0398
	MANUFACTURING OF WOODS AND RELATED PRODUCTS	0,8357	0,0154	-0,3254	0,0312
	PAPER AND ALLIED PRODUCTS	0,8772	0,0140	-0,2348	0,0030
	PRINTING AND PUBLISHING	0,8391	0,0127	-0,1596	0,0319
	CHEMICALS AND ALLIED PRODUCTS	0,7947	0,0132	-0,1883	0,0234
	RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS	0,8920	0,0108	-0,2831	0,0244
	OTHER NON-METALLIC MINERAL PRODUCTS	0,9057	0,0077	-0,3065	0,0195
	BASIC METALS	0,8583	0,0135	-0,1645	0,0270
	FABRICATED METAL PRODUCTS, EXCEPT MACHINERY	0,8572	0,0079	-0,3299	0,1580
	INDUSTRIAL MACHINERY AND EQUIPMENT	0,8098	0,0079	-0,3177	0,0143
	ELECTRICAL MACHINERY AND APPARATUS	0,8534	0,0119	-0,1072	0,0236
	MANUFACTURING OF OTHER TRANSPORT EQUIPMENT	0,7518	0,0299	-0,3490	0,0481
	FURNITURE AND OTHER N.E.C. MANUFACTURING INDUSTRIES	0,8609	0,0093	-0,3512	0,0187

Source: Our elaborations on Italian (ISTAT MICRO. 1) data. The selected sectors are those which include more than 200 firms

As Griliches and Mairesse (1997) vividly put it

“we ... thought that one could reduce heterogeneity by going down from general mixtures as “total manufacturing” to something more coherent, such as “petroleum refining” or “the manufacture of cement”. But something like Mandelbrot’s fractal phenomenon seem to be at work here also: the observed variability-heterogeneity does not really decline as we cut our data finer and finer. There is a sense in which different bakeries are just as much different from each others as the steel industry is from the machinery industry.”

For evolutionary scholars, heterogeneity in the degrees of innovativeness and production efficiencies should not come as a surprise. Indeed, this is what one ought to expect to be the outcome of idiosyncratic capabilities (or lack of them), mistake-ridden learning and forms of path-dependent adaptation. Differences in innovative abilities and efficiencies (together with differences in organizational set-ups and behaviours) ought to make-up the distinct corporate “identities” which in turn should somehow influence those corporate performances discussed in the previous section.

But do they? How? And on what time scales?

### **3.2 Corporate Capabilities, Competition and Performances**

Let us distinguish between profitability and growth indicators of performances.

The positive impact of innovativeness upon corporate profitabilities appears to be well documented: see Geroski, Machin and van Reenen (1003), Cefis (2004a), Cefis and Ciccarelli (2005), Roberts (1999), among others.

Together our Italian data highlight a positive relationship between profit margins and relative labour productivities (that is, normalized with the respective sectoral means): see figure 9.

At the same time, the impact of both innovativeness and production efficiency upon growth performances appears to be somewhat more controversial. Mainly North-American evidence, mostly at *plant* level, does suggest that increasing output shares in high-productivity plants and decreasing shares of output in low-productivity ones are very important drivers in the growth of average productivities, even if the process of displacement of lower efficiency plants is rather slow (cf. the evidence discussed in Baily et al. (1992) and Baldwin (1995)).

*Firm-level* data are less straightforward. For example, our Italian data show

- (i) a weak or non-existent relationship between growth and relative productivities (see figure 10): more efficient firms do *not* grow more;

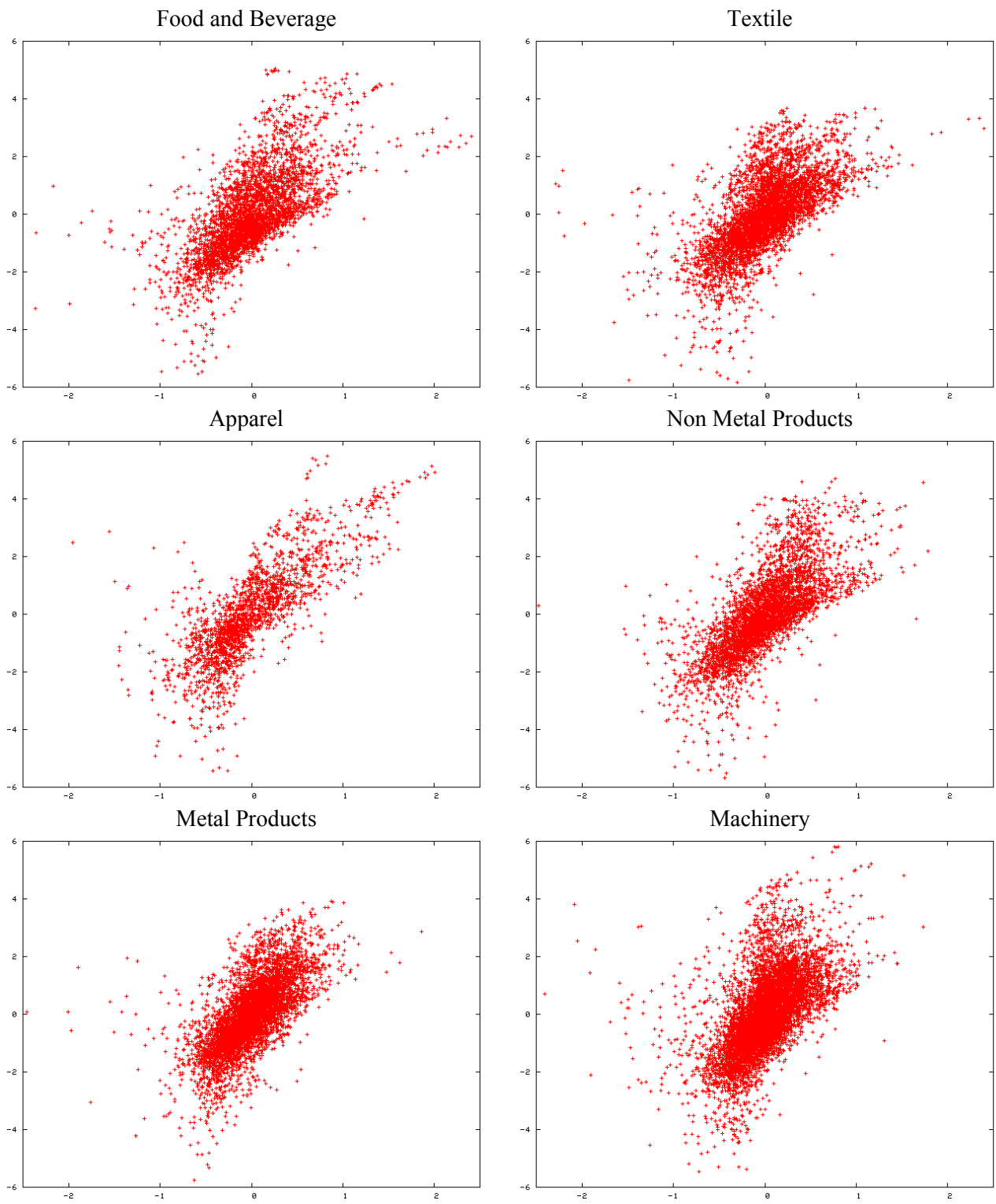


Figure 9: Gross margins and (normalized) labour productivity, 1989-1997  
 Source: our elaboration on Italian (ISTAT MICRO.1) data

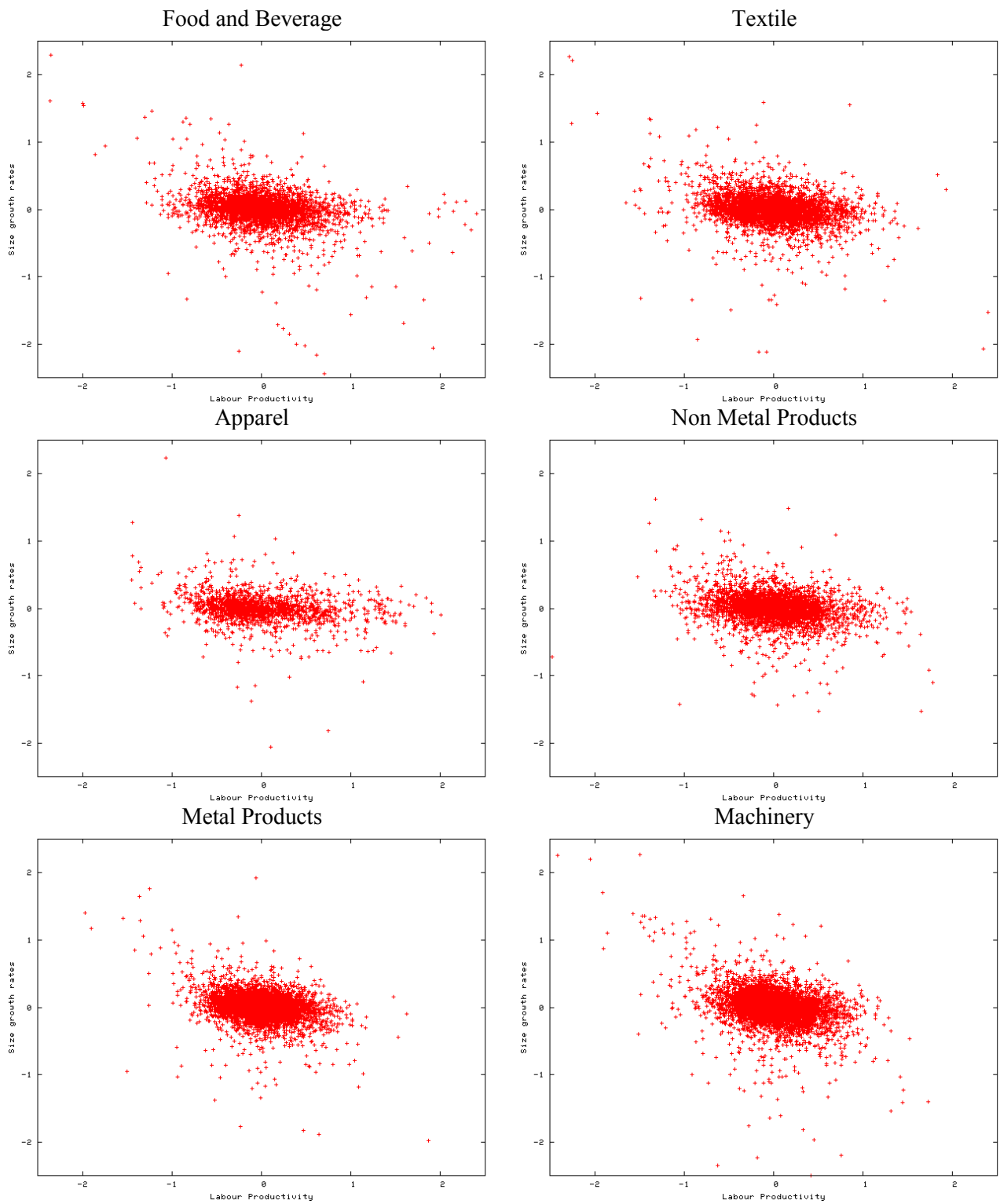


Figure 10: Labour productivity and growth rates (measured in terms of sales), 1989-1997  
 Source: our elaboration on Italian (ISTAT MICRO.1) data

- (ii) even when some positive relation between efficiency and growth appears, this is almost exclusively due to the impact of few *outliers* (the very best and the very worst);
- (iii) similarly, no systematic relation appears between (relative) profit margins and (relative) growth rates (cf. figure 11).

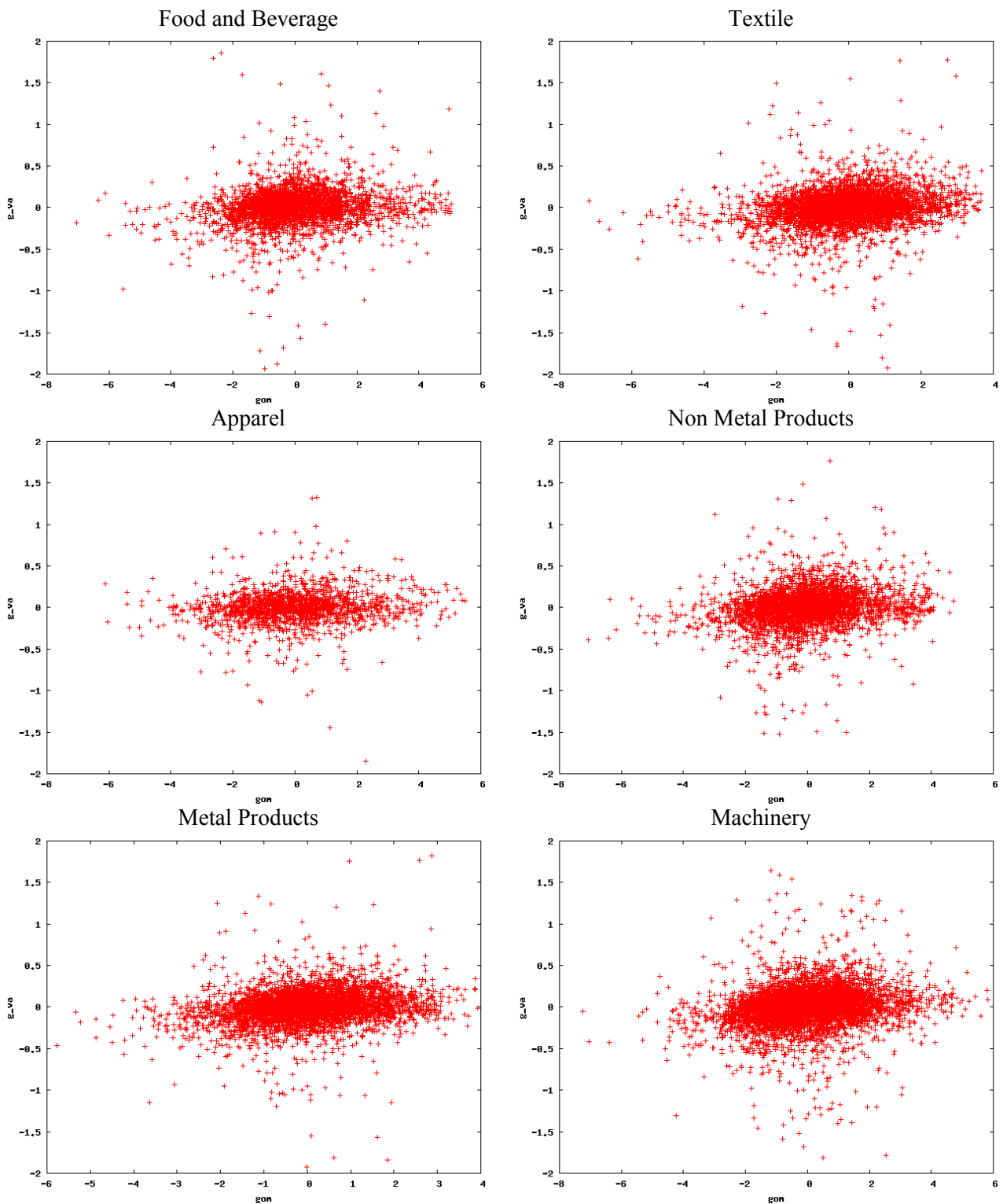


Figure 11: Growth rates and profit margins in different manufacturing sectors  
 Source: our elaboration on Italian (ISTAT MICRO.1) data

Moreover,

- (iv) the evidence from other data sets such as the international pharmaceutical industry shows that more innovative firms do *not* grow more (Bottazzi et al. (2001)). Rather the industry constantly displays the coexistence of heterogeneous types of firms (e.g. innovators vs. imitators).

The implications of all these empirical regularities, if confirmed by the observation of other countries and other industries are far-reaching. Let us consider them from an evolutionary perspective.

#### **4. EVOLUTIONARY INTERPRETATIONS: CORROBORATIONS ANC CHALLENGES BY WAY OF A CONCLUSION**

How well does the whole statistical story reviewed in this essay fit with evolutionary interpretation?

Certainly, the recurrent evidence at all levels of observation of *inter-firm heterogeneity* and its persistence over time is well in tune with an evolutionary notion of idiosyncratic learning, innovation (or lack of it) and adaptation.

Heterogeneous firms compete with each other and, given prevailing input and output prices obtain different returns. Putting it in a different language, they obtain different “quasi-rent” on conversely losses above/below the notional “pure competition” profitability. At the same time, even leaving aside any entry/mortality phenomenon, surviving incumbents undergo changes in their market shares and therefore in their relative (and, of course absolute) sizes.

In all that , the evidence increasingly reveals a rich structure in the processes of learning, competition and growth.

Various mechanisms of correlation – together with the “sunkness” and indivisibilities of many technological events and investment decisions – yield a rather structured process of change in most variable of interest – e.g. size, productivity, profitability – also revealed by the “fat-tailedness” of the respective growth rates.

At the same time, market selection – the other central tenet, together with learning, of evolutionary interpretations of economic change – do not seem to work particularly well, at least on the yearly time scale at which statistics are reported (while the available time series are not generally long enough to precisely assess what happens in the long run). Conversely, diverse degrees of efficiencies and innovativeness seem to yield primarily relatively persistent profitability differentials.

That is, contemporary markets do not appear to be too effective selectors delivering rewards and punishments according to differential efficiencies.

Moreover, the absence of any strong relationship between profitability and growth militates against the “naively Schumpeterian” (or for that matter “classic”) notion that profits feed growth (by plausibly feeding investments).

Finally, the same evidence appears to run against the conjecture, put forward in the '60s and '70s by the “managerial” theories of the firm on a trade off between profitability and growth with “managerialized” firms trying to maximize growth subject to a minimum profit constraint.<sup>11</sup>

In turn, the very fact that market selection might play less of a role than that assumed in many models of evolutionary inspiration would be as such an important advance in the understanding of how markets work (or do not).

More generally, the increasing availability of longitudinal panel data with an array of variables describing both the “inner features” and the performances of individual firms begins to unveil the rich statistical structure of the processes of industrial evolution. In that, one can go a long way, I have tried to show, with little or no use of (typically unobservable) strategic variables. One has just begun. Ahead lie, first, exercises of “evolutionary accounting” trying to disentangle the relative role of entry, market selection and incumbent learning as drivers of industrial change. Together, second, it is of paramount importance to try to condition the observed performance profiles of individual firms upon their underlying technological and organizational “identities”.

There is indeed a whole world to be discovered resting somewhere inbetween the “pure stochasticity” of a Gibrat-type framework, on the one extreme, and, the ex-post rationalization of whatever observation in terms of sophisticated hyper-rational behaviours, on the other.

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<sup>11</sup> In fact the absence of such a trade off had been already noted by Barna (1962). Note also that this proposition is horthogonal to the finding that current growth appears to be correlated with *future* long-term profitability (cf. Geroski, Machin, and Walters (1997))

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