

# Industrial dynamics - Part 1

Angelo Secchi\*

\*DSE, University of Pisa, Pisa.

MICRO APPROACHES TO INNOVATION AND INNOVATION  
NETWORK

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# Common Dissatisfaction

Lack of relation between theoretical and empirical investigations. . .

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# The Main Building block: Economic Distribution Laws

Economic distributions as steady-state equilibrium:

- certain economic distributions are stable over time
- we are aware of a continuing movement of the elements which make up the population in question

This suggests the idea of **steady-state equilibrium**: “a state of macroscopic equilibrium maintained by a large number of transitions in opposite directions” (Feller, 1957)

# An Example

Let us consider two “economic” populations

## HUMAN BEINGS

total population

age-structure

expected birth and death rates

## FIRMS

total number of firms

size distribution

expected gains/losses or ruin

plus entry

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# Outline

- 1 Setting the research framework
- 2 Firm Sizes, Growth Rates and Profitabilities
  - Size Distribution
  - Firm growth patterns
  - Profitability
- 3 Technological Characteristics of firms
  - Innovativeness
  - Labor Productivities
- 4 An interpretative framework

# Major question

- 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
- Given that, what are the statistical properties that such processes might possibly display?

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# Basic Questions

- *First*, are there distinct characteristics of the micro-entities (in primis, business firms) and their distributions which systematically persist over time?
- *Second*, how do such possible heterogeneous 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?

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# Size distribution and industrial concentration

# The Databases

**COMPUSTAT** U.S. publicly traded firms in the Manufacturing Industry (SIC code ranges between 2000-3999) in the time window 1982-2001. We have 1025 firms in 15 different two digit sectors.

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# Size distribution and industrial concentration

We consider  $S_{ij}(t)$  is the size of firm  $i$  in sector  $j$  at time  $t$ . We define the normalized (log) size

$$s_{ij}(t) = \log(S_{ij}(t)) - \langle \log(S_{ij}(t)) \rangle_i \quad (1)$$

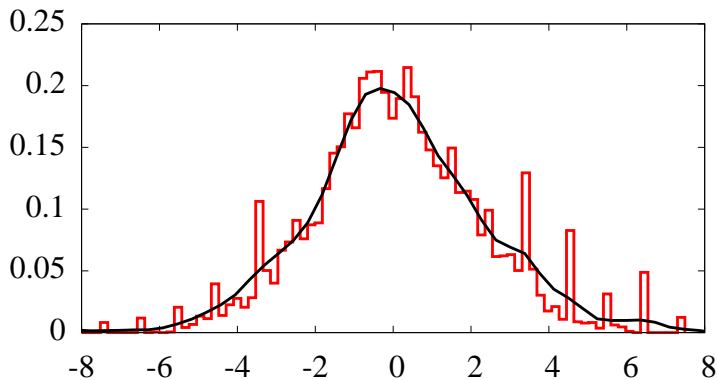
where  $\langle \log S_i(t) \rangle$  is the mean (log) size, ( $\equiv 1/N \sum S_i(t)$ ).

QfS: What's the mean of  $s_{ij}(t)$ ?

Let us have a quick look to the Lognormal distribution using Gnuplot.

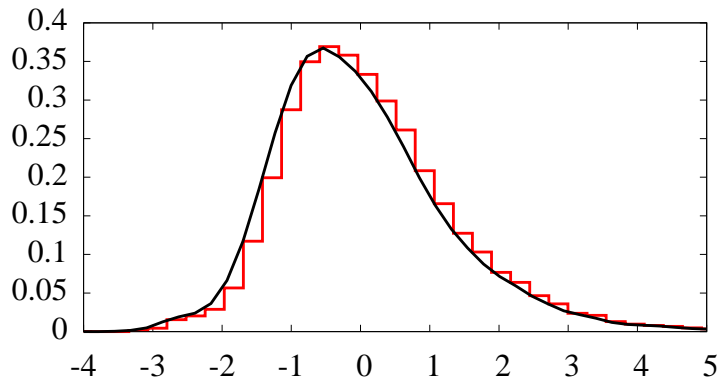
# Empirical Size Densities - US

Aggregate



# Empirical Size Densities - ITA

Aggregate



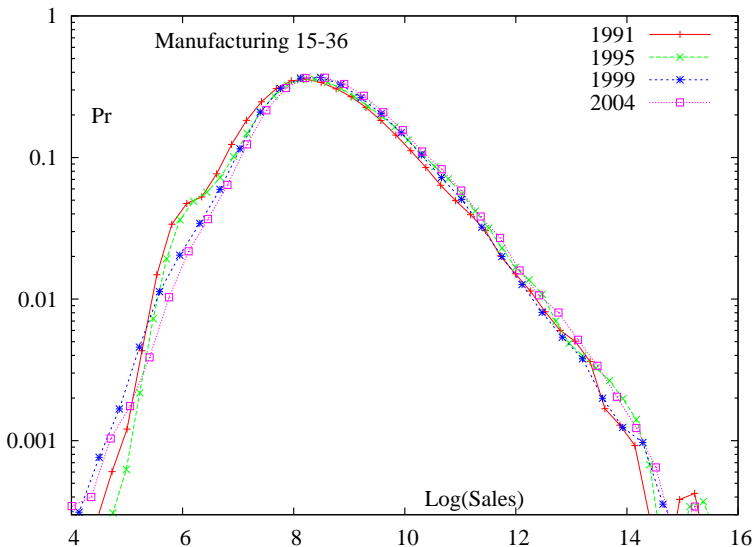


Figure 1: Empirical Densities of  $\log(S_i)$  in different years. Size measured in terms of sales. Thousands of euro, deflated with production price index.

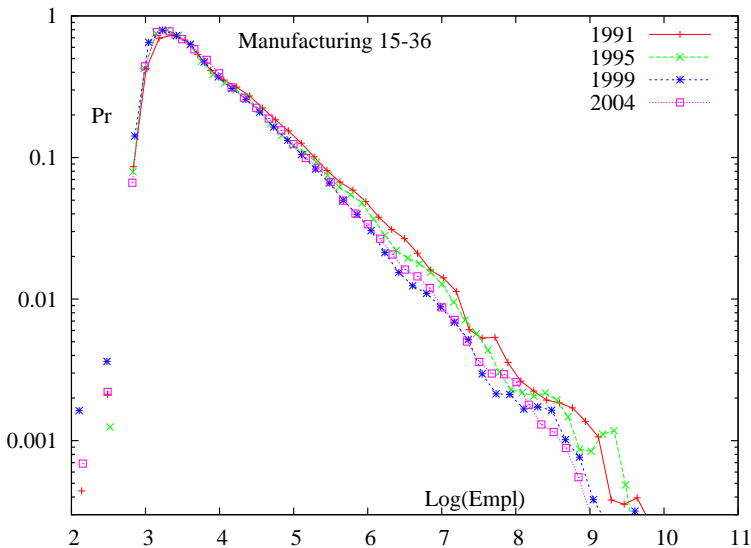
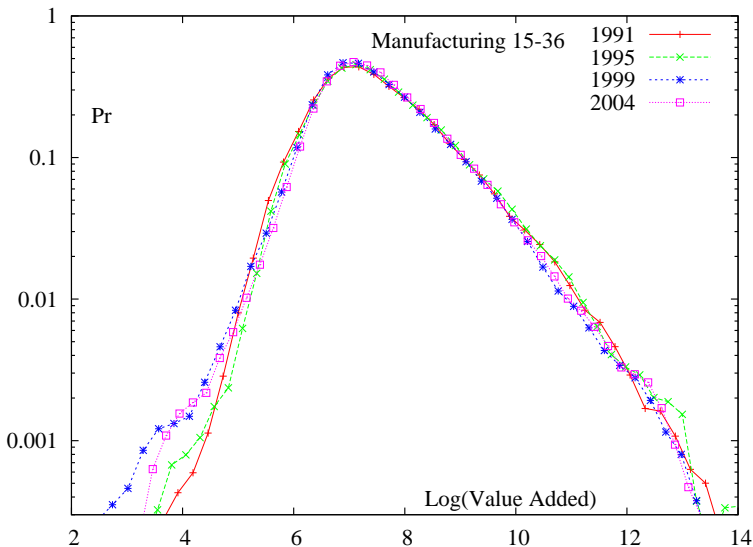


Figure 2: Empirical Densities of  $\log(L_i)$  in different years. Size measured in terms of number of employees.



**Figure 3:** Empirical Densities of  $\log(VA_i)$  in different years. Size measured in terms of Value Added. Thousands of euro, deflated with production price index.

Generic properties which hold across countries and using different size proxies:

But...

# Generic properties which hold across countries and using different size proxies:

- a) more than “Normal” variability of firm (log) sizes
- b) ruling out any naive notion of “optimal size” or theory of production simply based on U-shaped cost curve and implying the existence of an efficient scale
- c) skewed distributions, stable over time (cf. from Ijiri and Simon, 1977 and Steindl, 1965 all the way to Bottazzi and Secchi, 2003 and Bottazzi et al., 2007 )

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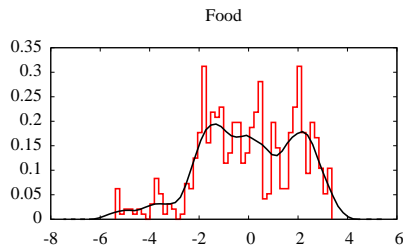
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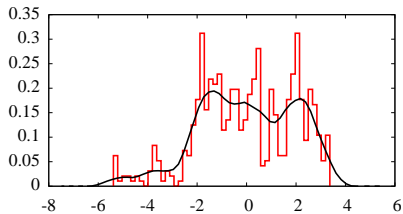
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Disaggregated at 2-digit level

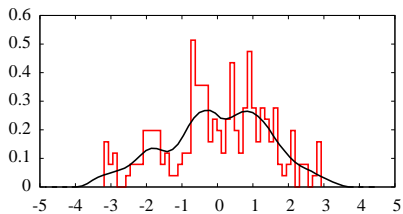
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Food



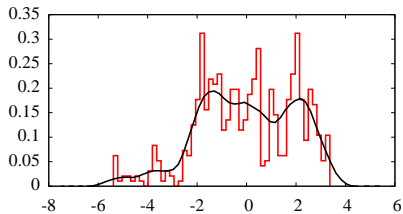
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Apparel



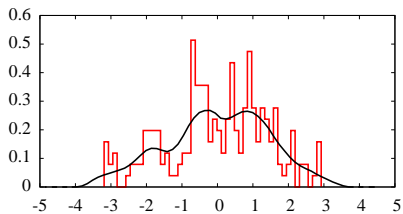
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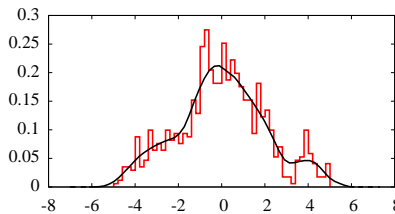


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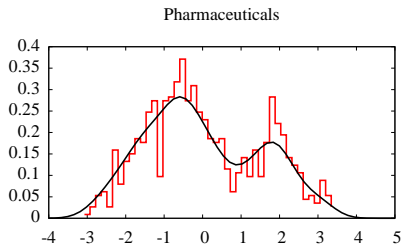
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Instruments



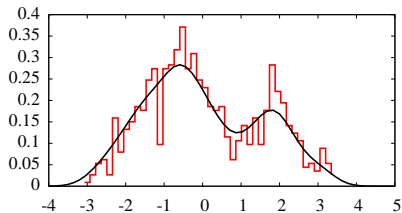
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Disaggregated at 3-digit level

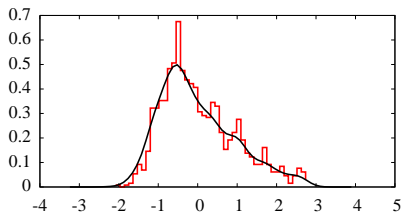
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Pharmaceuticals



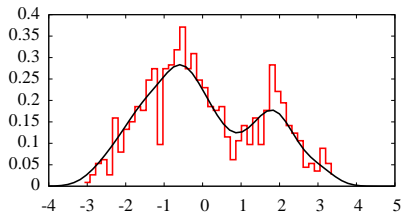
Disaggregated at 3-digit level

Cutlery, tools and general hardware



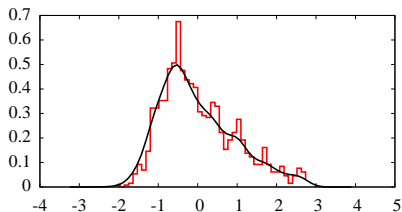
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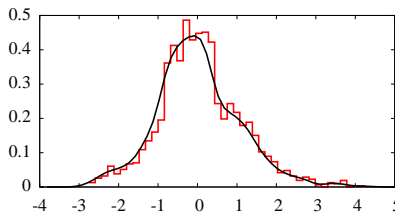


Disaggregated at 3-digit level

Cutlery, tools and general hardware



Footwear



Very different sector-specific distributions:

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- a) different shapes;
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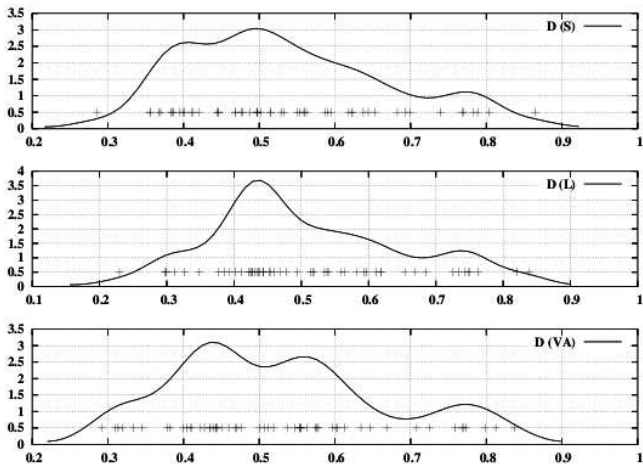
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# Concentration index

We define a concentration measure as:

$$d_{20}^4 = \frac{C_4}{C_{20}} \quad t = 1989, \dots, 1996 \quad (2)$$

where  $C_4$   $C_{20}$  are the sum of market shares of the top 4 and 20 firms in a sector, respectively.



**Figure 4:** Probability densities (kernel estimates) of the concentration index  $D_{20}^4$  in terms of Total Sales, Number of Employees and Value Added. The support of these densities is  $[0.2 \ 1]$ . Source Bottazzi et al. (2007).

# Pareto tail of the distribution

## Pareto tail of the distribution

Let  $S_i$  the size of firm  $i$  and let  $s_i = \log(S_i)$  its log,

$$F_s(x) = \text{Prob} \{s \leq x\} = \text{fraction of firms with } \log(\text{size}) \leq x .$$

Pareto (Type I) behaviour

$$1 - F_S(x) = \text{Prob} \{S > x\} \sim \left(\frac{S}{S_0}\right)^{-a}$$

On a log-log scale

$$\log(1 - F_s(x)) \sim -ax$$

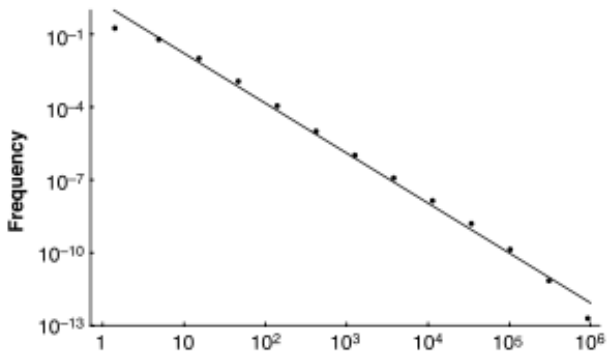


Figure 5: Firm Size (employees). Source Axtell (2001).

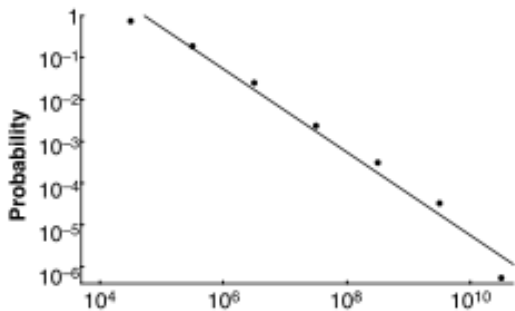


Figure 6: Firm Size (receipts). Source Axtell (2001).

## But...

Other estimates on the Fortune 500 firms for different years seem to display increasing departures from a Pareto distribution: see Fig. 7. The estimated models are

$$\log S_i = \alpha + \beta \log r_i \quad (3)$$

$$\log S_i = \alpha + \beta \log r_i + \gamma (\log r_i)^2 \quad (4)$$

where  $s_i = \log S_i$  is the size of firm  $i$  (in current dollar sales) and  $r_i$  is its rank in terms of sales themselves.

[More on the conjecture that Pareto distributions are a (puzzling) outcome of aggregation among sectors characterized by diverse regimes of technological learning, which do not display Paretian size distributions, is in Dosi et al. (1995) and Marsili (2001).]

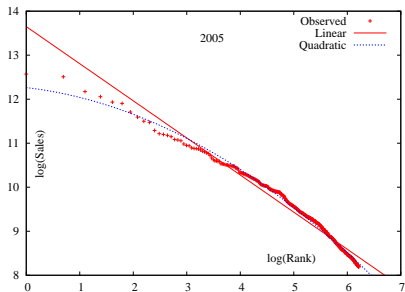
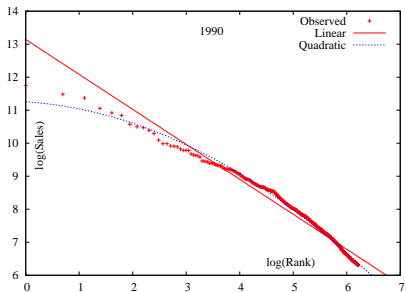
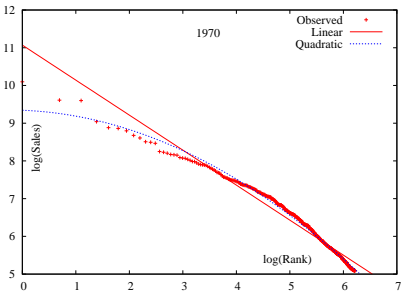
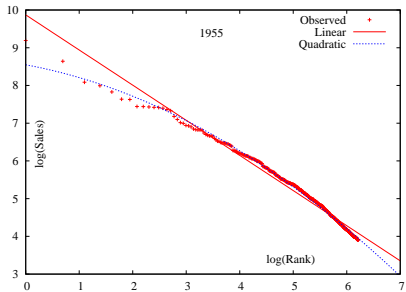


Figure 7: Zipf fit of Sales distribution for Fortune 500 firms, various years. Source Dosi et al. (2008).

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

**Table 1:** Fortune 500; Zipf fit. Linear and Quadratic Models. 5% statistically significant coefficients are in bold. Source Dosi et al. (2008).

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- a) different shapes;
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- c) evidence of separation core-fringe in several sectors
- d) high heterogeneity in concentration index
- e) no robust evidence of pareto tails

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# Firm growth patterns

Given the foregoing diversity in size distributions, what are the properties of *growth rates*?

Let us consider again:

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

where  $\langle \log S_i(t) \rangle$  is the mean (log) size, ( $\equiv 1/N \sum S_i(t)$ ). The growth rates are then defined as the first difference of  $s_i$ :

$$g_i(t) = s_i(t+1) - s_i(t)$$

## Setting the “strawman hypothesis”: ‘Gibrat Law’

- “Old” empirical starting point: firm size distribution conforms approximately to normality once plotted on a log scale (i.e. Lognormal)
- To explain how this distribution arises Kapteyn and Gibrat proposed the famous **Law of Proportionate Effect**:

$$X_t - X_{t-1} = \epsilon_t X_{t-1} \quad \epsilon \sim i.i.d.(\mu, \sigma^2) \quad (5)$$

- Two possible interpretations:
  - 1 in a process of growth equal proportionate increments have the same chance of occurring in a given time-interval whatever size happens to have reached
  - 2 growth in proportion to size is a random variable with a given distribution assumed constant over time

## Setting the “strawman hypothesis”: ‘Gibrat Law’

- This simple model corresponds to a special kind of stochastic process called Random Walk, in our case it is a RW in logs
- In the most elementary case of RW we consider discrete equal time-interval and an object which wanders on an infinite straight line taking at each time a unitary step leftward or rightward with probability  $p$  and  $1-p$  respectively.
- The RW considered by Kapteyn and Gibrat is slightly more complicated: the size of the step taken is itself a random variable.
- **Economic interpretation:** essentially no structure in the process of firm growth

## Setting the “strawman hypothesis”: ‘Gibrat Law’

$$s_i(t + 1) = \theta_i s_i(t) + \varepsilon_i(t) \quad . \quad (6)$$

### Strong Gibrat hypothesis:

- $\theta = 1$  for every  $i$ : multiplicative growth is an average independent of initial conditions, i.e. no systematic scale effects
- $\varepsilon$  is i.i.d., normally distributed

### Note:

$\theta < 1$  would be evidence corroborating regression-to-the-mean, and, indirectly, some underlying “optimal size” attractor;  
 $\theta > 1$  ought to capture persistent tendency toward monopoly.

Should we care about the “strawman”?

## Should we care about the “strawman”?

Corroboration of “Strong Gibrat’s HP” would turn out to be quite **damaging** for evolutionary theories of industrial change. After all, basic building-blocks of evolutionary theories are the twin notions of

- i) persistent heterogeneous characteristics among agents;
- ii) systematic processes of competitive selection among them.

The “strong version” of Gibrat, indeed is a falsification as good as one might get of evolutionary theories: multiples small, “atomless”, uncorrelated shocks to micro growth.

# The properties of growth-size relation

$\theta_i$  coefficients ought to be considered just as proximate coefficients for “static” returns to scale or spuriously correlated to “deeper” initial technological and organizational conditions:

- NO strikingly robust relation size  $\Leftrightarrow$  average rates of growth
- even if most often, smaller firms - on average - grow faster (caveat: small surviving firms...);  
[For a summary of quite a few econometric results see Lotti et al. (2003); conversely, on the relationship between size and growth and its lack of size dependency, above some size thresholds, cf. Bottazzi et al. (2001), Bottazzi et al. (2007) on Italian firms; Bottazzi and Secchi (2003) and Ijiri and Simon (1977) and Sutton (1997) for discussions]
- the relationship size-growth is modulated by the age of firms themselves (broadly speaking, exerting *negative* effects on growth rates, but *positive* effects on survival probabilities, at least after some post-infancy threshold ...)

# The cross-sectional and longitudinal properties of growth rate distributions

Conversely, the statistical properties of the “error term” offer precious clues on the basic characteristics of the processes of market competition and corporate growth over time.

- **Growth volatility and size**

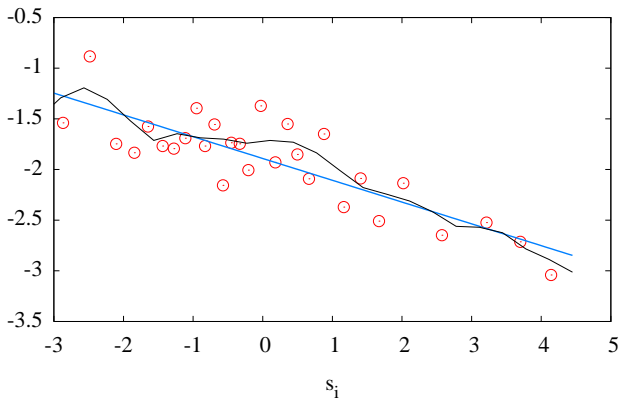
Quite robust evidence suggests that the variance of firms' growth rates fall as firms' size increases (“Scaling Law”):

$$\sigma(g|s) \sim S^\beta \text{ or } \log(\sigma(g|s)) \sim \alpha + \beta s$$

- **Growth rates distributions**

Studies include Stanley et al. (1996) and Bottazzi and Secchi (2003) on U.S. data; Bottazzi et al. (2001) on the international pharmaceutical industry; Bottazzi et al. (2002) and Bottazzi et al. (2007) on the Italian industry.

- **Growth rates autocorrelation**



**Figure 8:** The relation between the standard deviation of growth rates (on a log scale) and the size of the firm, together with the fit  $\log(\sigma(g/s)) = \alpha + \beta s$  and a non-parametric regression of the relation between  $\log(\sigma(g/s))$  and  $s$ . Source Bottazzi and Secchi (2006b).

# Scaling of variance

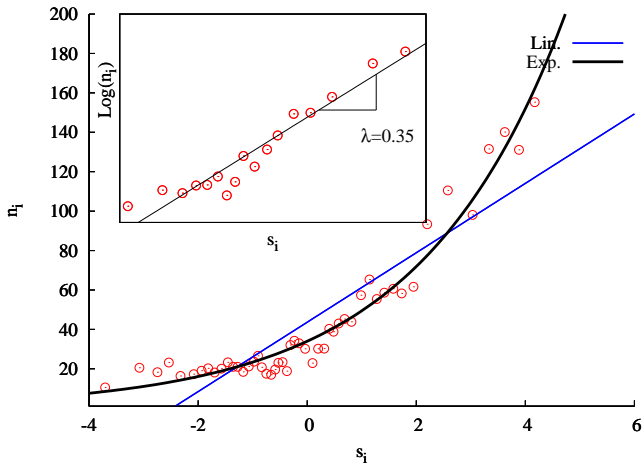
- ⇒ Aggregate Manufacturing, U.S. data:
  - ▶ Amaral et al. (1997):  $\beta \approx -.2 \pm .03$
  - ▶ Bottazzi and Secchi (2003):  $\beta \approx -.19 \pm .01$
- ⇒ International Pharmaceutical Industry:
  - ▶ Bottazzi et al. (2001):  $\beta \approx -.2 \pm .03$
- ⇒ Aggregate Sectoral Manufacturing, Italian data:
  - ▶ Bottazzi et al. (2002):  $\beta \approx 0$
  - ▶ ... as such a puzzling piece of evidence

## Interpreting the scaling of variance

An interpretation of the variance-scale relation is that it depends in fact on the diversification-size relation. See (Bottazzi and Secchi, 2006b) on the international pharmaceutical industry.

In turn, the evidence of Figure 9 can be accounted for by a *branching process* in diversification activities (Bottazzi and Secchi, 2006b).

N.B. Such a process of diversification is well in tune with *capability-driven* patterns of diversification, as capability-based theories of the firm would predict, with new activities incrementally building upon existing ones (cf. also the remarks in Teece et al., 1994).

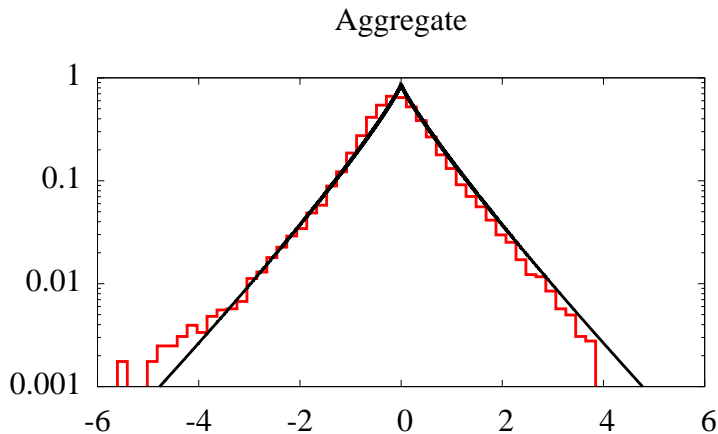


**Figure 9:** Number of submarkets a firm operates in vs. firm size. Source Bottazzi and Secchi (2006b).

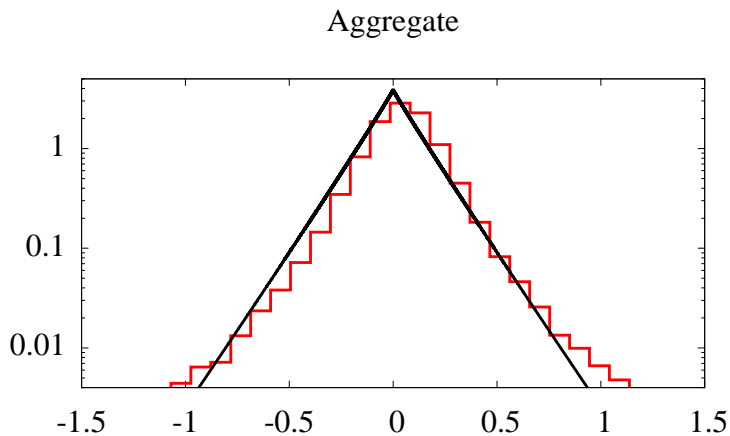
# The cross-sectional and longitudinal properties of growth rate distributions

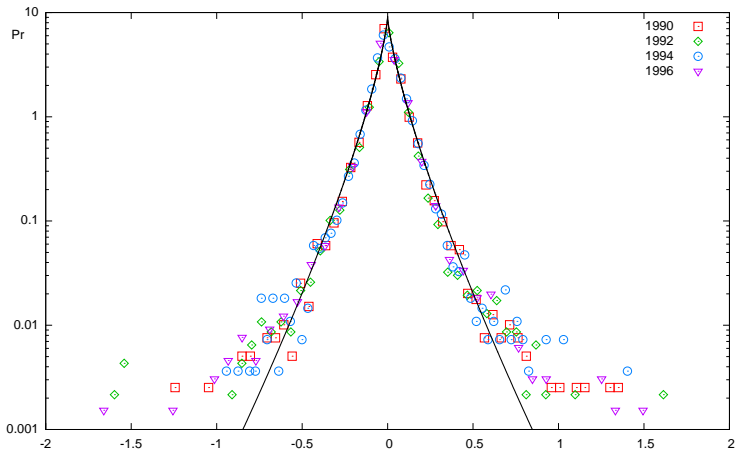
- Growth volatility and size
- **Growth rates distributions**  
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- Growth rates autocorrelation

# Empirical growth rates densities - US

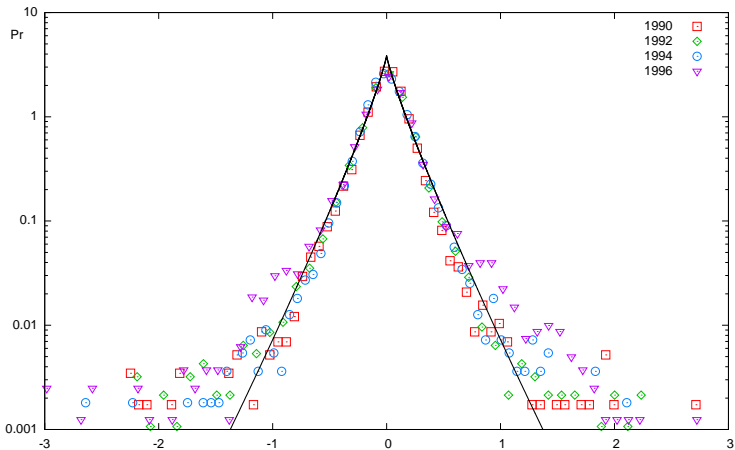


# Empirical growth rates densities - ITA





**Figure 10:** Growth rates distributions in different years. Size measured in terms of employees. Italian Aggregate Manufacturing. Source Bottazzi et al. (2003).



**Figure 11:** Growth rates distributions in different years. Size measured in terms of Value Added. Italian Aggregate Manufacturing. Source Bottazzi et al. (2003).

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# Generic properties which hold across countries and using different size proxies:

- a) shape is stable over time
- b) display similar shapes across sectors
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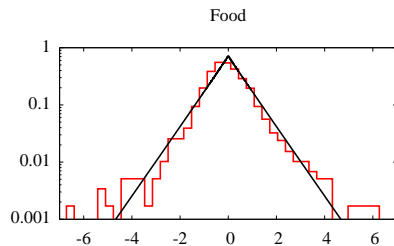
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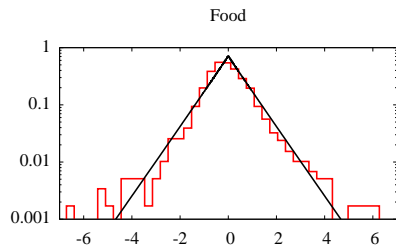
**But...**

# Empirical growth rates densities - US

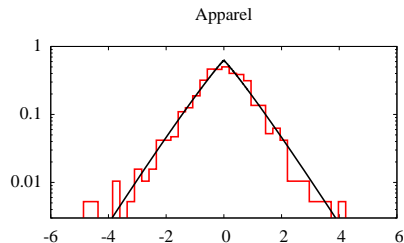


Disaggregated at 2-digit level

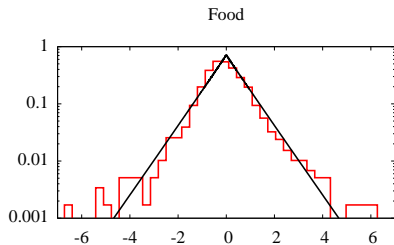
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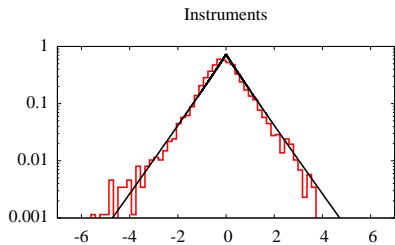
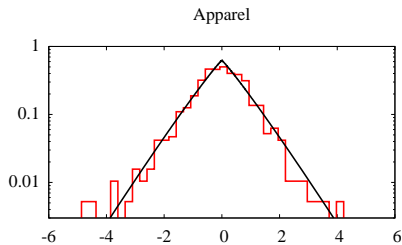
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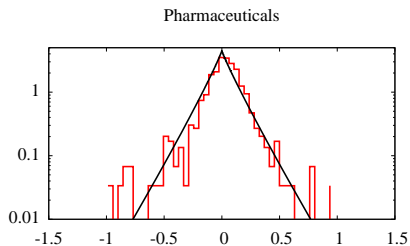
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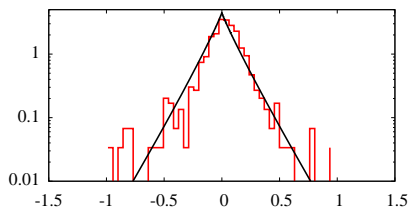
# Empirical growth rates densities - ITA



Disaggregated at 3-digit level

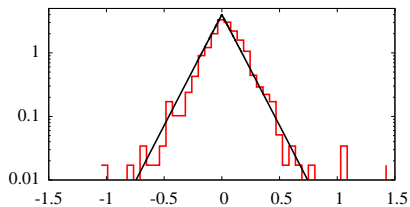
# Empirical growth rates densities - ITA

Pharmaceuticals



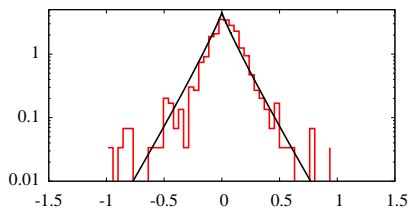
Disaggregated at 3-digit level

Cutlery, tools and general hardware



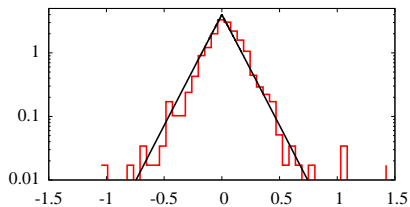
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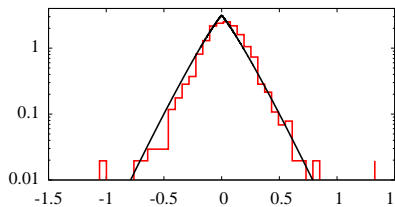


Disaggregated at 3-digit level

Cutlery, tools and general hardware



Footwear



# Generic properties which hold across countries and using different size proxies:

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But there's no but...these properties are robust against disaggregation!

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# The Subbotin Distribution

$$f_S(x) = \frac{1}{2ab^{1/b}\Gamma(1/b + 1)} e^{-\frac{1}{b} \left| \frac{x-\mu}{a} \right|^b} \quad (7)$$

Mikhail Fyodorovich Subbotin (1883-1966)

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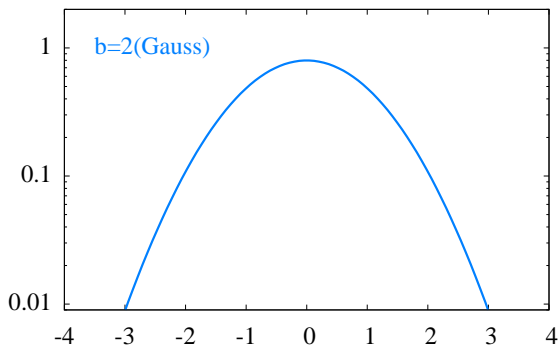
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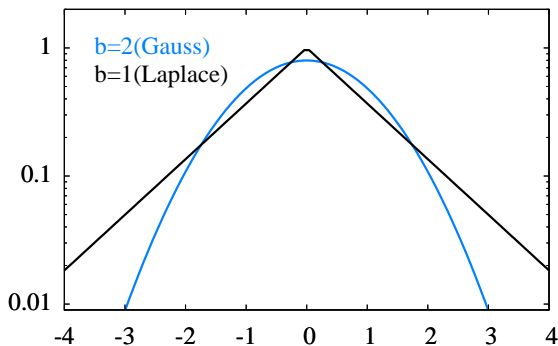


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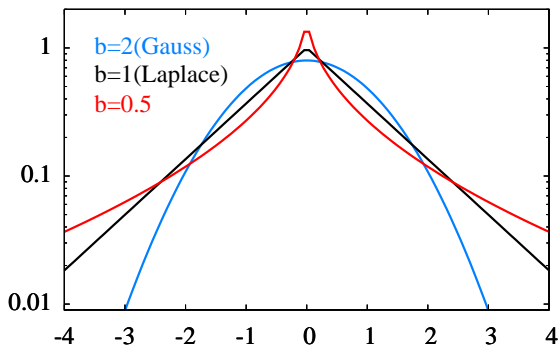


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# ML Estimation Procedure

We consider:

$$-\log(L_S(x; a, b, \mu)) = n \log \left( 2b^{1/b} a \Gamma(1 + 1/b) \right) + (ba^b)^{-1} \sum_{i=1}^n |x_i - \mu|^b \quad (8)$$

and we minimize it with respect to the parameters using a multi-step procedure.

These ML estimators are asymptotically consistent in all the parameter space, asymptotically normal for  $b > 1$  and asymptotically efficient for  $b > 2$ .

# Estimates on US Sectors

Ateco code	Sector	Parameter <i>b</i>		Parameter <i>a</i>	
		Coef.	Std Err.	Coef.	Std Err.
20	Food and kindred products	0.9888	0.0010	0.7039	0.0005
23	Apparel and other textile products	1.0819	0.0027	0.7664	0.0013
26	Paper and allied products	1.0999	0.0024	0.7663	0.0011
27	Printing and publishing	0.9621	0.0015	0.7115	0.0008
28	Chemicals and allied products	1.0164	0.0004	0.7562	0.0002
29	Petroleum and coal products	1.1841	0.0043	0.8370	0.0019
30	Rubber and miscellaneous plastics products	0.9487	0.0018	0.7148	0.0010
32	Stone, clay, glass, and concrete products	1.1023	0.0039	0.7720	0.0018
33	Primary metal industries	1.1254	0.0015	0.7870	0.0007
34	Fabricated metal products	0.9081	0.0013	0.6639	0.0007
35	Industrial machinery and equipment	0.9466	0.0003	0.6761	0.0002
36	Electrical and electronic equipment	0.8989	0.0003	0.6303	0.0001
37	Transportation equipment	1.0033	0.0011	0.7107	0.0005
38	Instruments and related products	0.9722	0.0004	0.6980	0.0002
39	Miscellaneous manufacturing industries	1.0232	0.0022	0.7447	0.0011

# Estimates on Italian Sectors

Ateco code	Sector	Parameter <i>b</i>		Parameter <i>a</i>	
		Coef.	Std Err.	Coef.	Std Err.
151	Production, processing and preserving of meat	0.83	0.05	0.089	0.004
155	Dairy products	0.91	0.07	0.080	0.004
158	Production of other foodstuffs (brad, sugar, etc...)	0.89	0.05	0.097	0.004
159	Production of beverages (alcoholic and not)	0.88	0.06	0.108	0.006
171	Preparation and spinning of textiles	1.19	0.07	0.142	0.005
172	Textiles weaving	1.12	0.06	0.122	0.004
173	Finishing of textiles	1.11	0.06	0.107	0.004
175	Carpets, rugs and other textiles	1.02	0.08	0.118	0.006
177	Knitted and crocheted articles	0.97	0.05	0.124	0.005
182	Wearing apparel	0.92	0.03	0.120	0.003
191	Tanning and dressing of leather	1.12	0.09	0.140	0.007
193	Footwear	1.12	0.05	0.150	0.004
202	Production of plywood and panels	0.98	0.09	0.104	0.007
203	Wood products for construction	0.94	0.08	0.105	0.007
205	Production of other wood products (cork, straw, etc...)	1.31	0.13	0.106	0.006

# Properties of growth rates distributions

To sum up:

- a) Exponential (Laplace) distribution as a very robust property which holds:
  - ▶ across levels of aggregation
  - ▶ across countries
  - ▶ across different measures of size (e.g. sales, employees, value added)
- b) some (moderate) heterogeneity across different sectors with respect to the distribution parameters  $b$
- c) stability over time

**Major interpretative question:** what are the underlying correlating mechanisms which generically yield the observed fat-tails in the distributions? [some hypotheses on underlying increasing-returns dynamics is in Bottazzi and Secchi, 2006a; other possibly complementary ones draw on Dosi et al., 1995.]

# The cross-sectional and longitudinal properties of growth rate distributions

- Growth volatility and size
- Growth rates distributions  
Studies include Stanley et al. (1996) and Bottazzi and Secchi (2003) on U.S. data; Bottazzi et al. (2001) on the international pharmaceutical industry; Bottazzi et al. (2002) and Bottazzi et al. (2007) on the Italian industry.
- Growth rates autocorrelation

# Autocorrelation in growth rates

We focus on autocorrelation of growth rates

International drug industry:

- long-lasting positive autocorrelation (up to the 7th lag)
- autocorrelation for each firm within specific markets present but lower than for the firm as a whole [N.B.: This should be taken as evidence that firms cannot be considered as aggregations on independent lines of business. Rather, the “competitiveness” of whole firms is revealed over time in the entire ensembles of market in which it operates]

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## U.S. evidence

- relatively weak autoregressive structure (generally one-lag only) with a good deal of inter-sectoral variability [this is a puzzle: could it be due to the fact that one still studies events at sectoral levels, aggregates which are too broad, actually comprising many industries?]

## Italian evidence

- average autocorrelation in most sectors nearly zero;
- ... but heterogeneous profiles across firms with the same sector [N.B.: systematic micro heterogeneity is confirmed by comparing the actual firm-specific distribution with “artificial ones” obtained via random bootstrapping of growth rates...]

# Outline

- 1 Setting the research framework
- 2 Firm Sizes, Growth Rates and Profitabilities**
  - Size Distribution
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  - Labor Productivities
- 4 An interpretative framework

## Firm profitability

Together with growth, profitability is another crucial measure of performance.

Building on the background literature on persistence in profitability differences across firms including Mueller (1986), Mueller (1990), Cubbin and Geroski (1987), Geroski and Jacquemin (1988), Gschwandter (2004), here we consider the distribution of gross margins within Italian manufacturing sectors and their persistence over time.

Consider the variable

$$GM_i(t) = (VA_i(t) - W_i(t))/VA_i(t)$$

where  $GM_i$  is gross operating margins;  $VA_i$  is value added;  $W_i$  is the total wage cost.

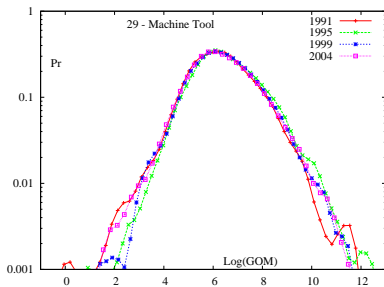
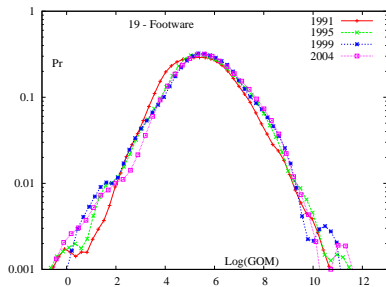
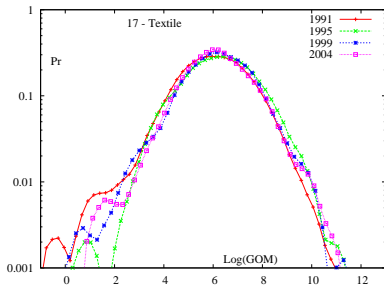
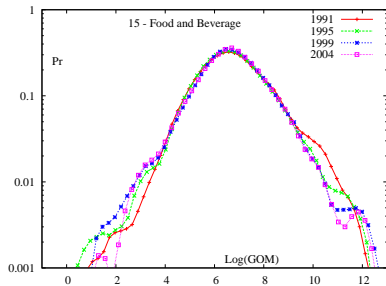


Figure 12: Empirical densities of (log) Gross Margin by sector. Thousands of euro, deflated with production price index. Our elaboration on Micro.3.

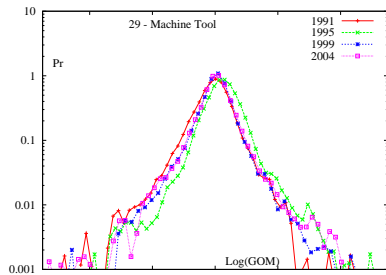
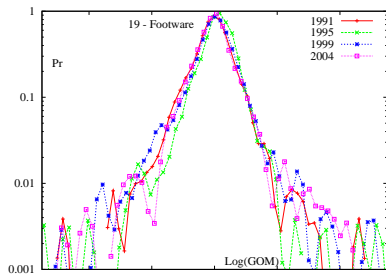
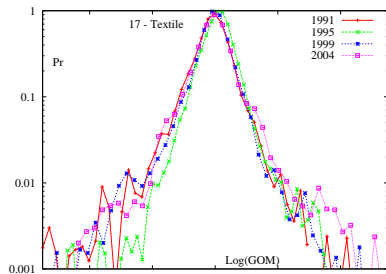
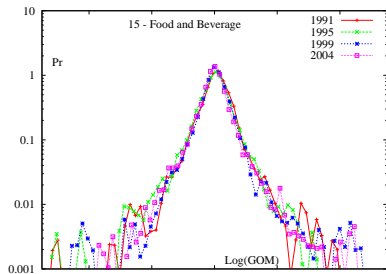


Figure 13: Empirical densities of (log) Gross Margin growth rates, by sector. Our elaboration on Micro.3.

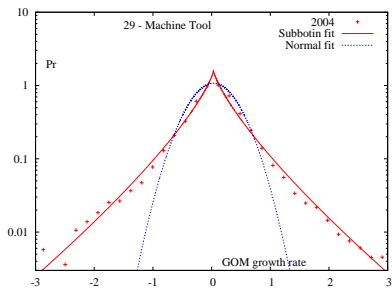
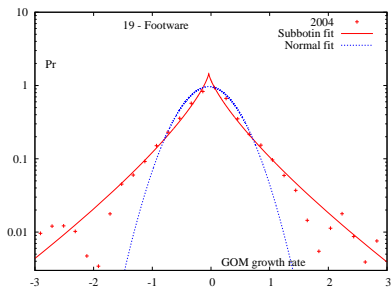
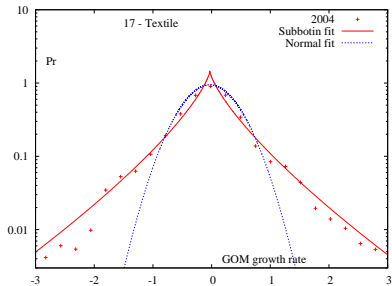
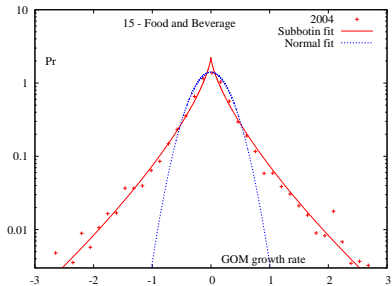


Figure 14: Empirical densities of (log) Gross Margin growth rates 03-04, by sector. Subbotin and Normal fit. Our elaboration on Micro.3.

NACE SECTOR	Levels		Differences	
	AR(1)	std err	AR(1)	std err
15 Food products and beverages	0.9516	0.0060	-0.3424	0.0190
17 Manufacture of textiles	0.9117	0.0067	-0.2953	0.0163
18 Wearing apparel; dyeing of fur	0.9328	0.0087	-0.3992	0.0254
19 Tanning, dressing of leather manuf. of luggage, footwear	0.8781	0.0144	-0.2984	0.0307
20 Manuf. of wood &cork prod	0.9430	0.0115	-0.3658	0.0332
21 Manuf. of pulp & paper prod	0.9432	0.0104	-0.2935	0.0298
22 Recorded media	0.9471	0.0098	-0.3917	0.0293
24 Manuf. of chemicals products	0.9370	0.0081	-0.3315	0.0216
25 Rubber and plastic products	0.9203	0.0085	-0.2917	0.0208
26 Other non-metallic mineral prod	0.9430	0.0067	-0.3337	0.0190
27 Basic metals	0.9149	0.0101	-0.3245	0.0248
28 Fabricated metal products	0.9213	0.0064	-0.2957	0.0155
29 Machinery and equipment n.e.c.	0.9207	0.0055	-0.3215	0.0137
31 Electrical machinery n.e.c.	0.9649	0.0086	-0.2382	0.0265
35 Other transport equipment no cars	0.9200	0.0175	-0.1824	0.0461

**Table 2:** Autocorrelation of Gross Margins Levels and Growth Rates. Our elaborations on Italian data (1989-1997).

# Major findings

- i) wide distributions of probabilities across firms characterize all sectors
- ii) stability over time
- iii) some (mild) regression to the mean tendencies

# Summing up

- i) More structure in the growth process than generally assumed:
  - ▶ ubiquitous fat-tailed distribution suggesting underlying correlation mechanisms
  - ▶ (some) autocorrelation over time
  
- ii) Wide variability in profitabilities, quite stable over time

These indicators, capturing two central aspects of firms performances reveal widespread and persistent heterogeneity. What about underlying differences in production efficiencies and degrees of innovativeness?

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  - **Innovativeness**
  - Labor Productivities
- 4 An interpretative framework

# Technological Characteristics of firms

## Innovativeness

- i) A lot of qualitative evidence from the economics of innovation suggests deeply asymmetric innovative capabilities (Freeman and Soete, 1997; Dosi, 1988; Dosi et al., 2005).
- ii) Moreover, differential innovativeness is often persistent over time (Cefis, 2003a).

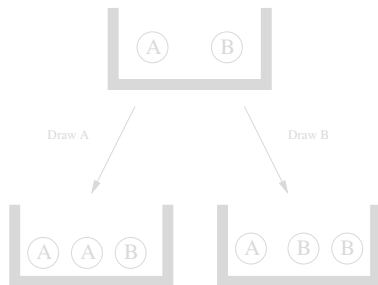
Regarding more specifically the international pharmaceutical industry:

- iii) Rare arrival of innovations: process of arrival by firm well described by a “Bose-Einstein” statistics. This possibility of correlated arrival is well in tune with an evolutionary notion of high-capability, persistent, innovators
- iv) Heterogeneity across firms in innovative content of product portfolios

# Self-reinforcing arrival of innovations

- 1 Consider an urn with  $N$  different balls, each representing a firm

Draw a ball and replace with **TWO** of the same kind. (Here the first draw from an urn with two types of ball)



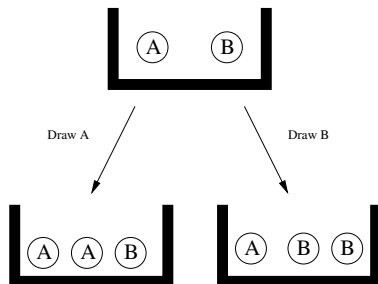
- 3 Repeat this procedure  $M$  times

RESULT: assignment of  $M$  innovations on  $N$  firms.

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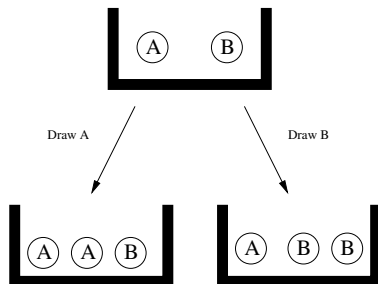
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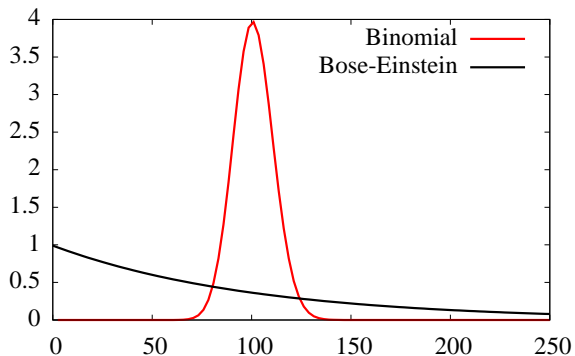
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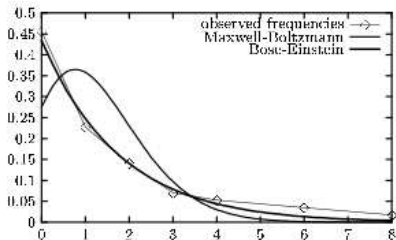
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# Occupancy Statistics



Bose-Einstein and binomial with  $N = 100$  and  $M = 10,000$ .



**Figure 15:** The frequencies of total New Chemical Entities over the firms populations in the international drug industry (x-axis: firms introducing 0,1, ..., 8 NCE's; y-axis: frequencies thereof. Source Bottazzi et al. (2001).

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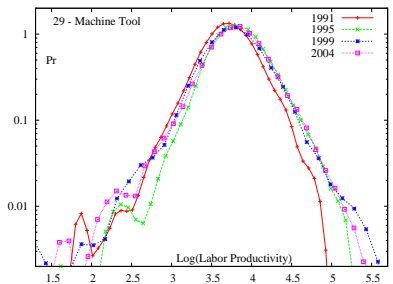
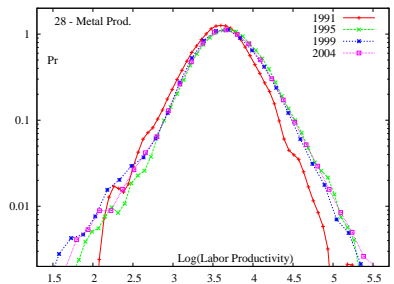
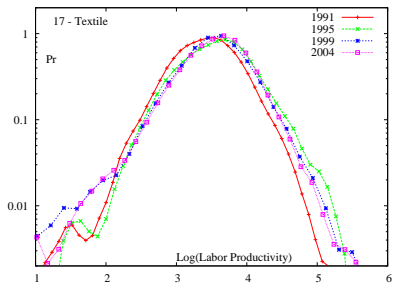
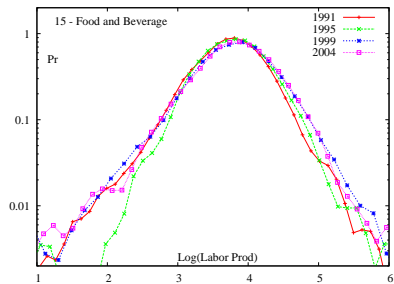


Figure 16: Empirical densities of (log) Labor Productivity. Deflated with production price index. Our elaboration on Micro.3.

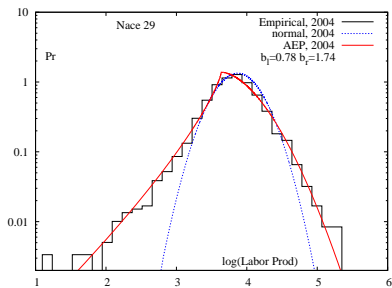
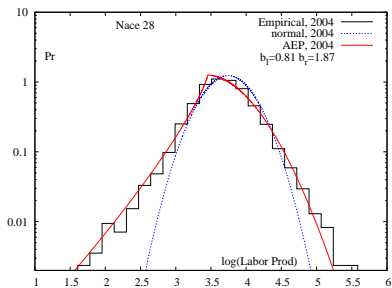
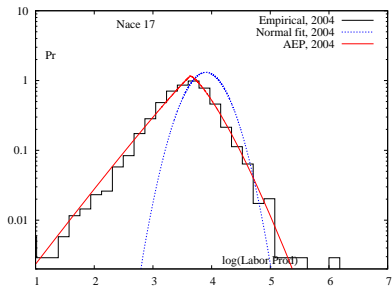
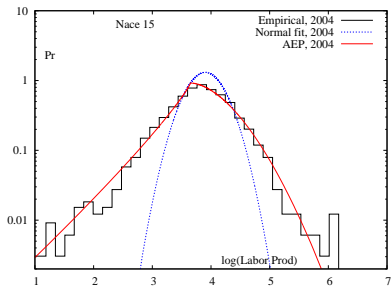


Figure 17: Empirical densities of (log) Labor Productivity, together with Normal and Asymmetric Exponential fit. Our elaboration on Micro.3.

NACE	'89	'91	'93	'95	'98	'00	'02	'04
15	6.9	6.7	7.2	5.9	8.0	8.0	8.3	8.2
	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
17	5.5	5.2	6.4	6.3	6.3	5.7	5.6	6.0
	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.3
18	6.6	7.1	8.2	7.4	9.1	11.6	11.0	11.8
	0.3	0.3	0.4	0.3	0.4	0.5	0.5	0.7
19	5.3	5.9	6.0	6.1	6.0	6.5	6.7	6.3
	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3
24	4.8	4.7	5.2	6.2	8.3	8.6	7.0	8.3
	0.3	0.2	0.3	0.6	0.7	0.6	0.4	0.6
25	4.0	4.2	5.0	5.1	4.6	4.9	4.5	4.9
	0.1	0.2	0.3	0.2	0.1	0.3	0.2	0.2
26	5.2	5.2	5.6	5.3	5.0	6.0	5.8	6.2
	0.2	0.2	0.2	0.2	0.2	0.6	0.2	0.2
27	4.3	3.9	4.5	5.4	4.7	5.0	4.9	6.1
	0.2	0.1	0.2	0.3	0.2	0.3	0.3	0.4
28	3.6	3.6	3.8	4.1	4.3	4.5	4.2	4.3
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
29	3.5	3.4	3.9	3.5	4.3	4.3	4.1	4.2
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
34	3.7	4.0	5.0	4.2	5.2	5.2	5.3	5.5
	0.2	0.2	0.3	0.3	0.4	0.4	0.3	0.4
35	4.5	5.2	7.3	5.2	5.5	6.8	8.6	6.9
	0.3	0.5	0.7	0.4	0.6	0.6	1.5	0.7
36	3.7	3.9	4.4	4.3	4.7	5.2	4.9	5.3
	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2

**Table 3:** Ratio of the average productivity (and relative std err) of the top decile over the bottom one. Source: Our elaboration on Micro.3

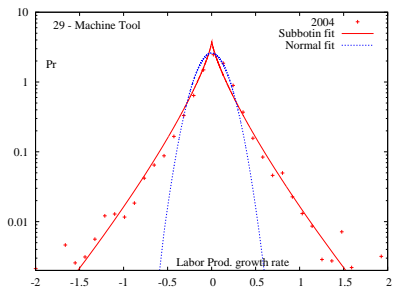
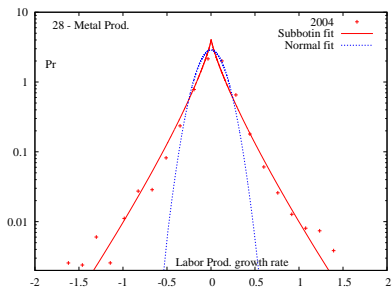
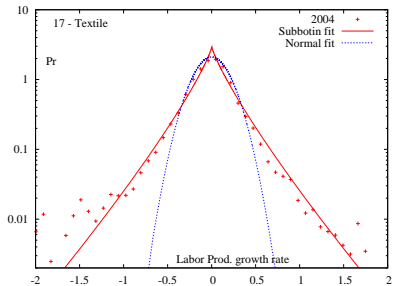
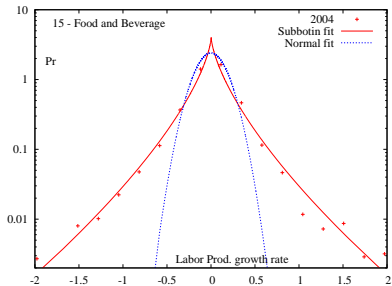


Figure 18: Empirical densities of Labor Productivity growth rates, together with Normal and Asymmetric fit. Our elaboration on Micro.3.

NACE SECTOR	Levels		Differences	
	AR(1)	std err	AR(1)	std err
15 Food products and beverages	0.8619	0.0092	-0.2641	0.0208
17 Manufacture of textiles	0.8699	0.0076	-0.2770	0.0171
18 Wearing apparel; dyeing of fur	0.9285	0.0087	-0.3428	0.0250
19 Tanning, dressing of leather manuf. of luggage, footwear	0.8932	0.0158	-0.3123	0.0398
20 Manuf. of wood &cork prod	0.8357	0.0154	-0.3254	0.0312
21 Manuf. of pulp & paper prod	0.8772	0.0140	-0.2348	0.0030
22 Recorded media	0.8391	0.0127	-0.1596	0.0319
24 Manuf. of chemicals products	0.7947	0.0132	-0.1883	0.0234
25 Rubber and plastic products	0.8920	0.0108	-0.2831	0.0244
26 Other non-metallic mineral prod	0.9057	0.0077	-0.3065	0.0195
27 Basic metals	0.8583	0.0135	-0.1645	0.0270
28 Fabricated metal products	0.8572	0.0079	-0.3299	0.1580
29 Machinery and equipment n.e.c.	0.8098	0.0079	-0.3177	0.0143
31 Electrical machinery n.e.c.	0.8534	0.0119	-0.1072	0.0236
35 Other transport equipment no cars	0.7518	0.0299	-0.3490	0.0481

**Table 4:** Autocorrelation of Labor Productivity Levels and Growth Rates. Our elaborations on Italian data (1989-1997).

## Labor Productivities (Italian data)

- i) Again, **widespread heterogeneity** within sectors, cf. Fig. 16 (see also Dosi and Grazzi, 2006).
- ii) **Stability** of the distribution **over time** and persistence of productivity differential over time (cf. the survey of Bartelsman and Doms, 2000).
- iii) **Asymmetries in the distribution** of (log) labor productivity (cf. Fig. 17):
  - ⇒ Both coefficients ( $b_l$  and  $b_r$ ) of the asymmetric Subbotin  $< 2$  but the left tail is much thicker.
  - ⇒ Support to the hypothesis of a weak selection process
  - ⇒ The support does not shrink over time ⇒ Table 3 ratio of the top over the bottom decile.
- iv) Some **(mild) regression to the mean** tendencies (Table 4).
- v) **Exponential distributions of growth rates** Fig. 18 and Bottazzi et al. (2005).

# Patenting Activity and Productivity

- Registered patents of Italian firms bigger than 20 employees (both USPTO and EPO).
- ⇒ Only 1883 firms have registered patents over 64000 of the manufacturing sector (Italian census Micro.3)
- Apparent differences in terms of labor productivity
- ... but not in terms of profitability (as  $ROS = GOM/Sales$ )

NACE	Total	Patenting	%	NACE	Total	Patenting	%
241	273	26	9.52	291	661	87	13.16
243	179	8	4.47	292	1494	139	9.30
244	267	75	28.09	293	214	26	12.15
245	184	4	2.17	294	457	60	13.13
246	230	14	6.09	295	1185	197	16.62
24	1177	132	11.21	297	199	34	17.09
251	256	16	6.25	29	4236	547	12.91
252	1569	103	6.56	30	112	7	6.25
25	1825	119	6.52	311	252	14	5.56
261	236	15	6.36	312	213	21	9.86
262	143	7	4.90	316	594	45	7.58
263	212	9	4.25	31	1329	92	6.92
264	124	2	1.61	322	211	13	6.16
266	573	8	1.40	32	406	24	5.91
267	244	5	2.05	332	198	23	11.62
26	1692	56	3.31	33	668	73	10.93
273	166	3	1.81	342	141	4	2.84
275	333	7	2.10	343	394	45	11.42
27	848	27	3.18	34	574	54	9.41
281	1145	16	1.40	35	395	25	6.33
284	522	11	2.11	361	1434	48	3.35
285	1772	31	1.75	362	282	8	2.84
286	324	32	9.88	366	211	15	7.11
287	973	52	5.34	36	2027	85	4.19
28	4930	158	3.20				

**Table 5:** Number of patents for a selection of 2 Digit and some of their nested 3 Digit sectors. Our elaboration on Micro.3

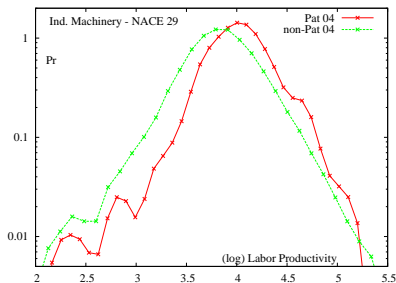
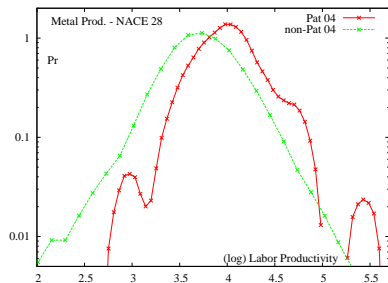
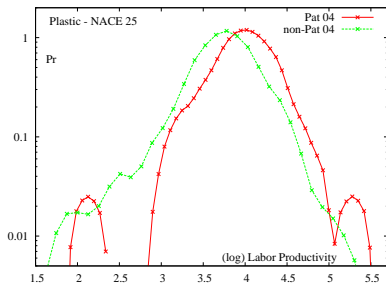
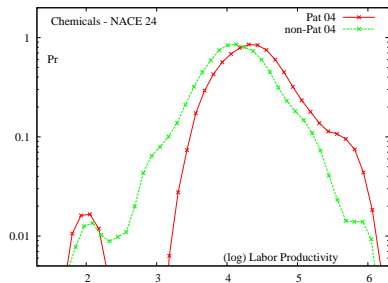


Figure 19: Empirical densities of Labor productivity for patenting and non-patenting firms in 2004. Our elaboration on Micro.3.

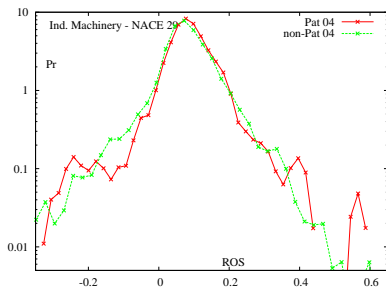
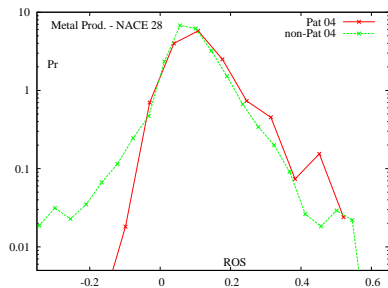
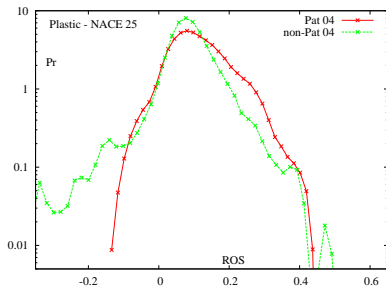
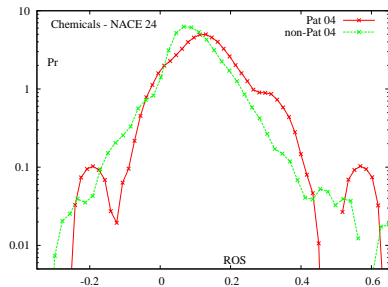


Figure 20: Empirical densities of Profitability (proxied by ROS) for patenting and non-patenting firms in 2004. Our elaboration on Micro.3.

# Plants vs. Firms

## **Heterogeneity across plants, their dynamics and their relation with firms characteristics**

(as from Baily et al. (1992) but cf. also Rumelt (1991) Baldwin (1998) Power (1998) and others) [caveat: most analyses are undertaken in terms of Total Factor Productivities, with all the ambiguities associated with the notion...]

### **Plant-level evidence**

- i) High degrees of heterogeneity in plant productivities
- ii) Increasing output shares in high-productivity plants and the decreasing shares of output in low-productivity plants are very important to the growth of manufacturing productivity
- iii) Plants at the top of the productivity distribution are able to stay on the top for long periods
- iv) High degrees of persistence (cf. 10-years transition matrix, showing strong plant-specific fixed effects)

## **Firm-level influences** Strong firm effects:

- a) Plants that are part of the high-productivity firms will also have higher productivity levels
- b) Plants in firms where there is rapid productivity growth will grow more rapidly

## **Major issues**

- ⇒ comparisons between within- vs. across firms measures of heterogeneity
- ⇒ what are the specificities in the relationship learning vs. selection across plants / within firms as distinct from that across firms

## an irreducible heterogeneity at all levels of observation

As Griliches and Mairesse (1999) 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 form the machinery industry.”

# An interpretative framework

[broadly in an evolutionary framework: cf. Nelson and Winter (1982), Winter (1984), Dosi et al. (1995)]

- 1) At any “initial” time there is a distribution of (short-term fixed) input coefficients across firms.
- 2) Heterogeneous firms compete with each other, and given prevailing input and output prices obtain different returns (or, putting it in a rather different language, different - positive or negative - “quasi-rents” above/below notional “pure competition” input prices).
- 3) Leaving aside any entry/mortality phenomenon, surviving incumbents undergo changes in their market shares and therefore in their relative (and, of course absolute) outputs.

## An interpretative framework (cont'd)

- 4) Realized market shares and realized profitabilities affect the future supply (and often future prices) of the various firms.

[N.B. So far, point 2, 3 and 4 describe selection/adaptation processes given initial conditions. Note also that this basic story, so far, may well be enriched by explicit details on demand structures, e.g. “horizontal”, “vertical” differentiation (à la Sutton) entailing correspondingly more “rugged” selection landscape]

- 5) Over time firms learn/innovate/initiate changing their input efficiencies and product characteristics.

⇒ Hence, what are the relationships between innovativeness/production efficiency, on the one hand, and economic performances (growth and profitabilities on the other).

## Major Properties

- i) Weak or non existent relationship between growth and relative productivities: more efficient firms do not grow more (cf. Fig. 21, on Italian data).
  - ⇒ This remains true even if we focus on the small sub-sample of firms with patents (cf. Fig. 22)
- ii) (In the case of the international pharmaceutical industry) more innovative firms do not grow more (cf. Bottazzi et al., 2001)).
- iii) A positive relation between relative efficiency and growth is often recovered through the impact of outliers (the very best and the very worst).
- iv) Industries appear to constantly involve the coexistence of heterogeneous types of firms (innovators/imitators, etc.)

Conversely,

- v) Innovativeness seems to bear a positive impact upon profitabilities (cf. Geroski et al., 1993, Cefis, 2003a, Roberts, 1999)
- vi) Moreover there appears to be a positive relation between relative productivities and profitabilities (Lesson 2 and Bottazzi et al., 2008)

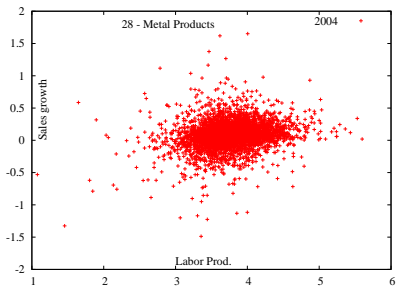
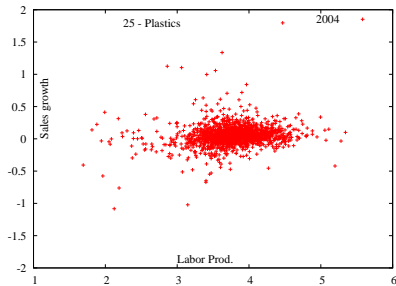
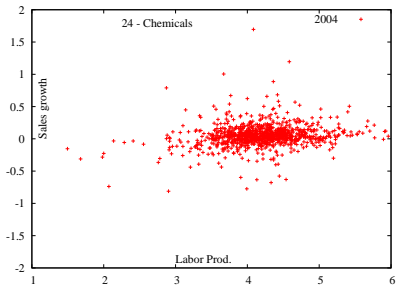


Figure 21: Relation between labor productivity and growth rates of sales, year 2004. Our elaboration on Micro.3.

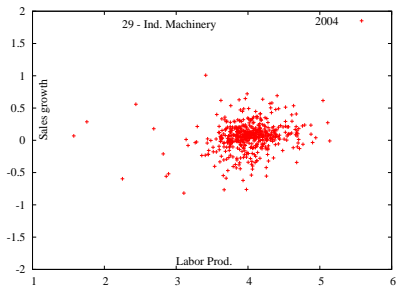
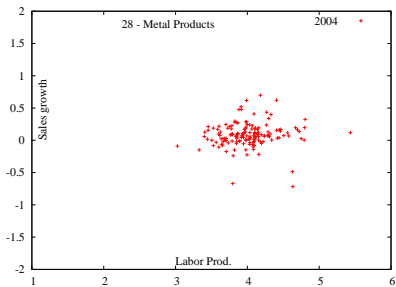
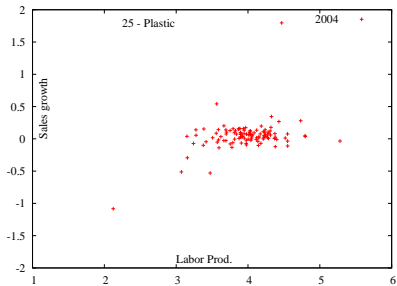
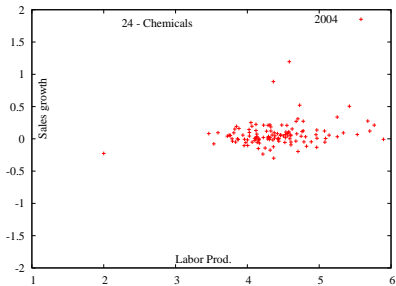


Figure 22: Relation between labor productivity and growth rates of sales for firms with patents, year 2004. Our elaboration on Micro.3.

		1st to 1st quantile	2nd to 2nd quantile	3rd to 3rd quantile	4th to 4th quantile
Pharmaceutical	Productivity	0.1042	0.1408	0.1071	0.7059
	Profitability	0.3559	0.2824	0.3521	0.4521
Primary Metal	Productivity	0.4182	0.0833	0.1778	0.8780
	Profitability	0.5217	0.2500	0.3333	0.6842
Machine Sector	Productivity	0.1746	0.0541	0.2018	0.8542
	Profitability	0.3627	0.2436	0.2763	0.7395
Textile	Productivity	0.1969	0.0784	0.2756	0.9244
	Profitability	0.4514	0.2868	0.4297	0.7379

**Table 6:** Transition Probabilities in Productivity and Profitability Five-year lag, diagonal values. Source Cefis (2003b)

## Concluding Remarks

All these pictures suggest indeed a process of evolution whereby

- i) heterogeneity concerns all aspects of firms characteristics and performances, which persist over time;
  - ⇒ The importance of the idiosyncratic part is also revealed by the microeconomic evidence ⇒ the fixed (firm) effect accounts for a large part of the explained variance of the dependent variable.
- ii) various mechanisms of correlation (together with the “sunkness” and indivisibilities of many technological events and investment decisions) yield to a relatively “structured” process of change in most variables (size, productivity, profitability) also revealed by the “fat-tailedness” of the respective growth rates.
- iii) Selection do not seem to work particularly well at least on the yearly time scale at which statistics are reported.
- iv) Rather different degrees of efficiency and innovativeness at least in the short term, seem to yield relatively persistent profitability differentials.

## Concluding Remarks (cont'd)

In turn major issues:

- the interpretation of idiosyncratic characteristics
  - ⇒ Capability-based theory of the firm
- Given the organizational characteristics what are the behavioral degrees of freedom?
  - ⇒ Behavioral rules and the degrees of discretionarity for strategic management

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