Characterizing the Production Process: A Disaggregated Analysis of Italian Manufacturing Firms

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A Foreword

- Describing the production technology is a relevant issue in economics
- Early applications have suffered from aggregate nature of the data
- Available database allow to recover a detailed picture of economic phenomena (i.e. production).

Purpose for the present work

- Disaggregated analysis aimed at exploring how production is carried out
- We investigate relations between inputs and output.
- We are interested in exploring and *recovering a ground* on which shaping a theoretical framework.

1. Outline

Non-Parametric Analysis :

- Inputs/output relation
- 2D kernel regression

Parametric Analysis : Cobb-Douglas with two inputs

- Inputs/output relation
  - A testable framework for the hypothesis of independency of output Vs. input ratio
  - Empirical evidence
- Production Function estimates
  - OLS estimates
  - Panel Data estimates

2. The Data

- MICRO.1 (Italian Statistical Office).
- Longitudinal data for Italian Manufacturing firms with number of employees ≥ 20. Period 1989 – 1997.
- Possibility of keeping track of the same firm during the interval
- Firms are classified according to their sector of principal activity $\Rightarrow$ ISIC code - 2 digit
- **Variables** :

  Output $\Rightarrow$ Total Sales (accounting for differences in initial/final stock)

  Inputs

  - Labor $\Rightarrow$ Number of employees
  - Capital $\Rightarrow$ Fixed tangible assets (original historic cost)

3. Non-parametric analysis

- Assess the extent of heterogeneity of firms in the same sector
- Relation between factors of production (capital and labor) and output
- Recover a perspective on how production is organized in a sector

Kernel Density Estimate

Fraction of firms using a given amount of inputs:

$$\hat{f}(l,k) = \frac{1}{N\,h_l\,h_k}\sum_{i=1}^{N} K\left(\frac{l-l_i}{h_l}, \frac{k-k_i}{h_k}\right) \qquad (1)$$

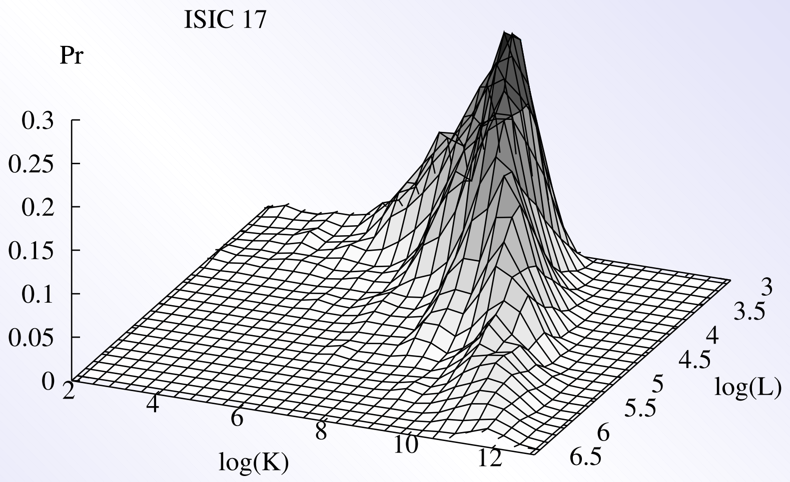

Figure 1: ISIC 17 Textile - Kernel density estimate of (k, l) in 1997.

Wide support: coexistence of firms of different size in the same sector

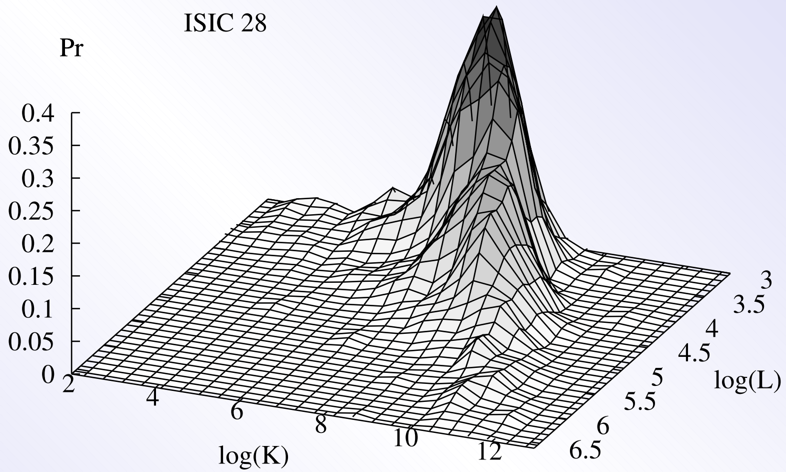

Figure 2: ISIC 28 Metal Products - Kernel density estimate of (k, l) in 1997.

Inter-firm differences are not sector-specific

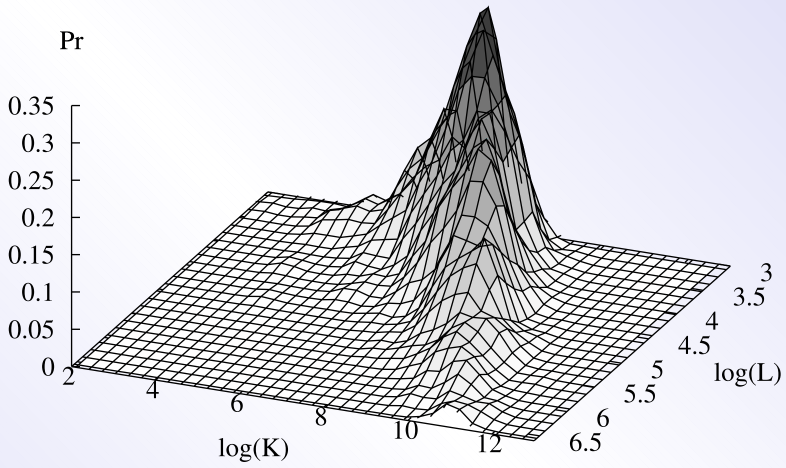

Figure 3: ISIC 17 Textile - Kernel density estimate of (k, l) in 1989.

The empirical density is time-invariant

Non-parametric regression

- Investigate how output depends on the vector of inputs
- Multivariate kernel regression does not impose any *a priori* structure on how production is organized within firms

We are interested in estimating the conditional expectation of output $E(s|(k,l))$ given a certain amount of inputs (k,l)

$$E[s|(k,l)] = \int s\, f(s|k,l)\, ds = \frac{\int s\, f(s,k,l) ds}{f(k,l)} \tag{2}$$

and replacing $f(s,k,l)$ with the multivariate kernel density estimates $\hat{f}(s,k,l)$:

$$\hat{E}[s|(k,l)] = \frac{\sum_{i=1}^{N} s_i\, K\left(\frac{k-k_i}{h_k}, \frac{l-l_i}{h_l}\right)}{\sum_{i=1}^{N} K\left(\frac{k-k_i}{h_k}, \frac{l-l_i}{h_l}\right)} \tag{3}$$

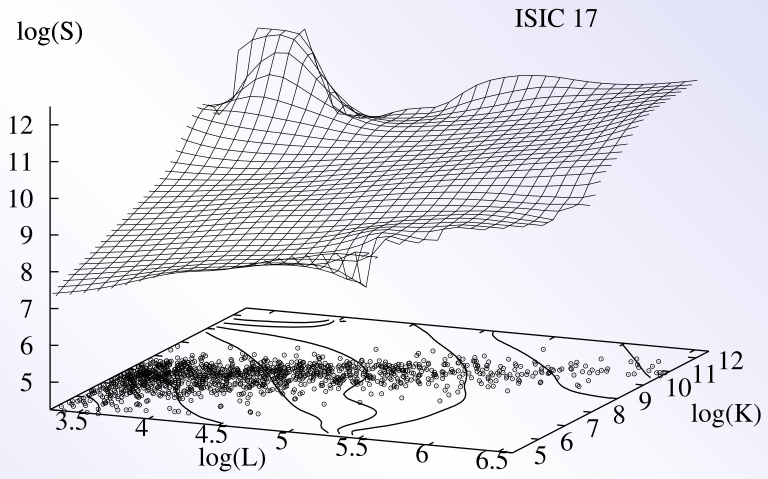

Figure 4: ISIC 17 Textile - Kernel estimate of the conditional expectation of output $\hat{E}(s|(k,l))$ in 1989. The estimation is computed in 60 points.

Heterogeneity in technologies: a given level of output can be attained with significantly different mix of inputs

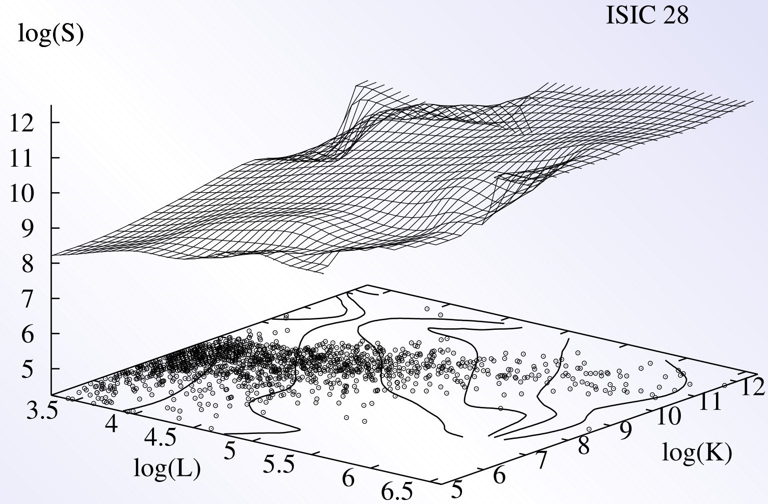

Figure 5: ISIC 28 Metal Products - Kernel estimate of the conditional expectation of output $\hat{E}(s|(k,l))$ in 1997. The estimation is computed in 60 points.

No evidence of convergence towards a common mixture over time

4. Parametric Analysis

- Investigate input-output relations in Cobb-Douglas framework

$$s = \alpha\, l + \beta\, k + c \tag{4}$$

- Returns to scale are not constrained to 1
- Possible problems with cross-sectional estimation

4.1. Panel Data and fixed effects

$$s_{i,t} = \alpha\, l_{i,t} + \beta\, k_{i,t} + \omega_i + e_{i,t} \tag{5}$$

• where $e_{i,t}$ are i.i.d. components and ω_i is unobserved and could be correlated with regressors.

• If ω_i are considered invariant they can be eliminated by subtracting the individual mean to obtain

$$(s_{it} - \bar{s}_i) = \alpha_L(l_{it} - \bar{l}_i) + \beta_K(k_{it} - \bar{k}_i) + (e_i - \bar{e}_i) \tag{6}$$

SECTOR	ISIC Code	Total Obs.	Fixed Effects (Within-group)			Random Effects (ML)		
			c	α	β	c	α	β
Food and Beverages	15	11715	5.817 (0.064)	0.432 (0.014)	0.268 (0.005)	5.114 (0.053)	0.568 (0.012)	0.282 (0.005)
Textiles	17	15423	5.534 (0.057)	0.565 (0.013)	0.149 (0.005)	4.821 (0.049)	0.654 (0.011)	0.185 (0.005)
Rubber Plastics	25	8950	4.575 (0.074)	0.737 (0.017)	0.193 (0.007)	4.368 (0.054)	0.724 (0.013)	0.243 (0.006)
Basic Metals	27	5190	4.734 (0.125)	0.692 (0.026)	0.191 (0.010)	4.140 (0.082)	0.792 (0.018)	0.255 (0.009)
Metal Products	28	20591	4.331 (0.052)	0.858 (0.012)	0.155 (0.004)	4.009 (0.036)	0.881 (0.009)	0.184 (0.004)
Indust. Machinery	29	21965	4.632 (0.054)	0.875 (0.012)	0.142 (0.005)	4.552 (0.033)	0.901 (0.008)	0.140 (0.004)
Electr. Machinery	31	8409	5.182 (0.077)	0.718 (0.017)	0.133 (0.007)	4.250 (0.050)	0.815 (0.013)	0.1901 (0.007)
Furniture Manufact.	36	13061	4.936 (0.062)	0.704 (0.015)	0.165 (0.005)	4.386 (0.050)	0.803 (0.012)	0.186 (0.005)

Table 1: Estimated coefficients for the Fixed Effects, Between-group and Random effects model (both Maximum Likelihood and GLS Estimates). Standard Errors in brackets.

Output Elasticity

- Cost Minimization Problem

$$\min_{L,K}\{L\,p_L + K\,p_K\} \qquad \text{such that} \qquad c\,L^{\alpha}\,K^{\beta} = S$$

- Solving for K and L we get factor demand equations.
- Input Ratio, r, as capital over labor, is:

$$r = \frac{K}{L} = \frac{\beta}{\alpha}\frac{p_L}{p_K}$$

⇒ In the Cobb-Douglas the input ratio does not depend on actual size

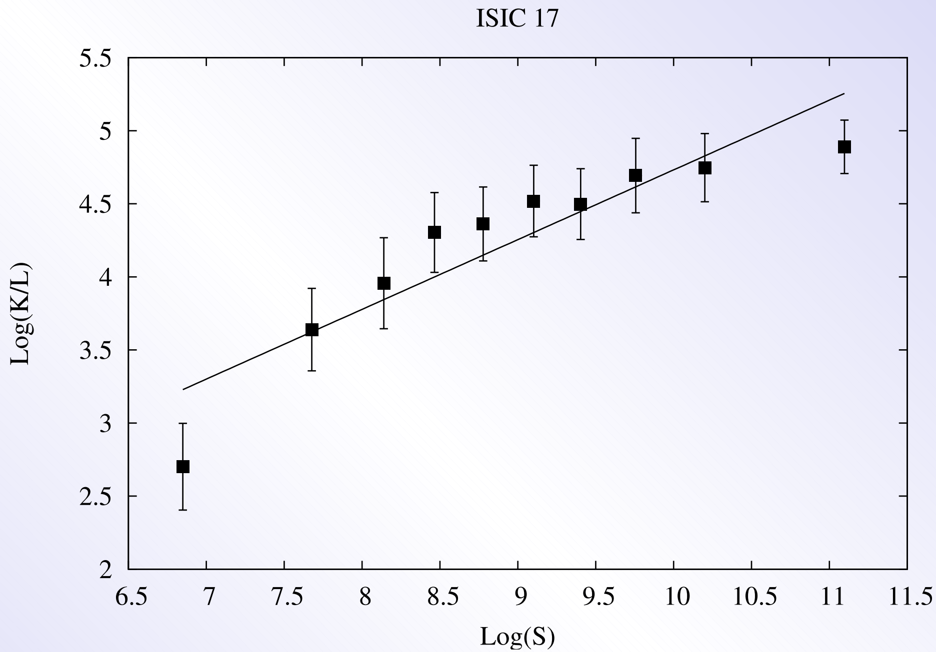

Figure 6: ISIC 17 Textile - Relation between output and input ratio, k/l: binned scatter plots in 4 sectors in 1994. Errorbars display two standard errors.

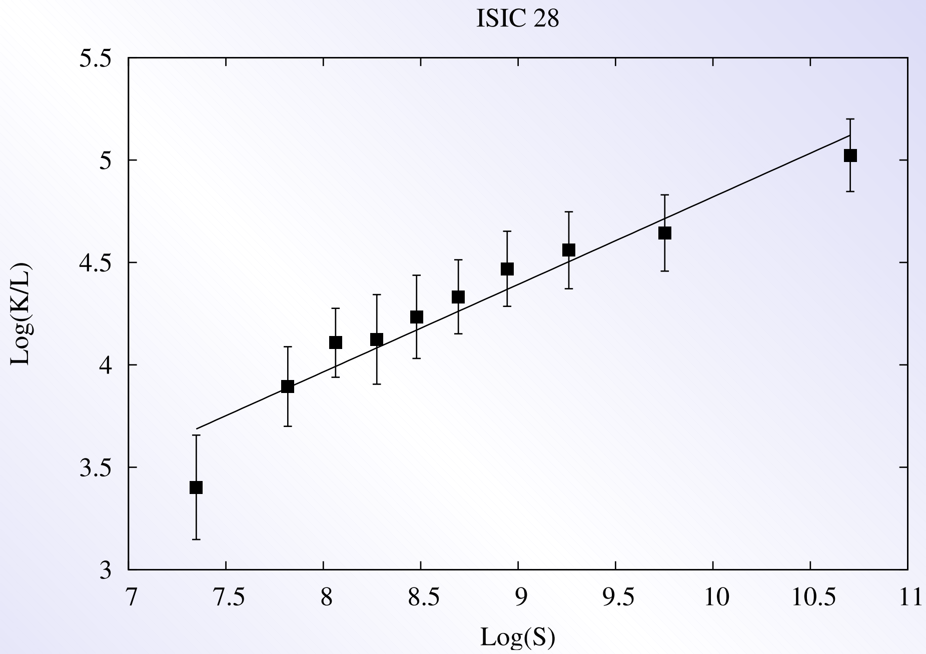

Figure 7: ISIC 28 Metal Products - Relation b/w input ratio, k/l and sales in year **1994**. Errorbars display one standard error.

5. Summary

- Description of how production is organized in different sectors of Italian Manufacturing industry

- Non-parametric analysis reveals the heterogenous nature of the production process:
  - a certain level of output can be attained with various mix of inputs
  - coexistence in the same sector of firms with very different procedures
  - tolerance to different levels of technical efficiency within sectors

- Parametric analysis:
  - support conjecture of sectoral stability of the technical coefficients item

Essential References

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