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In empirical regional economics, returns to scale are typically estimated at the regional level in search for evidence on alternative theories of growth and agglomeration. However, returns to scale may also have a firm-level dimension. In this paper, we exploit micro level data and estimate the dynamic Verdoorn law in a multilevel-setting, where returns to scale are obtained simultaneously for the micro and the regional level. Using Italian firm-level data and the NUTS-3 level of aggregation, we estimate the classic and augmented versions of Verdoorn law for all sectors and separately for manufacturing. Our results show that increasing returns to scale co-exist at both levels, with some degree of regional heterogeneity across the Italian peninsula.

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I. Introduction

Since Kaldor (1966), a popular approach to investigating regional returns to scale relies on estimating the relationship between labour productivity growth and output growth, known as the dynamic Verdoorn law (Verdoorn, 1949). However, the simplest form of the law is criticised for its potential problems of endogeneity and omitted variables and for taking little account of spatial heterogeneity. Also, the law is characterised by the so-called static-dynamic paradox (McCombie, 1982): it returns evidence of increasing returns to scale in the dynamic specification and constant returns to scale in the static log-level version.[1]

McCombie and Roberts (2007) suggest that the paradox may result from spatial aggregation bias, when data are averaged at the regional level, and argue that the dynamic specification is the correct one. Further, Angeriz, McCombie and Roberts (2008) estimate an alternative specification that considers total factor productivity in place of labour productivity in order to reduce potential problems arising from output endogeneity and the omission of the capital stock and emphasise the importance of the spatial dimension.[2]

While the above literature stresses the macro dimension of increasing returns to scale (see Kaldor, 1966; Young, 1928), it overlooks their microeconomic nature. Indeed, productive abilities should result from the combination of both factors internal and external to the firm. In this paper, then, we try to consider both the micro and the macro dimension and exploit multilevel methods to estimate the dynamic Verdoorn law for Small and Medium Enterprises and the NUTS-3 regions in Italy.[3]

[1]See McCombie, Pugno and Soro (2003) for a review. For regional evidence, see, among the others, Harris and Lau (1998), León-Ledesma (2000), Bianchi (2003).
[2] See also Fingleton (2001) on this point.
[3]For a first attempt at estimating the classic version of Verdoorn law for Brazilian firms in a multilevel setting see Britto (2008).

This approach entails a number of benefits. First, by exploiting micro-level data to obtain regional level estimates, it may help reducing the issue of spatial aggregation bias highlighted by McCombie and Roberts (2007). Second, it allows accounting for spatial heterogeneity. Third, it simultaneously estimates returns to scale for the firm level and for each region in the sample.[4] We further limit the omitted variable and endogeneity problems, comparing multilevel specifications of the simple Verdoorn law with alternative specifications which include capital or use total factor productivity (TFP) in place of labour productivity, as suggested by Angeriz *et al.* (2008).

The next section describes the methodology; section 3 discusses the data and the results. The final section concludes.

II. Verdoorn Law in a Multilevel Setting.

The dynamic version of Verdoorn law is traditionally estimated by means of cross-sectional or panel data as follows:

$$\Delta p_j = \beta_0 + \beta_1 \Delta q_j + \varepsilon_j \qquad (1)$$

where Δp_j and Δq_j are, respectively, the labour productivity and output growth of region j. An estimate of β_1 significantly greater than zero implies increasing returns to scale.

Equation 1 can be extended to recognise the hierarchical nature of spatial data, where firms are nested within regions. Then, using micro-level data the most general multilevel representation of Equation 1 incorporates regional heterogeneity in terms of both the variability of second-level intercepts and slopes in the relationship, i.e.:

[4]As opposed to the country average obtained using regional data.

$$
\begin{aligned}
&\Delta p_{ij} = \beta_{0j} + \beta_{1j}\Delta q_{ij} + \varepsilon_{ij} \\
&\beta_{0j} = \beta_0 + u_{0j} \\
&\beta_{1j} = \beta_1 + u_{1j}
\end{aligned}
\tag{2}
$$

or, in reduced form:

$$
\Delta p_{ij} = \beta_0 + (\beta_1 + u_{1j})\Delta q_{ij} + u_{0j} + \varepsilon_{ij} \tag{3}
$$

where β_{0j} and β_{1j} are region-level intercepts and slopes composed by a fixed part, β_0 and β_1, and random components, u_{0j} and u_{1j}, with $U_i = \left(u_{0j}, u_{1j}\right)^T \sim N\left(0, \Omega_u\right)$, and ε_{ij} is a general error term, $\varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2)$. Residuals at the same level may be correlated, allowing for spatial cross-fertilisation. The following variance-covariance matrix is estimated:

$$
\Omega_u = \begin{pmatrix} \sigma_{u0}^2 & \\ \sigma_{u01} & \sigma_{u1}^2 \end{pmatrix} \tag{4}
$$

where σ_{u0}^2 and σ_{u1}^2 are the region-level intercepts and slopes variances. In the above specification, the regional slopes may be interpreted as regional Verdoorn coefficients, i.e. a different return to scale estimate for each region, or level 2, in the sample.

Typically, the lack of investment data forces for the implicit assumption in equation 1 of identical growth rate of output and capital. Here, we can exploit firm-level capital stock data to estimate augmented versions of the law. The capital "augmented" version (see Rowthorn, 1979), of equation 3 is :

$$
\Delta p_{ij} = \beta_0 + (\beta_1 + u_{1j})\Delta q_{ij} + \beta_2 \Delta k_{ij} + u_{0j} + \varepsilon_{ij} \tag{5}
$$

where k_{ij} denotes capital per worker. However, since k_{ij} could be endogenous, we also follow Angeriz *et al.* (2008) and estimate a version of the law that uses TFP growth in place of labour productivity to "depurate" the right hand side of k_{ij} . Further, they add the initial level of TFP and regional output density to allow for catching up effects due to technology diffusion and increasing returns due to dynamic agglomeration economies.

Here, we estimate the firm level TFP using the Levinsohn and Petrin (2003) estimator and formulate the augmented TFP Verdoorn law, as follows:

$$\Delta tfp_{ij} = \beta_0 + (\beta_1 + u_{1j})\Delta q_{ij} + \beta_2 tfp_{ij0} + \beta_3 Density_{j0} + u_{0j} + \varepsilon_{ij} \qquad (6)$$

where Δtfp_{ij} is the firm-level TFP growth, tfp_{ij0} is the firm-level TFP at the beginning of period, $Density_{j0}$ is the output density of region j at the beginning of period.

III. Data and Results

To illustrate our methodology and perform the empirical estimation, we use balance sheet data from AIDA, the Italian section of the Bureau Van Dijk Database, which collects data on almost 90 percent of the existing Italian companies with value of production beyond 100.000 Euros. Since Small and Medium Enterprises represent the core of the Italian productive system, we limit our analysis to these firms using standard criteria, i.e. more than 10 and less than 250 employees and Total Assets between 2 and 43 million Euros. Our data covers the time-span 1999-2005.

This query together with further controls for data inconsistencies returns 9,269 units across the national territory. For these, we extract data on value added (that we deflate by sectoral prices), employees and total assets.

Table 1 presents estimates of the classic and the capital augmented Verdoorn law for all sectors and, separately, for manufacturing, where the law is typically estimated. Results show evidence of increasing returns to scale at the firm level with coefficients in the [0.35-0.37] range for all sectors in the economy and slightly higher at 0.4 for manufacturing. Investment enters with a positive significant sign without affecting size and significance of returns to scale.

Table 2 reports on the specification of Angeriz *et al.* (2008). Firm level returns to scale are larger ([0.46-0.58] for all sectors and [0.50-0.62] for manufacturing). The initial level of TFP is negatively signed and statistically significant, denoting evidence of firm-level catching-up. Output density is also signed as expected, but statistically significant only when all sectors are considered.[5]

With respect to the regional Verdoorn coefficients, i.e. the level-2 slopes, Tables 1 and 2 report a statistically significant variability, σ_{u1}^2 , which is higher in the labour productivity specification. This is further investigated in Table 3, where synthetic statistics on these coefficients are presented. The regional Verdoorn coefficients display higher variability, with lower minimum values, in the labour productivity specification. On average, coefficients are larger for the TFP specification and for the sub-sample of manufacturing firms. We further compare the regional coefficients of the two main macro-areas of Italian dualism (South and Centre-North) using Kolmogorov-Smirnov tests and mean-difference t-tests. These show that coefficients between the two macro-areas are significantly different only when the augmented TFP specification and all sectors are considered, with returns to scale significantly higher in the Centre-North.[6]

IV. Conclusions

In this paper we exploit multilevel models to simultaneously estimate simple and augmented versions of Verdoorn law for firms and NUTS-3 regions in Italy. Using firm level data, this approach considers spatial heterogeneity both in the intercepts and the slopes of Verdoorn law, returning a Verdoorn coefficient for each region.

[5] Multilevel estimation is robust to the problem of uneven class frequencies. Yet, we have re-estimated all models removing provinces with highest and lowest number of firms. Results (unreported) were qualitatively similar and are available upon request from the authors.
[6] These results seem in line with previous evidence from Byrne, Fazio and Piacentino (2009).

In all specifications, we find evidence of both firm-level and regional increasing returns. The latter tend to exhibit some degree of variability across regions, with the Centre North displaying stronger returns when all sectors and the most complete TFP specification are considered. These results may represent a starting point for further research into the relationship between the returns to scale at the two levels.

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Table 1. Verdoorn law (Δp_{ij})

	All sectors				**Manufacturing**			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
$\beta_1 \Delta q_{ij}$	0.374	0.377	0.351	0.359	0.401	0.403	0.394	0.404
	(0.009)	(0.009)	(0.016)	(0.017)	(0.011)	(0.011)	(0.021)	(0.021)
$\beta_2 \Delta k_{ij}$				0.205				0.196
				(0.005)				(0.007)
σ_{ε}^2	0.274	0.273	0.269	0.229	0.231	0.229	0.222	0.193
	(0.004)	(0.004)	(0.004)	(0.003)	(0.005)	(0.005)	(0.004)	(0.004)
σ_{u0}^2		0.002	0.001	0.001		0.002	0.000	0.001
		(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
σ_{u1}^2			0.012	0.014			0.022	0.022
			(0.003)	(0.003)			(0.006)	(0.005)
-2 log(L)	14318.3	14297.9	14236.9	12786.3	7171.02	7157.9	7074.6	6356.3

Notes: Estimation by Restricted Iteractive GLS; Standard errors in parenthesis. Constant is omitted.All variables are in logs.

Table 2. Verdoorn law (Δtfp_{ij})

	All sectors			Manufacturing				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
$\beta_1 \Delta q_{ij}$	0.575	0.577	0.556	0.46	0.615	0.617	0.609	0.505
	(0.006)	(0.006)	(0.01)	(0.01)	(0.007)	(0.007)	(0.014)	(0.014)
$\beta_2\, tfp_{ij0}$				-0.296				-0.287
				(0.007)				(0.009)
$\beta_3\, Density_{j0}$				0.008				0.005
				(0.004)				(0.004)
σ_{ε}^2	0.116	0.115	0.114	0.096	0.088	0.087	0.084	0.071
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)
σ_{u0}^2		0.001	0.000	0.002		0.001	0.000	0.001
		(0.000)	(0.000)	(0.001)		(0.000)	(0.000)	(0.000)
σ_{u1}^2			0.006	0.006			0.009	0.010
			(0.002)	(0.002)			(0.002)	(0.002)
-2 log(L)	6361.3	6330.4	6261.9	4792.5	2131.1	2108.2	2024.1	1159.3

Notes: Estimation by Restricted Iteractive GLS; Standard errors in parenthesis. Constant is omitted. All variables are in logs.

Table 3. Regional Verdoorn coefficients ($\beta_1 + u_{1j}$)

	Δp_{ij}		Δtfp_{ij}	
	All sectors	**Manufacturing**	**All sectors**	**Manufacturing**
Minimum	0.09	0.05	0.30	0.31
Maximum	0.60	0.67	0.63	0.69
Mean	0.36	0.40	0.46	0.50
Kolmogorov-Smirnov test				
	0.2075 (0.262)	0.1133 (0.570)	0.3152 (0.009)	0.188 (0.212)
t-test [H_0: diff.= mean(South) – mean(Centre-North)=0]				
H_a: diff. <0	Pr(T<t)= 0.1084	Pr(T<t)= 0.6148	Pr(T<t)= 0.0108	Pr(T<t)= 0.127
H_a: diff. ≠0	Pr(|T|>|t|)= 0.2169	Pr(|T|>|t|)= 0.7703	Pr(|T|>|t|)=0.0216	Pr(|T|>|t|)=0.254
H_a: diff. >0	Pr(T>t)= 0.8916	Pr(T>t)= 0.3852	Pr(T>t)= 0.9892	Pr(T>t)= 0.873

Notes: Estimates from columns 4 and 8 in Tables 1 and 2. P-values in parenthesis.