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The Law of Verdoorn: Evidence from Greek Disaggregated Manufacturing Time Series Data*

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Abstract: This paper tests the validity of Verdoorn's law in Greek manufacturing. Through the Generalised Method of Moments (GMM) methodology, estimates of the Verdoorn law in aggregated and disaggregated manufacturing Greek data are obtained in order to explain disparities in income and growth among Greek manufacturing sectors. The results provided evidence that increasing returns to scale with certain, albeit low, substitutability possibilities between capital and labour are present in Greek manufacturing groups.

I INTRODUCTION

According to the law of Verdoorn (1949) or Kaldor's second law (Kaldor, 1966; Thirlwall, 1983), the long-run elasticity of labour productivity with respect to output is constant and positive. The law has been used extensively to explain persistent disparities in the growth rates among countries as well as causation patterns of economic growth. In particular, higher output growth tends to increase manufacturing productivity and, thus, exports, which in turn stimulate output and so on.[1] More importantly, the law can explain what has

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[1] Certain alternative theories argue that productivity growth depends on the varying rates of diffusion of technology from lead to laggard nations (Gomulka, 1979). For an empirical estimation of this "diffusion of technology" hypothesis see, Fingleton and McCombie (1998).

really caused the decline of average labour productivity which the majority of economies have experienced (Michl, 1985). The law provides a link between the relationship of labour productivity and output to the division of labour. This reference to the division of labour seems to explain the causal relationship running from output to labour productivity and productivity in the economy as a whole. According to Fingleton and McCombie (1998), the law has been used to explain economic growth patterns within regions that display differences in labour productivity. They provide a Keynesian explanation for those disparities in growth patterns indicating the role of price competitiveness of the region's exports as well as that of the development of new technology industries with high income elasticities of demand. The law is also used by endogenous growth models to explain failures of convergence of growth rates, either on a national or a sector level (Lucas, 1988). The law has also been used to investigate the determinants of productivity growth and to compare the outcome with that provided by the neoclassical production theory (Jefferson, 1988). The majority of empirical evidence has used cross-country (country panel) or cross-industry (industry panel) data for manufacturing. However, McCombie and Ridder (1984) have argued that cross-country or cross-industry data do not tell the true story behind the law because it is not realistic to assume that all countries or all industries experience the same rate of growth in terms of exogenous technical progress. Thus, it is necessary for a researcher to implement the analysis through sectors or industries that experience the same growth rate of technical progress, something that justifies the grouping (explained later) of industries attempted in this paper.

This empirical paper attempts to establish whether the law holds within manufacturing sectors for the case of Greece through the employment of time series manufacturing data. McCombie (1986), McCombie and Thirwall (1994) and Harris and Lau (1998) argue that the law has received extensive criticism based on the following grounds. First, the empirical formulation stating the law, second, the omission of certain explanatory variables, such as the capital stock, and third, the econometric estimation of the law, depending upon whether output is considered to be endogenously or exogenously determined. As regards the last point of criticism, Rowthorn (1975) argues that productivity and output growth are jointly determined through the price mechanism. In particular, changes in productivity lead to changes in a country's relative price competitiveness, which, in turn, changes the demand for the output of this county. In other words, employment as well as output growth must be considered as jointly determined variables. If these critical points are not met then the results will be biased (Jefferson, 1988).

Developments of the manufacturing sectors in Greece over the period 1960-1995 are scrutinised. As far as the Greek industry is concerned, limited input substitutability may be attributed to certain sorts of distortions, i.e. the difficulty of Greek manufacturing to compete in the European Union market and the lack of sufficient human capital investment (Zikos and Petrakos, 1991), that characterise the Greek economy, at least for the majority of the period under investigation, and lead to allocative and X-inefficiency. Post-war Greek economic reality has been characterised by an excessive regulatory environment and by business finance constraints. The regulation and constraints include regulated monetary and financial sectors, labour union practices aggravating the principal-agent problem (Jouganatos, 1992), and the presence of persistence and hysteresis phenomena (Blanchard and Summers, 1987) in the labour market (Elmeskov and MacFarlan, 1993; Apergis, 1997).

An extensive search of the literature indicates that this is the first empirical attempt to test the validity of the Verdoorn's law in manufacturing as a total as well as among manufacturing sectors in Greece. The primary goal of this paper is to explain disparities in income and growth among Greek manufacturing sectors by making use of advanced econometric approaches (Generalised Method of Moments, GMM) to obtain estimates of the Verdoorn law in aggregated and disaggregated manufacturing Greek data by avoiding the problem of simultaneity (endogeneity). Section II discusses the literature on the law of Verdoorn and justifies the specific functional form that will be used for the purposes of the empirical analysis. Section III presents the empirical evidence on the law. Finally, Section IV provides some concluding remarks and policy implications.

II THE LAW OF VERDOORN

The Verdoorn law relates manufacturing productivity growth to manufacturing output growth:

$$pr_L = a_1 + a_2 Y \tag{1}$$

where pr_L and Y are labour productivity and output, respectively, in manufacturing, a_2 is the Verdoorn coefficient which is positive and it suggests that a rise in output causes an improvement in labour productivity and a fall in output results in a decline in labour productivity. According to Kaldor (1975), if a_2 does not differ significantly from unity, then the hypothesis of "increasing returns to scale" is rejected. The corollary resulting from the law is that the production function involved is characterised by increasing returns to scale. Kaldor emphasised the role of increasing returns to scale as the major source of differences in productivity growth rates. However, a substantial deficiency of the original law was that it did not include technical progress in (1).

A large literature has examined the empirical validity of the law and its interpretations (McCombie and de Ridder, 1984; Michl, 1985; McCombie, 1986; Bairam, 1990, among others). Kaldor (1975) found that the coefficient is approximately one-half, thus, providing support to increasing returns to scale and to the argument that the growth of output seems to be a substantial determinant of productivity growth. Whiteman (1987) demonstrated that the law held satisfactorily for the case of Australia. However, the Verdoorn coefficient did not remain constant in the long run but it kept changing in response to the market growth. For achieving increasing returns to scale and, thus, productivity and employment growth that validate the law, a macroeconomic stimulation in demand as well as the creation of new export markets seem to be crucially important. Nevertheless, his model results are subject to mis-specification bias, because he adopted the OLS approach which ignores the endogeneity problem. Moreover, Bougrine (1994) showed that while the Verdoorn's law is valid for the Canadian regions, the impact of capital accumulation as an explanatory determinant of labour productivity should not be ignored. Hodgson (1989) also argued that institutional variables could be an additional explanatory variable in the productivity equation. The relevant literature so far has suggested that the law remains valid only if certain assumptions are satisfied (Rowthorn, 1979; Boulier, 1984). De Vries (1980) argues that the capital-output ratio should remain constant in the long run. These additional assumptions are associated with the substitutability of the factors involved in the production process.

To the empirical end, a Constant Elasticity of Substitution (CES) production function is employed. Nikolaou (1980) has shown that in the total of Greek manufacturing sectors a CES production function is preferred over the Cobb-Douglas functional form, while the majority of manufacturing sectors operate under increasing returns to scale. By using more realistic assumptions, i.e. the presence of adjustment costs, as well as a more advanced econometric methodology about the pattern of production in the Greek manufacturing, Zanias (1991) confirmed the preference of a CES production function over alternative specifications. The CES production function is defined as:

$$Y = (\alpha L^{-\rho} + \beta K^{-\rho})^{-h/\rho} \tag{2}$$

with $-1<\rho<\infty$, $\rho\neq 0$, α, $\beta>0$, and $h>0$. h is a scale parameter, while $h>1$ corresponds to increasing returns to scale. The elasticity of substitution (σ) is defined as $1/(\rho+1)$. The parameters α and β are the distribution parameters that determine the shares of national income accruing to the production inputs.

Harris and Lau (1998) argue that the capital stock must explicitly be taken into consideration to estimate the degree of returns to scale. To this end, Equation (2) yields:

$$Y/L = [Y^{(h\rho-\rho)/h}\ 1/\alpha - (\beta/\alpha)\ (Y/K)^{\rho}]^{1/\rho} \qquad (3)$$

Under increasing returns to scale, ρ should have been positive. However, a positive ρ implies that the substitution elasticity is smaller than 1. As is known, perfect elasticity of substitution equals infinity, while absence of substitution implies a zero elasticity of substitution, thus, a positive ρ shows that substitution does occur, but it is not large. Finally, in order to overcome the problem of mis-specification due to the endogeneity problem, the GMM approach is employed.

III EMPIRICAL ANALYSIS

3.1 Data

Annual data on output (Y) measured by the value added production, employment (E) measured as the number of employees in manufacturing, prices (P) proxied by the consumer price index (CPI), and the gross capital stock (K) in manufacturing at the end of the year were obtained from both the total of manufacturing and from 20 individual manufacturing sectors in Greece. Data were made available by the Statistical Bulletin published by the National Statistical Service of Greece over the period 1960-1995. The definition of those 20 sectors is provided in Appendix I. Although data on the 20-digit sectors were available, those data were grouped into three main sectors: intermediate goods manufacturing group that is the sum of sectors 31-34, consumer goods manufacturing group that is the sum of sectors 20-30 and 39, and machinery equipment and transportation manufacturing group that is the sum of sectors 35-38. The reason for grouping emerged from the fact that only 36 observations for each of the 20 sectors exist. Thus, in order to overcome the sample size problem as well as to assume a common production function for all sectors a grouping methodology was followed. For the same reason, shift dummy variables were used. All series have been expressed in constant 1970 prices using the CPI deflator. The authors have not used specific deflators for each group to obtain data expressed in constant prices simply because deflators exist only for 11 out of the 20-digit sectors. Data on capital stock were kindly provided by the Research Department of the Centre of

Planning and Research (K.E.P.E.) in Athens. The construction of the capital stock variable, as it is used by K.E.P.E., is based on the methodology developed by Coen (1975). For more details of the methodology of construction, please refer to Appendix II. Throughout the paper, lower case letters denote variables expressed in logarithms. Finally, the RATS4.1 software assisted the empirical analysis.

3.2 Descriptive Statistics

Descriptive statistics of the variables of income, labour, capital stock, capital productivity, and labour productivity are reported in Table 1. The figures describe the average annual growth rates of the variables under study. In particular, income, labour, and capital stock grew faster in the intermediate goods sector, followed by that in the consumer goods sector. These developments of income, employment, and capital are reflected in the development of labour and capital productivity, which expanded more noticeably in the intermediate goods sector than in the remaining sectors (in the capital goods sector capital productivity has followed a negative course). The positive courses of productivity figures provide evidence in favour of the presence of increasing returns to scale. For more specific conclusions, however, an econometric analysis is needed. The sample skewness and kurtosis coefficients indicate that all distributions are not skewed and leptokurtic relative to the normal distribution. The Jarque-Bera test cannot reject normality, while the Ljung-Box statistics for 12 lags applied to prices, i.e. LB(12), and squared prices, i.e. $LB^2(12)$, indicate the absence of significant linear and nonlinear dependencies.

Table 1: *Descriptive Statistics*

Variable:		*Income*		
Sectors:	31-34	20-30 & 39	35-38	*Total*
Mean	0.0734	0.0491	0.0418	0.0535
Variance	0.0102	0.0039	0.0067	0.0041
Skewness	0.557[0.29]	–0.073[0.98]	0.306[0.49]	0.311[0.48]
Kurtosis	0.456[0.63]	–1.414[0.13]	–0.832[0.37]	–1.183[0.21]
J-B	4.599[0.37]	4.026[0.48]	5.018[0.32]	4.667[0.61]
LB(12)	4.115[0.25]	6.902[0.19]	5.661[0.22]	4.115[0.49]
$LB^2(12)$	5.884[0.19]	5.052[0.26]	3.227[0.41]	5.095[0.68]

Table 1: *Descriptive Statistics (contd.)*

Variable:		*Labour*		
Sectors:	31-34	20-30 & 39	35-38	*Total*
Mean	0.0185	0.0048	0.0039	0.0075
Variance	0.0016	0.0025	0.0048	0.0024
Skewness	0.557[0.29]	–0.073[0.98]	0.306[0.49]	0.311[0.48]
Kurtosis	0.456[0.63]	–1.414[0.13]	–0.832[0.37]	–1.183[0.21]
J-B	4.599[0.37]	4.026[0.48]	5.018[0.32]	4.667[0.61]
LB(12)	4.115[0.25]	6.902[0.19]	5.661[0.22]	4.115[0.49]
$LB^2(12)$	5.884[0.19]	5.052[0.26]	3.227[0.41]	5.095[0.68]
Variable:		*Capital Stock*		
Sectors :	31-34	20-30 & 39	35-38	*Total*
Mean	0.0551	0.0431	0.0294	0.495
Variance	0.0068	0.0019	0.0044	0.0028
Skewness	0.557[0.29]	–0.073[0.98]	0.306[0.49]	0.311[0.48]
Kurtosis	0.456[0.63]	–1.414[0.13]	–0.832[0.37]	–1.183[0.21]
J-B	4.599[0.37]	4.026[0.48]	5.018[0.32]	4.667[0.61]
LB(12)	4.115[0.25]	6.902[0.19]	5.661[0.22]	4.115[0.49]
$LB^2(12)$	5.884[0.19]	5.052[0.26]	3.227[0.41]	5.095[0.68]
Variable:		*Capital Productivity*		
Sectors :	31-34	20-30 & 39	35-38	*Total*
Mean	0.0183	0.0061	–0.0175	0.0109
Variance	0.0116	0.0025	0.0062	0.0033
Skewness	0.157[0.75]	–0.082[0.88]	–0.089[0.84]	0.564[0.20]
Kurtosis	0.902[0.42]	0.109[0.91]	0.715[0.57]	0.686[0.46]
J-B	3.224[0.51]	3.116[0.58]	4.827[0.35]	3.964[0.21]
LB(12)	4.005[0.29]	4.236[0.21]	5.104[0.17]	5.661[0.57]
$LB^2(12)$	5.409[0.23]	4.512[0.36]	3.115[0.59]	5.003[0.45]
Variable:		*Labour Productivity*		
Sectors :	31-34	20-30 & 39	35-38	*Total*
Mean	0.0549	0.0443	0.0349	0.0335
Variance	0.0071	0.0031	0.0058	0.0068
Skewness	0.159[0.29]	–0.491[0.59]	–0.137[0.76]	0.143[0.74]
Kurtosis	1.322[0.57]	1.002[0.28]	1.494[0.11]	1.111[0.19]
J-B	3.112[0.47]	3.559[0.47]	4.098[0.39]	5.116[0.43]
LB(12)	3.883[0.32]	4.991[0.56]	5.228[0.44]	6.077[0.66]
$LB^2(12)$	4.427[0.25]	4.095[0.48]	3.774[0.32]	5.449[0.49]

Notes: All the variables are expressed in real terms as well as in growth rates. Figures in brackets denote p-values. LB is the Ljung-Box statistic for serial correlation at 12 lags. J-B is the Jarque-Bera test for normality.

3.3 Integration Analysis

Unit root nonstationarity is tested through the Perron (1990) methodology, which allows unit root testing with an exogenous break. The unit root results are reported in Table 2. Note that integration tests were performed three times. Each time a dummy variable was being used to capture the impact of the 1973 and 1979 oil shocks, since Greek manufacturing is heavily dependent on oil imports as well as the 1980 membership of the country to the European Economic Community (EEC). Using a 1 per cent significance level the data clearly cannot reject the hypothesis of a unit root for all series in levels investigated later in the empirical analysis, i.e. output, labour productivity, capital productivity, and capital. When first differences were used, unit root nonstationarity is rejected in all cases.

3.4. GMM Estimates

Equation (3) is estimated by the Generalised Method of Moments (GMM) developed by Hansen (1982). The popularity of the method for estimating non-linear regressions lies on its simplicity as well as on the fact that in most of the cases of non-linearity GMM estimates (contrary to those from maximum likelihood methods) are always consistent and asymptotically unbiased (Ferson and Foerster, 1994; Johnston and Dinardo, 1997). Moreover, GMM estimators allow us to control for potential endogeneity of the explanatory variables (Arellano and Bover, 1995; Baltagi, 1995). Let θ be a Kx1 parameter vector and z an Mx1 vector of instruments. For Equation (3), $\theta=(\alpha, \beta, h, \rho)'$. Assuming that $M \geq K$ (a necessary condition for identification), permissible instruments are relevant variables dated t+1-v, where $v \geq 2$. The instrument vector used here is $z=(\text{constant}, \Delta(Y/L)_{t+1-v}, \Delta L_{t+1-v}, \Delta(Y/K)_{t+1-v})'$. Davidson and MacKinnon (1993) point out that in small samples efficiency gains from using more instruments are obtained at the cost of a greater bias in the estimates. To avoid such problems, in this study the values of v and M are chosen to be as small as possible so as to ensure parameter identification while minimising the bias. In particular, over the period under study the choices v=2 and M=4 are used. In order to get the estimated parameters from the non-linear regression, the error term of the non-linear regression, say η, is assumed to have a zero mean and to be serially uncorrelated. The tested hypothesis implies that the orthogonality conditions $z_{t+1-v}\ \eta_{t+1}=0$ must be satisfied. The last condition satisfies the presence of normality in estimations. Moreover, the GMM method makes it clear what conditions must be met to ensure normality.

Table 2: *Perron Unit Root Tests with an Exogenous Break*

	Levels		*First Differences*	
Variable(X)	*Without Trend*	*With Trend*	*Without Trend*	*With Trend*
I 1973 oil-price shock				
Income				
Total	–1.22(4)	–1.66(4)	–4.61(1)*	–5.33(1)*
31-34	–0.20(4)	–2.21(4)	–4.22(1)*	–5.05(1)*
20-30 & 39	–2.92(3)	–2.95(2)	–4.09(1)*	–4.19(1)*
35-38	–2.59(2)	–2.78(3)	–4.58(1)*	–4.64(1)*
Labour productivity				
Total	–2.28(4)	–2.35(4)	–4.62(1)*	–4.86(1)*
31-34	–2.14(4)	–2.39(1)	–4.13(1)*	–4.32(1)*
20-30 & 39	–2.53(4)	–2.67(1)	–4.17(1)*	–4.39(1)*
35-38	–1.28(4)	–2.39(2)	–5.48(1)*	–5.85(1)*
Capital productivity				
Total	–2.16(3)	–2.44(2)	–4.37(2)*	–5.65(1)*
31-34	–2.33(2)	–2.38(2)	–4.28(1)*	–6.04(1)*
20-30 & 39	–2.19(3)	–2.41(3)	–4.52(2)*	–6.27(2)*
35-38	–1.74(2)	–1.93(2)	–4.11(2)*	–5.49(1)*
Capital				
Total	–0.95(2)	–1.21(3)	–3.99(1)*	–4.54(2)*
31-34	–1.08(2)	–1.58(2)	–3.78(1)*	–4.11(2)*
20-30 & 39	–0.97(2)	–1.23(2)	–3.55(2)*	–4.01(1)*
35-38	–1.53(3)	–1.77(2)	–3.49(2)*	–3.82(2)*
II 1979 oil-price shock				
Income				
Total	–1.34(3)	–1.42(2)	–4.77(1)*	–5.04(1)*
31-34	–0.26(2)	–1.91(2)	–4.38(1)*	–4.85(1)*
20-30 & 39	–2.77(2)	–2.91(2)	–4.18(1)*	–4.47(1)*
35-38	–1.69(2)	–1.80(2)	–4.48(1)*	–5.23(1)*
Labour productivity				
Total	–2.13(3)	–2.17(3)	–4.77(1)*	–4.91(1)*
31-34	–2.09(3)	–2.25(1)	–4.65(1)*	–4.74(1)*
20-30 & 39	–2.22(2)	–2.51(1)	–4.50(1)*	–4.68(1)*
35-38	–1.86(2)	–2.40(2)	–4.93(1)*	–5.32(1)*
Capital productivity				
Total	–2.14(4)	–2.48(3)	–4.24(2)*	–5.27(2)*
31-34	–2.19(3)	–2.43(2)	–4.63(2)*	–5.07(1)*
20-30 & 39	–2.05(2)	–2.15(3)	–4.77(1)*	–6.29(2)*
35-38	–2.26(3)	–2.39(3)	–4.36(2)*	–5.78(1)*

Table 2: *Perron Unit Root Tests with an Exogenous Break (contd.)*

	Levels		*First Differences*	
Variable(X)	*Without Trend*	*With Trend*	*Without Trend*	*With Trend*
Capital				
Total	–2.03(2)	–2.45(2)	–3.95(2)*	–4.12(1)*
31-34	–1.23(2)	–1.59(1)	–3.67(1)*	–3.88(1)*
20-30 & 39	–0.94(1)	–1.35(2)	–4.01(1)*	–4.39(1)*
35-38	–1.22(2)	–1.59(2)	–3.99(1)*	–4.39(2)*
III. EEC participation				
Income				
Total	–1.76(3)	–1.89(3)	–4.09(1)*	–4.94(1)*
31-34	–1.32(4)	–2.09(4)	–4.37(1)*	–5.18(1)*
20-30 & 39	–2.95(2)	–3.05(2)	–4.27(1)*	–4.71(1)*
35-38	–2.17(2)	–2.87(2)	–4.24(1)*	–4.60(1)*
Labour productivity				
Total	–2.15(3)	–2.25(3)	–4.12(1)*	–4.13(1)*
31-34	–2.55(4)	–2.67(1)	–4.35(1)*	–5.29(1)*
20-30 & 39	–2.09(3)	–2.27(1)	–4.44(1)*	–5.12(1)*
35-38	–1.17(4)	–2.11(2)	–4.78(1)*	–5.22(1)*
Capital productivity				
Total	–2.26(3)	–2.46(2)	–4.18(1)*	–5.46(1)*
31-34	–2.33(2)	–2.90(3)	–4.29(1)*	–5.79(2)*
20-30 & 39	–2.09(4)	–2.72(2)	–4.27(3)*	–5.41(1)*
35-38	–1.94(3)	–1.98(3)	–5.62(2)*	–6.52(2)*
Capital				
Total	–2.03(2)	–2.27(1)	–4.55(1)*	–4.81(1)*
31-34	–1.38(2)	–1.69(2)	–4.11(1)*	–4.65(1)*
20-30 & 39	–1.65(3)	–1.78(2)	–4.59(2)*	–5.09(1)*
35-38	–1.70(2)	–1.93(2)	–4.96(2)*	–5.38(1)*

Notes: The Perron regression estimated is:

$$\Delta x = a + a_1 \, TIME + a_2 \, TT + a_3 \, TB + a_4 \, x_{-1} + \sum_{i=1}^{q} bi \, \Delta x_{-i} + \eta$$

where x denotes the logarithm of income or labour productivity or capital productivity or capital, TT is a dummy variable defined as: 0 values up to 1974 or 1980 or 1981 and 1 thereafter, TB is a dummy variable defined as: 1 at 1974 or 1980 or 1981 and 0 otherwise, and η is a random error. Numbers in parentheses denote the optimal number of lags used in the augmentation term of the following regression and it was obtained through the Akaike criterion.

* denotes that the unit root null hypothesis is rejected at the 1 per cent level.

The sample counterpart of the orthogonality conditions is denoted as:

$$g(\theta) = (1/T) \sum_{t=v}^{T} z_{t+1-v}\, \eta_{t+1} \tag{4}$$

where T is the number of observations that are available for estimation after the construction of growth rates (variables in logged differences). The GMM method chooses θ to minimise the quadratic form $g(\theta)'S^{-1}g(\theta)$, where S is an MxM symmetric weighting matrix. In order to get autocorrelation-consistent standard errors, the Newey-West (1987, 1994) methodology was followed and the value of the "lag truncation parameter" was set equal to $L=[4(T/100)^{2/9}]$, where T is the number of parameters and the brackets define the 'integer part of' what they include. For our empirical purposes, T=36. Finally, a set of dummy variables were included in the estimation to control for certain macroeconomic conditions, i.e. the oil price shock of 1973, the oil price shock of 1979 and the EEC participation in 1981. An evaluation of the estimates of α, β, h, ρ, and σ implied by the GMM estimates yield the values shown in Table 3.

Table 3: *Estimates from the CES Specifications*

Groups:	*Total*	*31-34*	*20-30 & 39*	*35-38*
Parameters				
ρ	3.67	3.93	6.69	15.13
	(4.16)*	(3.84)*	(3.99)*	(4.56)*
h	2.08	2.44	2.08	1.67
	(5.71)*	(4.68)*	(5.69)*	(5.27)*
α	0.87	0.71	0.81	0.77
	(4.29)*	(3.62)*	(4.57)*	(3.98)*
β	0.48	0.64	0.58	0.47
	(3.16)*	(3.48)*	(3.78)*	(4.05)*
σ[=1/(1+ρ)]	0.214	0.223	0.130	0.162
H_0: h = 1	1.08[0.62]	1.22[0.55]	1.97[0.25]	0.89[0.81]
Diagnostics				
J	2.08[0.52]	2.11[0.47]	1.96[0.58]	2.14[0.43]
F_{AR1}	1.63[0.39]	1.71[0.34]	1.44[0.45]	1.61[0.46]
F_{AR2}	1.27[0.51]	1.55[0.39]	1.38[0.56	1.40[0.53]
LR1973	4.47[0.53]	5.09[0.47]	5.19[0.44]	4.81[0.51]
LR1979	6.79[0.69]	6.11[0.62]	5.83[0.57]	6.86[0.72]
LR1981	5.91[0.58]	4.74[0.42]	4.19[0.33]	3.68[0.20]
x^2 test of parameter instability across sectors		7.84[0.76]	6.93[0.68]	8.53[0.82]

J denotes a test for the validity of instruments used (Sargan's test). F_{AR1} and F_{AR2} denote tests for first- and second-order serial correlation, while LR is a likelihood-ratio type statistic testing for structural stability. Finally, x^2 is a test for testing whether there are differences in the estimations of the parameters across sectors. Figures in parentheses are t-ratios and those in brackets p-values.
* denotes statistical significance at 1 per cent.

The obtained results can be summarised as follows: The model performs reasonably well since the test of J statistic (Sargan's instrument validity test) provides no evidence of mis-specification. The statistic J is asymptotically distributed as x^2_{M-K}. The null hypothesis of a correctly specified model, i.e. an instrument-validity test, cannot be rejected. Next, F-statistics, denoted as F_{AR1} and F_{AR2}, for testing first- and second-order serial correlation show that serial correlation is not present. Finally, LR tests, proposed by Ghysels and Hall (1990), and used to test the hypothesis of structural stability indicate the absence of structural instability for three policy events, i.e the 1973 oil price shock, the 1979 oil price shock and the 1981 European Economic Community participation.

The Verdoorn effect is present in total manufacturing as well as in all three individual manufacturing groups and it is equal to 1.15, 1.41, 1.23, and 1.3, respectively. Thus, the growth of output is considered as an important determinant of labour productivity growth. Moreover, productivity tends to grow faster in the intermediate goods group. All hs are positive and greater than unity, implying the validity of the increasing returns to scale hypothesis. Moreover, the hypothesis that h is significantly equal to 1 is clearly rejected. The evidence of increasing returns to scale is similar to that reached by Zanias (1991). However, his study makes use of an old sample as well as of OLS methods that do not take into consideration the problem of endogeneity.

According to our results, the highest returns to scale are recorded in the intermediate goods group, followed by the consumer goods group and the machinery equipment, and the transportation group, demonstrating that the first group is expanding more than the two latter groups. The results imply that the growth of output is considered as an important determinant of productivity growth, while productivity tends to grow faster in the intermediate goods group. In addition, the substitutability between capital and labour (σ) is smaller than unity in all cases but still greater than zero, implying that Greek manufacturing does not operate under fixed coefficients in production. Similar results have been reached by Zikos and Petrakos (1991). By contrast, opposite results have been reached by Lianos (1979) and Papatheodorou (1991). However, our results are not comparable with those reached by the aforementioned studies due to the drawbacks of their econometric methodology used, i.e. OLS methods cannot capture the presence of endogeneity among the variables under study.

Nevertheless, the possibilities of substitution between capital and labour in Greek manufacturing are low. Substitutability is higher in the intermediate goods group and lower in the machinery equipment and transportation group, with the consumer goods group lying in the middle. Finally, a test, proposed by Holtz-Eakin *et al.* (1988), to investigate whether there are differences in the estimated parameters across sectors, is performed. The procedure first estimates the non-linear regression allowing the parameters to differ and then it restricts the parameters to be equal across sectors. The test is conducted by comparing the J statistics. The results are unable to reject the hypothesis of parameter stability across sectors at 1 per cent.

3.5 Robustness Tests: Evidence through a Cobb-Douglas Production Function

To test the empirical validity of the CES results, an alternative production function pattern, i.e. a Cobb-Douglas production function is employed. A Cobb-Douglas production function has the form: $Y = A\,L^{\gamma}K^{\delta}$, where A captures all the factors that contribute to production in addition to labour and capital, i.e total factor productivity. To express this production function in terms of the Verdoorn law yields:

$$Y/L = (AK^{\delta}/Y)^{1/\gamma}\,Y \tag{5}$$

or

$$\ln(Y/L) = (1-1/\gamma)\ln Y + 1/\gamma\,(\ln A + \delta \ln K) \tag{6}$$

or

$$\ln(Y/L) = (1-1/\gamma)\ln Y + 1/\gamma \ln A + \delta/\gamma \ln K \tag{7}$$

or

$$\ln(Y/L) = \text{constant} + (1-1/\gamma)\ln Y + \delta/\gamma \ln K \tag{8}$$

or

$$\Delta\ln(Y/L) = (1-1/\gamma)\,\Delta\ln Y + \delta/\gamma\,\Delta\ln K \tag{9}$$

Equation (9) has a linear pattern and it could be estimated by employing an Instrumental Variable (IV) approach to avoid the problem of endogeneity. The Verdoorn coefficient is proxied by $(1-1/\gamma)$. By making use of the following instrument set (constant, $\Delta(Y/L)_{-1}$, $\Delta(Y/L)_{-2}$, ΔY_{-1}, ΔY_{-2}, ΔK_{-1}, ΔK_{-3}), the results are shown in Table 4.

As regards the diagnostics, the model seems to perform relatively satisfactorily. However, the Verdoorn coefficient, that is $(1-1/\gamma)$, although it is statistically significant in total manufacturing as well as in all three individual manufacturing groups, it turns out to be negative, a result which obviously invalidates the validity of the law as well as the increasing returns to scale hypothesis. In other words, the growth of output is considered as an adverse important determinant of labour productivity growth, which of course cannot be accepted. Moreover, statistical tests of the hypothesis that $\gamma + \delta = 1$

cannot reject the validity of the constant returns to scale hypothesis, which has not been observed in the Greek manufacturing history. As a result, a Cobb-Douglas production function or any other type of a linear production function type cannot describe properly the working of Greek manufacturing.

Table 4: *Estimates from the Cobb-Douglas Specification*

Groups:	*Total*	*31-34*	*20-30 & 39*	*35-38*
Coefficients				
1-1/γ	–0.85	–0.89	–1.04	–0.85
	(3.82)*	(3.51)*	(3.27)*	(3.88)*
δ/γ	0.72	0.79	0.84	0.78
	(3.08)*	(4.22)*	(2.87)*	(4.56)*
Diagnostics				
Adjusted R^2	0.28	0.32	0.11	0.17
D-W	1.96	1.92	1.81	1.89
J	2.08[0.52]	2.11[0.47]	1.96[0.58]	2.14[0.43]
H_0: $\gamma + \delta = 1$	1.77[0.43]	1.49[0.64]	1.85[0.31]	1.19[0.72]
LR1973	3.55[0.38]	3.28[0.35]	4.02[0.46]	3.97[0.43]
LR1979	5.56[0.62]	5.12[0.51]	5.77[0.67]	4.17[0.47]
LR1981	7.12[0.59]	4.22[0.31]	7.73[0.65]	6.33[0.50]
x^2 test of parameter instability across sectors		9.22[0.61]	8.79[0.55]	9.03[0.60]

D-W is the Durbin-Watson statistic for measuring autocorrelation. Figures in parentheses are t-ratios and those in brackets p-values. The remaining are similar as above.
* denotes statistical significance at 1 per cent.

IV CONCLUDING REMARKS

This study tested the law of Verdoorn for Greece with aggregated manufacturing time series data as well as disaggregated time series data for three manufacturing groups of sectors, i.e. intermediate goods, consumer goods, and machinery equipment and transportation, over the period 1960-1995. The objective was to assess whether the law provides an appropriate theoretical framework to interpret developments of output, employment, and productivity in Greek manufacturing by avoiding certain problems identified in the international literature, such as the omission of the capital stock and the endogeneity or simultaneity problem associated with a single-equation estimation.

Verdoorn's law has been examined in association with the CES production function. By using the methodology of GMM, an extended version of the law was formulated. The empirical results revealed that productivity growth in Greek manufacturing appears to be strongly affected by the Verdoorn effect. In all cases, the hypothesis of increasing returns to scale receives strong support. Moreover, substitutability between capital and labour does exist, implying that policies to achieve higher output growth could be successful through various combinations of capital and labour. The results confirm the presence of increasing returns to scale in the Greek industry, a result which appears to be the norm for the majority of manufacturing internationally considered. These results cannot be confirmed by the adoption of an alternative, linear type, production pattern, i.e. a Cobb-Douglas production function. According to traditional growth theory, this feature of Greek business suggests that there is a strong growth potential toward constant returns.

APPENDIX I

Manufacturing Sectors

20 = Food, 21 = Beverages, 22 = Tobacco, 23 = Textiles, 24 = Footwear, 25 = Wood and Cork, 26 = Furniture, 27 = Paper, 28 = Printing and Publishing, 29 = Leather and Fur Products, 30 = Rubber and Plastic Products, 31 = Chemicals, 32 = Petroleum and Coal Refining, 33 = Non-metallic Mineral Products, 34 = Basic Metals, 35 = Fabricated Metal Products except Machinery, 36 = Machinery and Appliances except Electrical, 37 = Electrical Machinery, Apparatus, Appliances and Supplies, 38 = Transport Equipment, and 39 = miscellaneous manufacturing products.

APPENDIX II

Construction of the capital stock according to Coen (1975).

The capital stock for period t can be defined as a weighted sum of current and past capital expenditures:

$$K_t = (1\text{-}d_0)\ I_t + (1\text{-}d_0\text{-}d_1)\ I_{t\text{-}1} + (1\text{-}d_0\text{-}d_1\text{-}d_2)\ I_{t\text{-}2} + \ldots$$

where I stands for real gross investment. The weights are the same for all t and they represent the fraction of the productive capacity of a capital good which is lost in the ith period. For the calculation purposes of this paper, the methodology employed assumes that $d_i = 1/n$, with i=1, …, n. This pattern implies that productive capacity declines by the same amount in each year of the service life. However, this pattern is expected to change beginning from January 1st, 2003 following the adoption of international accounting standards. According to the new pattern, more rapid capacity depreciation in the earlier years than in the later years of the service life will be assumed.

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