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ORTHODOX PRODUCTION FUNCTIONS WITH VARIABLE RETURNS TO SCALE: SOME ANALYSIS AND TESTING USING SOVIET AND POLISH REGIONAL DATA

Erkin BAIRAM*

Abstract. This paper examines limitations of orthodox production functions and estimates appropriate production functions for Soviet and Polish regional industries.

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1. INTRODUCTION

The main aim of this study is to estimate appropriate orthodox production functions for Soviet and Polish regional industries. For this purpose pooled Soviet Republic and Polish regional data are used and different estimation procedures are tried.

In the literature, to date, Soviet and Polish aggregate regional data have not been used for the estimation of production functions. This study is the first attempt to exploit these data for such a purpose. Therefore, the estimates will, it is hoped, provide new and fresh evidence relevant to the debate over the specification and estimation of aggregate production functions and help to resolve the controversies concerning technical progress and returns to scale in the European socialist countries in general, and the USSR and Poland in particular. (See, *inter alios*, Gomulka (1977), Bergson (1979), Desai (1976b, 1985) and Bairam (1987c, 1988a and b).)

The outline of this paper is as follows. Sections II and III detail the model and the pooled regional data used for estimation purposes. Section IV presents the results and discusses them in some detail. In IV. 1 the estimated degrees of returns to scale in Soviet and Polish regions are analysed. In IV.2 the estimated spatial disparities in the rate of technical progress are reported and in IV. 3 these disparities are explained in terms of regional socio-economic policy and the degree of specialization in the USSR and Poland. Finally, Section V summarizes the

* I have benefitted from discussions with J. McCombie. I am also indepted to P. Dalziel, N. Devlin, P. Maitra and J. Parker for helpful comments.

results and assesses their implications for the debate concerning production function specifications in general, and appropriate production functions for the Soviet and Eastern European total industry in particular.

II. THE MODEL

Recently, Kennedy and Foley (1978), McCombie and de Ridder (1984) and McCombie (1985) estimated the degree of returns to scale in the Irish and the US manufacturing industries. For this purpose they used the following relationship

$$tfp=\zeta_1+\psi_1 q \tag{1}$$

where tfp, the growth of total factor productivity, is defined as $q-(\omega_1 e+\omega_2 k)$. The variables q, e and k are the exponential growth rates of output, employment and capital stock, respectively. ω_1 and ω_2 are relevant weights of e and k and sum to unity. ψ_1 provides an estimate of $[1-(1/\nu)]$ where ν is the degree of homogeneity and ζ_1 provides an estimate of (λ/ν) where λ is the rate of technical progress.

Equation (1) is a preferred specification of the Verdoorn Law (Verdoorn (1949)), although the latter has been traditionally specified as the regression of the growth of labour productivity on that of output (see Bairam (1987c)). The use of total factor productivity has the advantage that it explicitly incorporates the contribution of capital. Hence, it separates the impact of the accumulation of capital from that of economies of scale.

The concept of total factor productivity used in these studies is similar to the geometric index of Solow (see the next section). The underlying structure of Eq. (1) may thus be interpreted as Cobb-Douglas production function (Verdoorn (1980) and Bairam (1987c)).[1]

Since the growth of output appears on both sides of Eq. (1), a specification which avoids the problem of spurious correlation is

$$f=\zeta_2+\psi_2 q \tag{2}$$

where f is the growth of total factor inputs $(\omega_1 e+\omega_2 k)$. The coefficient ψ_2 is the estimate of $(1/\nu)$ and ζ_2 is the estimate of $-(\lambda/\nu)$.

The specification of the Verdoorn Law with output growth as the regressor is based on the assumption that growth is essentially demand and not supply constrained and, in the long run, the growth of capital is a function of output (see, for example, Kaldor, (1978)). If, on the other hand, the converse assumption is made, namely, that growth of output is determined by exogenously given rates of growth of factor inputs, the correct specification is either

$$q=\lambda+\alpha e+\beta k \tag{3}$$

or

$$q=\lambda+\mu f \tag{4}$$

[1] For the mathematical derivations of Eqs. (1)–(4) given in this section see Appendix I.

where $(\alpha+\beta)=\mu(\omega_1+\omega_2)=\nu$.

Consequently, in most published studies estimates of these conventional Cobb-Douglas specifications are also reported. Nearly all the Verdoorn Law estimates presented in these studies suggest that industry is subject to substantial economies of scale. However, the Cobb-Douglas estimates from the same data refute the increasing returns to scale hypothesis. These conventional production function estimates generally suggest that industry is subject to constant returns to scale. Statistically this is not surprising. The relationship between the Verdoorn coefficient, ψ_2, and the regression coefficient obtained by regressing q on f, μ, is given by

$$\mu=(R^2/\psi_2) \tag{5}$$

where R^2 is the coefficient of determination.

Hence, if there is a perfect fit ($R^2=1$), then $\mu=1/\psi_2$. However, since in practice both R^2 and ψ_2 take a value around 0.5 (Bairam (1987c), it follows that μ takes a value around unity. Thus, McCombie (1985, p. 68) concluded;

> "... Even using the same data set, contradictory results are obtained which are dependent upon the exact specification chosen.... The results suggest the need for further work with perhaps more narrow specifications which are also plausible on *a priori* grounds. At the very least, the results show that the estimates are sensitive to the exact error structure assumed and provide a warning against the uncritical acceptance of a single model."

Fortunately, as far as this study is concerned, the correct specification is not controversial. This is because it is widely accepted that industrial growth in the socialist countries of Europe (especially since the early 1960s) has been essentially supply constrained.[2] Therefore, inputs growth rather than output growth should be regarded as the independent variable. Thus on *a priori* grounds, for these countries the orthodox specifications (Eqs. (3) and (4)) are a more appropriate model than the Verdoorn Law. Consequently, in thi spaper the analysis is confined to these conventional specifications.[3] However it should be emphasized that, depending on the type of data used, further problems may arise when formulating the appropriate statistical model for estimation and testing. These problems are discussed in Section III. 2 which also explains how regional data is used to resolve such specification problems.

III. THE DATA

1. Sources and Problems

The gross output, employment (number of persons employed) and gross fixed

[2] See, for example, Feshbach and Rapawy (1976), Gomulka (1983) and Bairam (1988a).

[3] The CES production function was also studied (Bairam (1988a)) for the nine major Soviet industrial branches but the empirical results confirm the findings of other studies at branch level of aggregation that suggest the CES does not generally statistically differ from the Cobb-Douglas. See, for example, Zarembaka (1970), Griliches and Ringstad (1971), Desai (1976a) and McCombie (1985).

assets (gross fixed capital stock) statistics for Soviet Socialist Republics (SSRs) are taken from statistical handbooks of the fifteen Republics in general, and from various issues of *Harodroye, thozyaystro ...... SSR v 1900 godu: Statistiochesky yezhegodnik* (*The National Economy of the s .... SSR in 15--: A Statistical Yearbook*' *should read* '*Narodnoye Khozyaystva .... SSR v 19--gode: Statisticheskiy yezhegodnik*. (*The National Economy of the .... SSR in 19--: A Statistical Yearbook*)' in particular. All the statistical handbooks for the Republics are published by the Central Statistical Administrations attached to the Council of Ministers of SSRs. A complete list of the available Republic statistical handbooks can be found in Gillula (1980). The relevant statistics for the twenty-two Polish regions are complied from various issues of *Concise Statistical Yearbook of Poland* published by the Central Statistical Office in Warsaw.

The growth rates used throughout the study are for the entire period, 1961–75, and for the subperiods 1961–65, 1966–70 and 1971–75 pooled. For estimation purposes these samples give 15 and 45 observations for the USSR and 22 and 66 observations for Poland, respectively.

For the USSR using SSRs as regional units has a disadvantage. Unlike the twenty-two Polish regions, unfortunately, there is a great disparity in the size of the fifteen Republics. Therefore, a division of the USSR into more equal units would be preferable for the analysis. But this is not possible because most of the current statistics relate to the Union Republics. There is little information about the differences within the Russian Federal Republic (RSFSR) or within Ukraine—the two Republics that account for over 70% of the Soviet Union's population and area. However, it should be also emphasized that using the Republics as the regional units has its advantages as well. Firstly, the individual Republics have regional autonomy and, therefore, some residual social and economic independence. Secondly, each Republic is dominated by one nationality. Consequently, most of the people living in any one Republic share the same language, religion and culture. This means that when the Union Republics are used as regional units it can be assumed that the socio-political factors affecting efficiency and labour supply are similar everywhere in each region.

Another problem with the data is that the choice of *gross* output and fixed assets may not be fully satisfactory from a theoretical point of view, however, it is inevitable because the data on *net* output and fixed assets is not available at the regional level of aggregation. Furthermore, it should be emphasized that these statistics are not entirely consistent or reliable. Measurement errors are likely, especially in gross output and fixed asset statistics for both countries. From the input side there is a common tendency to assume that there are no significant variations in the degree of utilization of input factors. However, the flow of *labour services* can deviate from the growth rates of *number of persons employed* (which is the employment measurement used for estimation purposes) due to either underemployment or adjustment of the working-week. Both of these problems, but especially the former, are serious in Soviet and Polish economies.

A similar situation exists with regard to gross fixed assets data. There are two particular issues of concern here. One is the need to account for the *quality changes* in the assets. The other is the need to adjust the data for variations in *utilization rates*. Finally, on the output side the data may embody measurement errors due to the non-scarcity nature of Soviet and Polish prices. It is widely recognized that 'official' relative prices in Comecon countries deviate considerably from those that would follow from the opportunity cost considerations. Use of official price weights to aggregate data may lead to biased aggregate output series, with the direction of bias depending upon the combination of the relative direction of price biases and the relative growth rates of individual products. However, it should be noted that such aggregations are not always bad; most notably when errors at the product level of aggregation are off set at the industry level of aggregation. (See, for example, Grunfeld and Griliches (1960), and Aigner and Goldfeld (1974).)

Finally, the growth rates of total factor inputs used for estimation purposes are computed from the following index

$$F_{jt}=E_{jt}^{\omega_1}K_{jt}^{\omega_2} \tag{6}$$

where F_{jt}, K_{jt} and F_{jt} are the indices of total factor inputs, capital stock (gross fixed assets) and employment (number of employees) in region j, year t, respectively. It is well known that for Western capitalist countries the market shares of capital and labour in total input earnings are generally used to estimate ω_1 and ω_2. Unfortunately not enough information is available to compute these parameters for the fifteen Soviet Republics and twenty-two Polish regions from the income shares of capital or labour used in each region. But even if it was possible to calculate ω_1 or ω_2 from the available information on earnings (or from other similar information), the estimated value would not be very accurate. This is because socialist countries are not competitive economies. Hence, the marginal productivity theory of distribution (which is the theoretical justification of such calculations) is not valid for these regions. Nevertheless, this problem notwithstanding, most authorities believe that in the Soviet and Polish industrial sectors the share of capital input is around 30%—$\omega_2=0.3$. (See, for example, Weitzman (1970), Desai (1976a and b), Bergson (1979) and Gomulka (1983).). The validity of this weight is tested using the unrestricted and restricted specifications of the conventional production function (equations (3) and (4), respectively) and F-tests. The tests reveal that, at the 0.95 confidence level, the restriction: $(\alpha+\beta)=\mu(\omega_1+\omega_2)$ holds for all the estimated equations. Therefore, this weight is indeed appropriate for capital. Consequently, 0.7 and 0.3 are used as the correct weights for labour and capital, respectively, to compute F_{ij} for the fifteen Soviet Republics and twenty-two Polish regions.[4]

The data used show wide variations between Soviet Republics and between

[4] A variety of other plausible values for ω_1 and ω_2 are also used but the results do not prove sensitive to the exact figures chosen.

Polish regions and, therefore, minor inaccuracies are hopefully of little significance. Furthermore, allowance is made for biases that the above problems may induce by estimating the specifications not only with OLS but with Durbin's (1954) ranking instrumental variable (IV) method as well. It is hoped that the latter method reduces the biases in the estimated parameters which could be induced by measurement errors. Nevertheless, it should be emphasized that even the instrumental variable approach is only a 'second best' solution to the measurement error problem and, therefore, the estimates must be interpreted in this light.

2. *Regional Data and Production Function Estimation*

It is well known that the Verdoorn Law and the more conventional production function specifications are usually estimated using cross-country data or annual time-series data from a single country. However, unless the statistical model is reformulated for estimation and testing, serious specification problems arise when such data are used (see Bairam (1987c)). In this section it is shown that the type of data used in this paper resolves these specification problems without reformulating the appropriate model.

Production functions estimated from *cross-country* data rest upon a critical assumption. They assume that the rate of technical progress (λ) is the same across all countries included in the samples which are used to estimate technological parameters. Unfortunately, this assumption does not hold for most of the *cross-country* data sets which have been used to estimate technological parameters in general, and the rate of technical progress in particular.[5]

Neo-classical growth theorists hypothesize that differential rates of industrial productivity and output growth among countries are mainly due to differential rates of exogeneous *technical* progress (progress that does not depend on economic variables) and/or differential rates of adoption (diffusion) of *technological* progress (progress in science and prime technology). Gomulka (1971, 1978, 1979 and 1983), among others, has suggested that the rate of growth of industrial output and productivity of a country depends upon its stage of economic development. It is generally accepted that if a country is relatively backward in its stage of economic development, its technology also lags behind the more mature economies. Hence, by importing the most advanced technology from the industrial leaders, it can manage to accelerate its exogenous technical progress rate.[6] Consequently, it can be the case that productivity growth is partly or totally due to diffusion of more advanced technology. The serious implications of this can be seen from Fig. 1.

As the figure illustrates, in all countries included in the sample, constant returns to scale prevail ($\mu=1$). The lines are drawn under the assumption that the exogenous technical progress rate varies from country to country mainly due to the

[5] See the review of the literature by Bairam (1987c).

[6] For empirical evidence see, *inter alios*, Clark (1960), Cornwall (1977), Gomulka (1983) and Bairam (1986, 1987a).

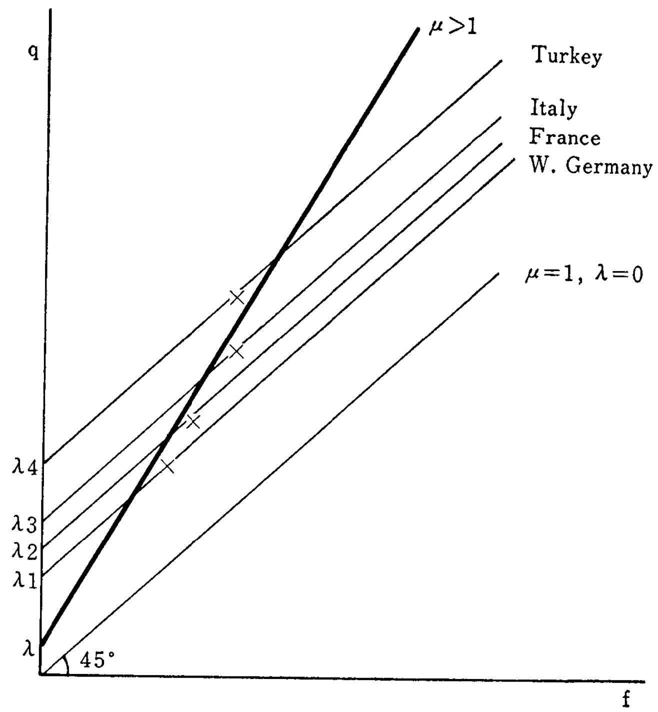

Fig. 1. A Spurious Production Function Estimate: $q=\lambda+\mu f$.

reason noted above. The spurious production function estimate (bold line) is obtained when q is regressed on f using the cross country data. Hence, a scale parameter (μ) greater than unity does not imply anything about the degree of returns to scale, unless the countries from which the statistics are drawn are at similar stages of their economic development.

Therefore, all this suggests that cross-country estimates can not satisfactorily assess the relative roles of returns to scale and technical progress in industrial growth. On the other hand, total industry data drawn from *different* regions within the *same* country may resolve this controversy. This is mainly because diffusion of new technology from one region to another, especially in Eastern Europe and the USSR, is not constrained by licensing, import controls and socio-economic factors.[7] Consequently, it is very likely that differences in the level of technology among the regions are small. Thus, the mis-specification problem shown in Fig. 1 should not be significant.[8]

The other type of data used in the literature to estimate production functions (especially for the USSR and Eastern Europe) is also problematical. Time-series estimation of production functions with variable returns to scale for individual countries is known to run into identification problems (see, for example Desai (1985) and Bairam (1988a and b)). Therefore, with such data it is difficult to estimate both returns to scale and technical progress at the same time. The

[7] This last factor causes some problems for the regional study of the USSR (see Sections IV. 2 and IV. 3).

[8] This assertion is explicitly tested in Section IV. 2.

second merit of the *pooled* cross-regional data is that they can be used to estimate both the degree of returns to scale and the rate of technical progress at the same time. The former is captured by the degree of homogeneous production function and the latter by its shift over time.

Therefore, given these advantages of the pooled data used, the results obtained provide fresh evidence relevant to the debate over the Verdoorn Law and, more significantly, to the controversies over the roles of technical progress and economies of scale in the industrial sectors of the European socialist countries in general, and the USSR and Poland in particular.

IV. THE RESULTS AND THEIR INTERPRETATION

1. Returns to Scale in the Soviet and Polish Regional Industry

For the Soviet and Polish regional industry the two conventional specifications (Eqs. (3) and (4)) are estimated. The results are reported in Table 1. The 'total factor inputs' specification (Eq. (4)) is a restricted version of the 'individual inputs' specification (Eq. (3)). The validity of this restriction is tested; namely $(\alpha e+\beta k)=[\mu(\omega_1+\omega_2)f]$ using the appropriate F-test statistic.[9] The test results reveal that the labour and capital weights used to compute f from e and k (0.7 and 0.3, respectively) are, at the 0.95 confidence level, accepted by the data used. This is also obvious from the estimates in Table 1. These results clearly show that the scale and technical progress rate parameters given by the two conventional specifications are very similar, if not identical. Nevertheless, despite this, it is worthwhile noting that the results obtained from the restricted specification (Eq. (4)) are more reliable for hypothesis testing than those obtained from Eq. (3). This is because the former specification eliminates the potential danger of multcollinearity between the explanatory variables (e and k in Eq. (3)). Consequently, from now on the analysis is confined to the restricted specification.

It is clear from the results in the table that 'pure' cross-section data give λ values which are slightly lower and ν values which are slightly higher than the corresponding values that can be obtained from the pooled data for the same period and country. However, these differences are not significant. On the other hand, the $\bar{R}^2$ values improve significantly when the pure cross-section data are used

[9] The appropriate F-test statistics is

$$F=((\mathrm{RSS}_r-\mathrm{RSS}_u)/d)/\sigma^2$$

where

$$\sigma^2=\mathrm{RSS}_u/(n-m)$$

RSS_u=Residual sum of squares of the unrestricted specification.

RSS_r=Residual sum of squares of the restricted specification.

d=Number of restrictions.

n=Number of observations used in the estimation.

m=Number of parameters in the unrestricted specification.

The null-hypothesis is accepted, at a given significance level, if $F<F_c$, (where F_c is the appropriate critical F value from the F-table).

TABLE 1. ORTHODOX PRODUCTION FUNCTION ESTIMATES FOR SOVIET AND POLISH REGIONAL INDUSTRY

$q_j=\lambda+\alpha e_j+\beta k_j$ and $q_j=\lambda+\mu f_j$

Pooled Data (PD): 1961–65, 1966–70 and 1971–75; USSR: $n=45$ and Poland: $n=66$
Cross Section Data (CSD): 1961–75; USSR: $n=15$ and Poland: $n=22$

	λ	α	β	μ	$\bar{R}^2$	SEE	Method	ν
USSR								
(1)	5.40	.47	.20		.442	1.38	OLS/PD	0.67+
	(7.03)	(3.35)	(1.01)*					
(4)	5.48	.51	.17			1.39	IV/PD	0.68+
	(6.71)	(3.03)	(1.11)*					
(3)	4.56	.43	.32		.625	0.81	OLS/CSD	0.75+
	(4.30)	(1.99)	(1.69)*					
(4)	4.57	.43	.31			0.81	IV/CSD	0.74+
	(4.23)	(1.97)	(1.72)*					
(5)	5.61			.65	.444	1.39	OLS/PD	0.65
	(9.50)			(5.98)				
(6)	5.23			.68		1.41	IV/PD	0.68
	(7.26)			(5.68)				
(7)	4.50			.73	.619	0.82	OLS/CSD	0.73
	(4.88)			(5.92)				
(8)	4.48			.73		0.82	IV/CSD	0.73
	(4.61)			(5.86)				
Poland								
(1)	4.19	.85	.29		.649	1.35	OLS/PD	1.14+
	(7.14)	(6.77)	(3.90)					
(4)	3.98	.83	.31			1.35	IV/PD	1.14+
	(6.59)	(6.41)	(3.93)					
(3)	4.01	1.01	.19		.903	0.64	OLS/CSD	1.20+
	(6.40)	(7.90)	(2.84)					
(4)	3.86	.93	.22			0.65	IV/CSD	1.15+
	(5.94)	(7.83)	(2.61)					
(5)	4.30			1.07	.639	1.38	OLS/PD	1.07+
	(7.59)			(10.14)				
(6)	4.29			1.07		1.38	IV/PD	1.07+
	(6.83)			(9.23)				
(7)	3.98			1.12	.801	0.92	OLS/CSD	1.12+
	(5.30)			(8.35)				
(8)	3.88			1.14		0.93	IV/CSD	1.14+
	(4.97)			(7.83)				

Sources: See text.

Variables: q_j, e_j, k_j and f_j are the rates of growth of industrial output, employment, capital stock and total factor input in region j, respectively.

Notes: Figures in parentheses are t-statistics. SEE is the standard error of the equation and ν is the degree of returns to scale. * indicates a coefficient not significantly different from zero and $^+$ denotes a degree of returns to scale not significantly different from unity at the 0.95 confidence level.

instead of the pooled data. But this is not surprising at all because using the 'long-run' growth rates (1961–75) smooths out the 'short-run' fluctuations (i.e. deviations from the trend) in the growth rates during the subperiods (1961–65, 1966–70 and 1971–75). Consequently, the pure cross-section data estimates for 1961–75 give higher $\bar{R}^2$ values.

It can also be seen from table 1 that, regardless of the type of data and estimation technique used, all the estimated parameters have the correct sign (positive) and, with the exception of the capital coefficient (β) in the individual inputs specification for the USSR (Eqs. (1)–(4)), all the estimated parameters obtained are significant at the 0.95 confidence level.

Finally, the results further suggest that, in so far as OLS and IV procedures give very similar results, measurement errors are not important in estimating the orthodox production function specifications. However, it is worthwhile emphasizing that the instrumental variables used may not be all that satisfactory (see Griffiths, Judge, Hill and Lee (1980)).

The results presented in Table 1 generate some interesting conclusions. They clearly show that decreasing returns to scale prevail in the Soviet regional industry. Both the individual and total factor inputs specification estimates (Eqs. (1)–(8)) give ν values which are around 0.7 and, in the case total factor inputs specification, all these values are statistically significantly less than unity.[10] These scale parameter estimates clearly challenge the constant returns to scale ($\nu=1$) assumption imposed upon time-series Soviet aggregate production function estimates. (See, *inter alios*, Weitzman (1970), Gomulka (1977) and Desai (1976a and 1985).) The decreasing returns to scale suggested by the aggregate estimates presented here are also supported by the *industrial branch* CES and Cobb-Douglas production function estimates obtained from pooled Soviet Republic data. These branch estimates reported in Bairam (1987b, 1988a) give weighted and unweighted branch *averages* of ν between 0.7 and 0.8. Thus, all the estimates reveal that the *a priori* constant returns to scale assumption imposed upon Soviet production function specifications is wrong. This clearly implies that the conclusions drawn from such restricted estimates are suspect.

On the other hand, the estimated equations for Polish regions in Table 1 suggest that constant returns or slightly increasing returns (although the latter are not statistically significant) prevail in their industrial sectors. This implies that the rate of growth of inputs affects the rate of growth of output to a greater extent in Poland when compared with the USSR.

Finally, the rates of exogenous technical progress (λ) given by all estimated equations are very high (4.0–4.5% per annum in Poland and 4.5–5.5% per annum in the USSR). These parameter estimates are very consistent with the other available studies (see the review by Bergson (1979)). The next two sections examines

[10] Note that because of large standard errors in the estimated β coefficients, the ν ($=\alpha+\beta$) values given by equations (1)–(4) for the USSR are not statistically significantly less than unity at the 0.95 confidence level.

the rate of technical progress in more detail. Before going any further, however, it is worthwhile mentioning that the dummy variable approach and F-tests for separate subperiod estimates of Eqs. (3) and (4) (not reported) reveal that the estimated λ values (and ν values) are stable over time. This suggests that it is appropriate to 'pool' the data for the subperiods.

2. Estimated Spatial Disparities in the Rate of Technical Progress

As has already been pointed out a major criticism of the aggregate production function estimates from international data derives from the assumption that all countries have access to the same blue-print of technology which is used in the production process. Given that such an assumption is implausible (see Section III. 2) this criticism is not surprising. On the other hand, it has been suggested that if the specifications are estimated from regional data, drawn from a single country, the assumption is rather more plausible. Unfortunately, this still does not necessarily mean the rate of technical progress is identical in all regions, because having access to new technology does not necessarily mean that all regions use it in their new plants. The application of new technology does not depend only on its availability but also upon its diffusion, which in turn depends on regional socio-economic factors in general, and the stage of development in particular.[11]

A dummy variable, D_j, has been introduced into the restricted specification (Eq. (4)) to test the differences in the rate of technical progress between the more developed and less developed regions in the USSR and Poland. The criteria used to distinguish more developed regions from less developed ones are; the share of non-agricultural employment in total employment and the share of urban population in total population in each region ($D_j=1$ if j is a less developed region and $D_j=0$ if otherwise). Note that this dummy variable is a crude proxy for the level of development but it is shown below that using other proxies does not affect the conclusions that can be drawn from the dummy variable estimates presented in Table 2.

It can be seen from Table 2 that, regardless of estimation technique and type of data used, there are no significant differences in the rate of exogenous technical progress between the more and the less developed regions in Poland (i.e. λ_2 estimates are not significantly different from zero at the 0.95 confidence level). On the other hand, all the estimated equations for the USSR show small but statistically significant differences in the rate of technical progress between the more and the less developed Soviet Republics. The dummy variable estimates in Table 2 suggest that λ is about 1.0% per annum *higher* in the *more developed* Republics (such as the RSFSR and the Baltic Republics) when compared with the less developed ones (such as the Central Asian Republics).

However, it could be argued that these results are not reliable because the criteria used to decide which regions are relatively advanced (i.e. the share of non-agricultural labour in total and the level of urbanization) may not be good proxies

[11] The regional socio-economic policy in the USSR and Poland is analysed in the next section.

TABLE 2. ORTHODOX PRODUCTION FUNCTION ESTIMATES FOR DIFFERENTIAL RATE OF TECHNICAL PROGRESS IN SOVIET REPUBLICS AND POLISH REGIONS

$$q_j=\lambda_1+\lambda_2 D_j+\mu f_j \text{ and } q_1=\lambda_1+\lambda_3 Y_j+\mu f_j$$

Pooled Data (PD): 1961–65, 1966–70 and 1971–75; USSR: n=45, Poland: n=66
Cross-section Data (CSD): 1961–75; USSR: n=15, Poland: n=22

	λ_1	λ_2	λ_3	μ	$\bar{R}^2$	SEE	Method	ν
USSR								
(1)	5.90	− .85		.68	.448	1.33	OLS/PD	0.68
	(9.94)	(−2.07)		(6.43)				
(2)	5.67	− .91		.70		1.33	IV/PD	0.70
	(9.42)	(−2.13)		(6.37)				
(3)	5.09	−1.01		.73	.628	0.75	OLS/CSD	0.73
	(6.87)	(−2.45)		(6.24)				
(4)	5.00	−1.12		.74		0.76	IV/CSD	0.74
	(6.23)	(−2.54)		(5.81)				
(5)	5.84		.03	.71	.473	1.35	OLS/PD	0.71
	(9.36)		(2.03)	(6.38)				
(6)	5.81		.03	.71		1.35	IV/PD	0.71
	(9.05)		(2.18)	(6.03)				
(7)	4.87		.03	.75	.687	0.76	OLS/CSD	0.75
	(4.99)		(2.12)	(5.97)				
(8)	4.61		.03	.76		0.76	IV/CSD	0.76
	(4.79)		(2.14)	(5.45)				
Poland								
(1)	4.23	.18		1.06	.631	1.40	OLS/PD	1.06+
	(7.17)	(.50)*		(10.01)				
(2)	4.20	.19		1.06		1.40	IV/PD	1.06+
	(6.91)	(.53)*		(9.46)				
(3)	3.93	.24		1.09	.807	0.91	OLS/CSD	1.09+
	(6.29)	(.94)*		(8.57)				
(4)	3.85	.26		1.11		0.91	IV/CSD	1.11+
	(5.88)	(.96)*		(8.14)				

Source: See text.

Variables: q_j and f_j are the rates of growth of industrial output and total factor inputs in region j, respectively. D_j is the intercept dummy, $D_j=1$ if j is a less developed region and $D_j=0$ if j is a developed region. Y_j is the percentage deviation of total per capita income of Soviet republic j from total per capita income of the USSR (see text).

Notes: Figures in parentheses are t statistics. SEE is the standard error of the equation and ν is the degree of returns to scale. * indicates a coefficient not significantly different from zero and + denotes a degree of returns to scale not significantly different from unity at the 0.95 confidence level.

for the stage of economic development. Fortunately, for Soviet republics another proxy, per capita income (see Appendix II), is available. Following Gomulka (1983) the percentage deviation of total per capita income from national weighted average, Y_j, has been used as an alternative measure of the stage of economic development. The dummy variable, D_j, in the total factor inputs specification is replaced with this new proxy Y_j and the specification for Soviet Republics has been re-estimated.[12] As can be seen from Table 2, the results confirm the dummy variable estimates presented in the same table. They clearly show that technical progress rate is significantly higher in the more developed Union Republics.

The Y_j values (calculate from the data in Appendix II) and Eqs. (3) and (6) in Table 2 are used to estimate the rate of technical progress in *individual* Republics. The results are given in Table 3. It is obvious from the table that the rate of

TABLE 3. THE AVERAGE RATE OF TECHNICAL PROGRESS, λ_j (in % per annum), BY SOVIET REPUBLIC, 1961–75

Union Republic	Individual Inputs Specification ($\lambda_j=5.23+.03Y_j$)	Total Factor Inputs Specification ($\lambda_j=4.78+.03Y_j$)
USSR	5.23	4.87
RSFSR	5.47	5.11
Ukraine	5.13	4.74
Belorussia	4.98	4.62
Moldavia	4.75	4.22
Baltic Republics:		
Estonia	6.07	5.71
Latvia	5.90	5.54
Lithuania	5.55	5.19
Central Asian Republics:		
Kirghizia	4.50	4.14
Tadzhikistan	4.30	3.94
Turkmenia	4.71	4.35
Uzbekistan	4.49	4.13
Transcaucasian Republics:		
Armenia	4.83	4.47
Azerbaydzhan	4.26	3.90
Georgia	4.88	4.52
Kazakhstan	4.97	4.61

Sources and Notes: The first column is calculated from Eq. (3) and the second column from Eq. (6) in Table 2. Y_j values used are the averages for the period 1960–75 and are from per capita income statistics in Appendix II.

technical progress in the more developed five Republics (the RSFSR, Ukraine and the Baltic Republics) are higher than in the ten less developed Republics.[13] However, it should be emphasized that, although the differences are statistically significant, at the 0.95 confidence level, in absolute terms they are small. Consequently, inclusion of D_j or Y_j as an additional explanatory variable does not change the estimated values of the scale parameters significantly (see Tables 1 and

[12] $Y_1=[(I_r-I_j)/I_r]100$, where I_r is the per capita *total* income of the USSR and I_j is the per capita *total* income of republic j. Per capita *industrial* output statistics are also used to compute Y_j (not reported). However, the estimated equations, when the per capita industrial output figures are used as measures of the stage of economic development, are not any different than those obtained using per capita total income statistics presented in Appendix II.

[13] This is contrary to the diffusion hypothesis but, nevertheless, in the next section it is shown that it can be consistently explained.

2). The estimates still reveal significant decreasing returns to scale in the fifteen Soviet Republics during the period under consideration.

The next logical step is to examine whether or not the implications of these results are consistent with the resource endowments of individual regions and with the central planners' regional socio-economic policies.

3. *Regional Policy, Resource Endowments and Technical Progress Rate Disparities*

Regional policy in the European Comecon countries in general and in the USSR, in particular, have two main goals. First; maximization of output growth for the *entire* country. Second; the equalization of per capita income among the country's regions. The former is called the 'efficiency objective' and the latter the 'equality objective'. The efficiency objective can be mainly achieved by finding the best industrial mix and technology appropriate for each region given its human and natural resource endowments. Hence, it implies specialization of each region in industrial branches in which it has a 'comparative advantage'. However, this efficiency objective is often in conflict with the equality objective. Consequently, the planners have to face an efficiency versus equality dilemma and, unfortunately, solving such a dilemma is not a simple task—mainly because the choice between the two objectives has important political and economic implications.

The politicians and planners in the two Comecon countries that are studied here favour the efficiency criteria. (See Wagener (1973), Koropeckyj (1972 and 1977) and McAuley (1979).) This means that new resources (especially high technology investment) are to be directed to the regions with high resource productivity (which are usually more advanced regions), otherwise the efficiency objective can not be facilitated. Unfortunately, if the new resources are directed to the regions with high resource productivity, the remaining regions are bound to suffer. Hence, as a result of such a policy inter-regional differences in welfare in general and in technical progress, in particular, are bound to follow.

However, for the Polish economy the conflict between the two objectives is not very serious. This can be mainly attributed to the following three factors. Firstly, Poland is a relatively small country. Therefore, transport costs do not play a major role when industrial locations for new plants are decided. Secondly, long-term defence considerations are not of decisive importance for the geographical distribution of industry and its mix. Finally, since it possesses distinct national characteristics (same language, religion etc.), geographical distribution of labour is even and labour mobility is high. Hence, when all these factors are considered it becomes clear why the conflict between the efficiency and the equality objectives is not very important. Thus, it becomes obvious why the planners can give equal treatment to all regions—even though they believe the efficiency objective is paramount. For example, Koropeckyj (1977) found that in the 1960s the less developed regions in Poland received 54% of all new plants and 62% of new plants without restrictions. Therefore, it is plausible to say that regional policies followed by the Polish planners may very well lead to similar rates of technical progress in all regions. And it goes without saying that this is consistent with the implications that can be drawn from the estimated equations discussed in the previous section.

On the other hand, the conflict between the efficiency and the equality objectives is a serious problem for the Soviet planners. The USSR is the largest country in the world by area and its resource endowments (both natural resources and labour) vary significantly from one Republic to another. If the distinct national characteristics of the fifteen Republics and defence considerations are also included, it is not surprising that the conflict between full utilization of resources and assuring equalization of living standards among the fifteen Republics is very serious. Consequently, by giving priority to the efficiency objective, the planners cause diversity in the regional technical progress and per capita income growth rates.

A study of industrial location policy in the USSR by Wagener (1973) shows that, during the 1960s, textiles and mining branches are dominant in the less developed Republics. This is not surprising because the natural resource endowments of these republics and their fast growth of population favour labour-intensive branches. Earlier studies by Bairam (1987b, 1988a)) have shown that in the labour-intensive branches of Soviet industry (such as Light Industry and some sub-branches of mining) the rates of technical progress are much lower than the rates in the capital-intensive, high-technology branches in general and that in Machine Building and Metal Working industry (MBMW), in particular. Therefore, it is not at all surprising to find that the overall rates of technical progress in the less developed Republics (which generally specialize in stagnating labour-intensive branches) are relatively low when compared with the more developed Republics in the North, as the latter specialize in the high-technology, capital-intensive industrial branches.

Since specialization goes a long way in explaining the regional technical progress rate dispartities reported in Table 3, it is useful to examine it more closely. For this purpose the location quotients, LQ_j, can be used. The location quotient is defined as follows:

$$LQ_j=[(B_j/I_j)/(B_u/I_u)]=[(B_j/B_u)(I_u/I_j)] \qquad (7)$$

where B is the branch value of a certain variable (e.g. stock of capital, number of employees etc.) and I is the total (aggregate) industry value of the same variable. The suffixes j and u denote Republic and Union, respectively.

Hence, the LQ_j relate a regional share weighted by the regional total (of a specific indicator) to the Union share weighted by the Union total (of the same indicator). Thus, it is clear from this definition that 'specialization' and 'balanced development' are implied by LQ_j significantly greater than unity and equal to unity, respectively.

Wagener (1973) calculates the LQ_j for Soviet Republics according to the two major inputs—labour and capital. His labour statistics are for the period 1960–66 and capital statistics for the period 1962–70. The present study extends to the period 1961–75 and reports the LQ_j calculated from the capital stock data in Table 4 and the LQ_j from the employment data in Appendix III.[14] The LQ_j computed from both data have very similar implications. They can be summarized as follows.

TABLE 4. SSR LOCATION QUOTIENTS BASED ON THE AVERAGE DISTRIBUTION OF CAPITAL STOCK, 1961–75

Union Republic	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RSFSR	1.20	0.90	0.93	1.04	1.13	0.95	1.30	0.97	0.89
Ukraine	0.77	1.22	2.44	0.91	0.94	0.89	0.36	0.60	1.08
Belorussia	1.21	0.51		1.44	1.18	1.35	1.21	2.01	1.28
Moldavia	1.16			0.07	0.57	1.46	0.61	1.97	4.76
Baltic Republics:									
Estonia	1.71	0.94		0.40	0.59	1.18	1.28	1.86	2.16
Latvia	1.18	0.20		0.61	1.00	1.21	1.47	2.22	2.46
Lithuania	1.27	0.18		0.42	0.91	1.48	1.27	2.28	2.47
C. Asian Republics:									
Kirghizia	1.14	1.22			0.94	1.16	0.35	2.11	1.63
Tadzhikistan	2.23	0.34			0.41	1.78	0.32	3.61	1.26
Turkmenia	0.79	3.28		1.14	0.26	1.25	0.14	1.30	0.82
Uzbekistan	1.39	0.77		1.30	0.68	1.59	0.34	2.59	0.93
Trans. Republics:									
Armania	1.79			1.83	0.88	1.26	0.33	1.76	1.24
Azerbaydzhan	0.85	3.62	0.37	0.94	0.35	0.58	0.16	0.83	0.65
Georgia	1.49	0.48	1.38	0.92	0.61	1.16	0.60	1.42	1.27
Kazakhstan	1.15	1.05	1.19	0.66	0.45	1.46	0.39	0.76	0.77

Source: Gillula (1981).

Notes: See text.
Branches: (1) Electricity; (2) Fuel Industry; (3) Chemicals and Petro-chemicals; (5) Machine Building and Metal Working (MBMW); (6) Construction Materials; (7) Wood, Paper and Pulp Industry; (8) Light Industry; (9) Food Processing.

Firstly, the regional extremes are marked by Azerbaydzhan and the RSFSR. Azerbaydzhan is specialized in fuels only and, since an LQ_j below unity indicates an industrial branch that has smaller weight in the regional economy than in the national economy, it is apparent from the tables that specialization in fuels has taken place at the expense of all other branches. Unfortunately, since the rates of technical progress in most fuel and mining sub-branches are slow (see Bairam (1986, 1987a, and b, 1988a)), the overall industrial technical progress rate in the Azeri industry is the *lowest* when compared with the rates experienced by the other fourteen republics (see Table 3). The RSFSR, on the other hand, deviate little from the USSR branch averages (i.e. calculated LQ_j are very close to unity). This can be explained by the size of the Russian Federal Republic; with a share in total

[14] The labour and capital statistics used are from Feshbach and Rapawy (1976) and Gillula (1981), respectively.

industry of 60–65%, it is not surprising to find that the estimated values of LQ_j are not significantly different from the USSR average (i.e. from unity). Consequently, this suggests that only for smaller Republics the LQ_j values contain meaningful information. Secondly, looking at the industrial branches, as expected, the branches that depend on natural resources (e.g. Fuel Industry; Metallurgy and Wood, Paper and Pulp) are distributed unevenly among the fifteen Republics. The less developed Central Asian and South Eastern Republics have specialized in fuels and this is consistent with their natural resource endowments. On the other hand, the more developed Northern republics have large Wood, Paper and Pulp industries, as this branch is highly dependent on raw materials available in these republics. Most of the remaining branches' distribution depends mainly on each Republic's stage of economic development and human resources. For example, the Soviet Light Industry (which is characterized with a slow rate of technical progress) is strongly represented in the labour-rich, less developed Southern republics, whereas the capital-intensive Food Processing Industry and high-technology MBMW (which are characterized with fast rates of technical progress) are predominant in the developed Northern republics rich in capital. Hence, all this evidence clearly indicates that the rates of overall industrial technical progress experienced by the more developed Republics are higher than those rates experienced by the less developed labour-rich Republics.

V. SUMMARY AND CONCLUSIONS

In this paper orthodox production functions are estimated using pooled cross-regional data drawn from the USSR and Poland. Pooled regional data drawn from a single country provide more accurate estimates of the scale (ν) and the technical progress rate (λ) parameters than those provided by time-series data from a single country and by international data. This is because the use of pooled regional data may overcome a number of serious specification problems associated with the use of time-series or cross country data.

The estimation of the conventional Cobb-Douglas production function specifications suggests statistically significant decreasing returns to scale for the Soviet industrial sector and constant or slight increasing returns for the Polish industrial sector. Consequently, these scale parameter estimates imply that the production function studies of the USSR and Eastern European industrial sectors which generally restrict ν to unity (i.e. make the *a priori* assumption that constant returns to scale prevail) and only estimate the rate of technical progress are suspect, as the value of ν is obviously significantly different from unity in the industrial sectors of some Comecon countries.

Finally, the results reported in this paper reveal that the rates of technical progress in all regions of the two countries considered here are quite high (between 4.0 and 5.5% per annum). The technical progress parameter estimates for Soviet republics also suggest the rate varies among the Republics. They are generally about 1.0–1.5% per annum lower in the less developed Central Asian and Trans-caucasian Republics when compared with the rates in the more developed Baltic Republics and the RSFSR. These differences can be attributed mainly to the differences in socio-economic conditions and natural resource endowments between the more and less developed republics. These factors force the planners to invest and specialize in less progressive, labour-intensive branches in the backward Central and South Eastern Republics and in more progressive, capital-intensive branches in the advanced Northern Republics. No such significant differences in the λ parameter estimates for Polish regions are found. The similar, if not identical, rates of technical progress experienced by all Polish regions can be mainly attributed to country's smaller size and its homogeneous culture and language.

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APPENDIX I.

It is easy to show that the underlying structure of Eqs. (1)–(4) given in Section II is the Cobb-Douglas production function.

The conventional Cobb-Douglas production function is specified as:

$$Q_t = A(\exp)^{\lambda t} E_t^{\alpha} K_t^{\beta} \tag{A1}$$

where Q, E and K are the levels of output, employment and capital stock, respectively, and t is a time trend. A is the scale parameter denoting the efficiency of technology and units of measurement, λ is the Hicks-neutral rate of technical progress and $(\alpha+\beta)=\nu$ is the degree of returns to scale.

Equation (A1) can also be written as:

$$Q_t = A(\exp)^{\lambda t} F_t^{\mu} \tag{A2}$$

where $F = E^{\omega_1} K^{\omega_2}$, is the level of total factor input [i.e. the sum of labour and capital inputs weighted by ω_1 and ω_2 $(=1-\omega_1)$, respectively—see Section III. 1].

Taking the natural logarithms of (A1) and differentiating it with respect to time gives Eq. (3) in Section II:

$$q = \lambda + \alpha e + \beta k \tag{A3}$$

(where the lower case latters denote the growth rates of relevant variables.)

Taking the natural logarithms of (A2) and differentiating it with respect to time gives Eq. (4) in Section II:

$$q = \lambda + \mu f \tag{A4}$$

where $\mu(\omega_1+\omega_2)=(\alpha+\beta)$*.

Rearranging (A4) gives one of the Verdoorn Law specifications—Eq. (2) in Section II:

$$f = \xi_2 + \phi_2 q \tag{A5}$$

where $\xi_2 = -(\lambda/\mu)$ and $\phi_2 = (1/\mu)$.

Since the rate of growth of total factor productivity: $tfp=(q-f)$, (A5) can also be written as Eq. (1) in Section II:

$$tfp = \xi_1 + \phi_1 q \tag{A6}$$

where $\xi_1 = (\lambda/\mu)$ and $\phi_1 = [1-(1/\mu)]$.

* This is because: $q=\lambda+\mu f=\lambda+\mu(\omega_1 e+\omega_2 k)=\lambda+\mu\omega_1 e+\mu\omega_2 k$, hence, $q=\lambda+\alpha e+\beta k$, where $\alpha=\mu\omega_1$ and $\beta=\mu\omega_2$.

APPENDIX II.

Total per Capita Income (USSR = 100)
Soviet Socialist Republics 1960–75

Union Republic	1960	1965	1970	1975
USSR	100.0	100.0	100.0	100.0
RSFSR	107.5	106.8	107.1	11.00
Ukraine	94.0	97.8	96.6	94.7
Belorussia	82.7	89.6	94.6	100.0
Moldavia	70.9	85.6	87.2	92.2
Baltic Republics:				
Estonia	129.2	121.9	133.1	127.7
Latvia	124.6	122.2	124.4	118.3
Lithuania	105.7	109.0	116.4	111.7
Central Asian Republics:				
Kirghizia	73.8	79.6	75.0	74.4
Tadzhikistan	68.7	74.6	66.1	67.0
Turkmenia	86.4	84.9	88.2	87.7
Uzbekistan	78.0	73.9	75.7	73.8
Transcaucasian Republics:				
Armenia	86.4	84.9	88.2	87.7
Azerbaydzhan	74.5	70.1	68.4	70.9
Georgia	93.5	87.9	84.4	87.4
Kazakhstan	95.7	91.7	90.8	86.4

Source: Spechler, H. J. (1979). "Regional development in the USSR", in Joint Economic Committee, Congress of the USA, *Soviet economy in time of change*, Volume 1, Washington: Government Printing Office.

APPENDIX III.

SSR Location Quotients Based on the Average Distribution of Employment, 1961–75

Republic	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RSFSR	0.92	0.77	0.88	1.08	1.09	0.78	1.18	0.93	0.87
Ukraine	0.82	2.00	1.98	0.85	0.94	1.15	0.56	0.80	1.15
Belorussia	1.14	0.46		0.98	0.92	1.15	1.25	1.33	1.21
Moldavia	1.02			0.24	0.52	1.74	0.71	1.77	2.61
Baltic Republics:									
Estonia	1.42	1.61		0.47	0.57	0.99	1.21	1.56	1.46
Latvia	0.77	0.26		0.86	0.85	0.80	1.45	1.39	1.50
Lithuania	1.11	0.29		0.61	0.82	1.21	1.06	1.54	1.64
C. Asian Republics:									
Kirghizia	1.43	1.25			0.85	1.22	0.43	1.60	1.35
Tadzhikistan	1.60	0.54			0.40	1.43	0.47	2.58	1.50
Turkmenia	2.72	1.25		1.95	0.41	1.99	0.49	2.06	1.32
Uzbekistan	1.42	1.00		0.85	0.77	1.58	0.38	1.94	1.18
Trans. Republics:									
Armenia	1.16			1.61	0.85	1.41	0.39	1.79	1.05
Azerbaydzhan	1.56	2.54	0.81	1.43	0.58	1.00	0.41	1.55	1.18
Georgia	1.42	0.56	1.48	0.99	0.59	1.33	0.72	1.52	1.74
Kazakhstan	2.39	1.34	0.92	0.68	0.65	1.73	0.57	1.03	1.24

Source: Feshbach and Rapawy (1976).
Notes: See text.
Branches: (1) Electricity; (2) Fuel Industry; (3) Ferrous Metallurgy; (4) Chemicals and Petrochemicals; (5) Machine Building and Metal Working (MBMW); (6) Construction Materials; (7) Wood, Paper and Pulp Industry; (8) Light Industry; (9) Food Processing.

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