Another look at the inflation-productivity trade-off

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Abstract

Our aim in this paper is to test the robustness of the relation between total factor productivity growth and inflation to the specification of the model adopted for its identification. In doing so we estimate a generalized Box-Box cost function using data from the two-digit Standard Industrial Classification of manufacturing industries in Greece during the period 1964-1980. The results confirm that the acceleration of inflation from 1964-1972 to 1973-1980 reduced total factor productivity growth in a way that was both statistically significant and sizeable. In addition, they reveal that, even when the effect of inflation is separated from the effects of technical change and economies of scale, the choice of functional form is most crucial. The reason being that cost functions such as the translog, the generalized Leontief, and the generalized square root quadratic are not general enough to account for the sensitivity of estimates to model specification. On these grounds then we conclude that, for a precise estimation of the adverse impact of inflation on total factor productivity growth, it is imperative both to sort out the three effects involved and do so by adopting the most general flexible functional form available for the cost function.

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I. Introduction

The efforts by a long list of investigators in the last two decades to shed light on the relation between total factor productivity growth and inflation have focused on two tasks. To establish its analytical form, and to characterise its significance and robustness to changes in the data and the research methodologies used. The literature that has accumulated shows that the results have been quite disparate. More specifically, while on the one hand the evidence indicates beyond reasonable doubt that total factor productivity growth is inversely related to inflation, on the other hand, the significance and robustness of the estimated relation remain uncertain.

For an example in this respect, consider the findings by Buck and Fitzroy (1988), Grimes (1991), Barro (1991), Cozier and Selody (1992), Fischer (1993), Smyth (1995), Clark (1997) and Motley (1998) more recently. Even though they employ different sets of data and research approaches, all of them find that the relation between total factor productivity growth and inflation is negative. But with regard to its significance, some detect negligible effects of inflation on total factor productivity growth, whereas others come up with sizeable influences. Barro (1991), for instance, finds that, if a country reduced its inflation from, say, 7% to 2%, it would see its growth rate rise by only a little more than .01%. This implies that the government of that country would not need to strive to reduce inflation, because its gains in terms of total factor productivity growth would be marginal. On the contrary, Motley (1998) obtains a strikingly different result. According to this, a reduction in inflation by 5% would increase the growth rate of real Gross Domestic Product (GDP) per capita at least 0.1 percentage point. Hence the government would have a strong incentive to adopt anti-inflationary policies.

In view of this uncertainty researchers turned their attention to the reasons that might be responsible. From their endeavours it emerged that the main problem had to do with the specification of the models employed in the estimations. Two characteristic examples in this regard are the studies by Levine and Renelt (1992) and Clark (1997), which find that "…the estimates of the relationship suffer robustness problems that plague a variety of model specifications". So when in Bitros and Panas (1998) we visited the same issue, we were aware of the particular shortcomings that had to be overcome in order to advance the evidence beyond the state it had reached at the time.

Our view then was that previous efforts had failed to pin down the relation because researchers had not managed to distinguish the effect of inflation on total factor productivity growth from the effects of technical change and scale economies. This realisation implied two consequences. First, that researchers attributed to inflation an effect that could very well be due to some extent to these sources; and, second, that it was natural for the effect of inflation to be very sensitive to model specification, because the models used in the estimations had not been targeted to account for the variability of technical change and scale economies. For this reason, in Bitros and Panas (1998), we adopted a translog cost function approach that enabled us to sort out these three effects.

However, while occupied with the aforementioned paper, we had not realised that by following Appelbaum (1979) and Berndt and Khaled (1979) we could have generalized our model even further. For, if instead of the translog we had adopted a generalized Box-Cox cost function, we could have tested far more strenuously the sensitivity of our estimates to model specification, since this function includes the translog, the generalized Leontief, and the generalized square root quadratic cost functions as special cases. This is exactly the objective we have set in this paper. Namely, our aim here is to estimate a generalized Box-Cox cost function using the same data as before, and to test the robustness of the results to the new specification of the model.

The estimates we obtain confirm that, on the average, the acceleration of inflation in Greece from 1964-1972 to 1973-1980 reduced total factor productivity growth in the two-digit Standard Industrial Classification manufacturing industries, in a way that was both statistically significant and sizeable. Moreover, they reveal that, even when the effect of inflation is separated from the effects of technical change and economies of scale, the choice of functional form is most crucial. For these reasons we conclude that, for a precise estimation of the adverse impact of inflation on total factor productivity growth, it is imperative both to sort out the three effects involved and to do so by adopting for the cost function the most general flexible functional form available.

The remainder of the paper is organised as follows. The next Section presents the model we use to assess the impact of inflation on total factor productivity growth. Section III describes the sources of our data as well as the definition and the construction of the variables that enter the estimations. Section IV presents and comments on the empirical results, and, finally, in Section V we summarise our conclusions.

II. The econometric model

Economic theory suggests that there is a function $C = C(p_1, p_2, ..., p_n, y)$, where C denotes the total cost, $p_1, p_2, ..., p_n$ are the observed prices of the $1, 2, ..., n$ inputs and y is the output produced. But economic theory is silent regarding the form of this cost function. For this reason, in most cases, researchers have approximated it by a flexible functional form.

Diewert (1974) has defined a flexible functional form as one that can provide a second-order approximation to an arbitrary twice-differentiable function. The most popular flexible functional forms in this class have been the translog function[1] and the generalized Leontief function.[2] Their basic merit being that they do not constrain the partial elasticities of substitution or their ratios to a given constant.

The present paper adopts the generalized Box-Cox approximation to the cost function. Berndt and Khaled (1979) introduced it because of its superior advantages over the above-mentioned flexible functional forms. In particular, the generalized Box-Cox cost function:

- Includes the translog, the generalized Leontief and the generalized square root quadratic functions as special cases.
- Imposes a priori restrictions neither on the partial elasticities of substitution or their ratios nor on the returns to scale or the bias of technical change, and
- Facilitates considerably the introduction of certain simplifications by recourse to the theory of duality.

To highlight the last advantage, recall, say, from Varian (1978) that, given a cost function that is non-decreasing, homogeneous, concave, and continuous in prices, there exists a production function of which that cost function is a representation. More specifically, let

$$y = f(K, L, E, t) \tag{1}$$

be a production function where y is output, K is capital, L is labour, E is energy, and t is time, serving as a proxy for technical change. If we assume that the producer minimises the cost of production subject to a given level of output, then (1), may be represented by the following dual cost function which summarises the underlying production process:

$$C = \Phi(p_1, p_2, p_3, y, t) \tag{2}$$

where C is total cost and p_1, p_2, p_3 are respectively the input prices of K, L, and E.

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1 See Christensen, Jorgenson and Lau (1971, 1973, and 1975).

2 See also Diewert (1971).

So this study begins by assuming that the production technology of firms is represented by the generalized Box-Cox cost function:

$$C = [1 + \lambda G(p)]^{1/\lambda} . y^{\beta(y, p, \pi)} \tag{3}$$

where

$$G(p) = \alpha_0 + \sum_i \alpha_i p_i(\lambda) + 0.5 \sum_i \sum_j \gamma_{ij} p_j(\lambda) \tag{4}$$

$$\begin{aligned} &p_i(\lambda) = (p_i^{\lambda/2} - 1)/(\lambda/2), \quad \text{for} \quad i, j = K, L, E, && \text{(i)} \\ &\beta(y, p, \pi) = \beta + (\theta/2)\log y + \sum \varphi_i \log p_i + \alpha_{y\pi} \pi \log \pi. && \text{(ii)} \end{aligned} \tag{5}$$

For (3) to exist as a well behaved cost function it must satisfy several conditions. First, in order for it to be dual to a production function, it must meet the condition of *linear homogeneity* with regard to input prices. According to Berndt and Khaled (1979), this entails that:

$$\begin{aligned} &\sum_i \alpha_i = 1 + \lambda \alpha_0 && \text{(i)} \\ &\sum_j \gamma_{ij} = (\lambda/2)\alpha_i && \text{(ii)} \\ &\sum_i \phi_i = 0. && \text{(iii)} \end{aligned} \tag{6}$$

Second, the system of input demand equations resulting from (3) must satisfy the condition of *integrability*. The reason being that only then these functions will integrate into an aggregate cost function characterized by the properties of *monotonicity* and *concavity*. In this respect, Hurwicz (1971) and Hurwicz and Uzawa (1971) have shown that a system of demand equations is integrable, if and only if, its Hessian matrix is symmetric. Thus, under cost minimization, for a well-behaved aggregate cost function, and hence for a well behaved production function to exist, it must hold that:

$$\gamma_{ij} = \gamma_{ji}, \quad (i \neq j). \tag{7}$$

Next, in order to introduce disembodied technical change (see, Berndt and Khaled (1979)), (3) is modified as follows:

$$C = [1 + \lambda G(p)]^{1/\lambda} y^{\beta(y,p,\pi)} e^{T(t,p,\pi)} \tag{8}$$

where:

$$T(t,p,\pi) = \alpha_t t + \sum_i r_i t \ln p_i + \alpha_\pi \pi + \sum_i \alpha_{i\pi} \pi \ln p_i . \tag{9}$$

$$\begin{aligned} &\sum_i r_i = 0 \qquad \text{(i)} \\ &\sum_i \alpha_{i\pi} = 0 \qquad \text{(ii)} \end{aligned} \tag{10}$$

When conditions (6) -(7) and (9)-(10) are imposed, (7) transforms into:

$$C = \{(2/\lambda) \sum\sum \gamma_{ij} (p_i p_j)^{\lambda/2}\}^{1/\lambda} y^{\beta(y,p,\pi)} e^{T(t,p,\pi)}, \tag{11}$$

where $\beta(y, p, \pi)$ is defined in (5) and $T(t, p, \pi)$ is defined in (9). From (11) it is easy to verify that: a) when λ=1, (11) is equivalent to the generalized Leontief cost function, b) when λ=2, (11) is equivalent to the generalized square root quadratic, and c) when $\lambda \to 0$, (11) is equivalent to the translog. Therefore, (11) is indeed more flexible than all these functions

In addition, (11) is non-homothetic with exponential non-neutral technical change. The parameters φ_i are the non-homotheticity coefficients. These parameters indicate the presence of scale economies with respect to the individual inputs. For instance, if φ_i=0 for all i, the production structure is homothetic. If in addition θ=0 the production is homogeneous of degree 1/β. The parameter $\theta(=\partial^2 \ln C/\partial \ln y^2)$ carries information regarding the slope of the cost curve of the industry. When θ>0 the minimum point of the average cost curve is reached as output increases.

Hicks-neutral technical change may be imposed by constraining the non-neutrality parameters r_i=0 $\forall$ i, $i = K, L, E$. If this condition is not imposed, technical change is factor i-saving, if $r_i < 0$, or factor i-using, if $r_i > 0$.

According to Diewert (1974), given a generalized Box-Cox cost function that is: a) positive for positive values of y, an b) homogeneous of degree one, increasing and concave in p_1, p_2, and p_3, it is possible to obtain the conditional factor demands by applying Shephard's lemma. The expression in (11) is such a cost function. Therefore, differentiating it with respect to the input prices, the conditional factor demand functions that result are given by:

$$\frac{K_t}{y_t} = \{(2/\lambda)[\gamma_{12}(p_{2t}/p_{1t})^{\lambda/2} + \gamma_{11} + \gamma_{13}(p_{3t}/p_{1t})^{\lambda/2}]\}\cdot$$
$$y_t^{\lambda.((\beta+(\theta/2)\log y+\alpha_\pi\pi+\alpha_{y\pi}\pi\log y+\varphi_2(p_{2t}/p_{1t})+\varphi_3(p_{3t}/p_{1t})-1)\cdot}$$
$$e^{\lambda(\alpha_t t+r_2t(p_{2t}/p_{1t})+r_3t(p_{3t}/p)+\alpha_{2\pi}\pi(p_{2t}/p_{1t})+\alpha_{3\pi}\pi(p_{3t}/p_{1t}))} \tag{12}$$
$$(C_t/y_t p_{1t})^{1-\lambda} + ((C_t/y_t p_{1t})(\varphi_1 \log y + r_1 t + \alpha_{1\pi}\pi),$$

$$\frac{L_t}{y_t} = \{(2/\lambda)[\gamma_{22} + \gamma_{12}(p_{1t}/p_{2t})^{\lambda/2} + \gamma_{23}(p_{3t}/p_{2t})^{\lambda/2}]\}\cdot$$
$$y^{\lambda((\beta+(\theta/2)\log y+\alpha_\pi\pi+\alpha_{y\pi}\pi\log y+\varphi_2(p_{2t}/p_{1t})+\varphi_3(p_3/p_1)-1)\cdot} \tag{13}$$
$$e^{\lambda(\alpha_t t+r_2t(p_2t/p_{t1})+r_3t(p_{3t}/p_{1t})+\alpha_{2\pi}\pi(p_{2t}/p_{1t})+\alpha_{3\pi}\pi(p_{3t}/p_{1t}))}$$
$$(C_t/y_t p_{2t})^{\cdot} + (C_t/y_t p_{2t})(\varphi_2 \log y + r_2 t + \alpha_{2\pi}\pi),$$

$$\frac{E_t}{y_t} = \{(2/\lambda)[\gamma_{23}(p_{2t}/p_{3t})^{\lambda/2} + \gamma_{31}(p_{1t}/p_{3t})^{\lambda/2} + \gamma_{33}]\}\cdot$$
$$y^{\lambda((\beta+(\theta/2)\log y+\alpha_{y\pi}+\alpha_{y\pi}\pi\log y+\varphi_2(p_{2t}/p_{1t})+\varphi_3(p_{3t}/p_{1t})-1)\cdot} \tag{14}$$
$$e^{\lambda(\alpha_t t+r_2t(p_{2t}/p_{1t})+r_3t(p_{3t}/p_{1t})+\alpha_{2\pi}\pi(p_{2t}/p_{1t})+\alpha_{3\pi}\pi(p_{3t}/p_{1t}))\cdot}$$
$$(C_t/y_t p_{2t})^{1-\lambda} + (C_t/y_t p_{3t})(\varphi_3 \log y + r_3 t + \alpha_{3\pi}\pi).$$

These equations are the equations that are used in estimating the coefficients of the generalized Box-Cox cost function for each manufacturing industry.

The Allen partial elasticities of substitution, σ_{ij}, are defined by the relationship:

$$\sigma_{ij} = C^{\cdot}C_{ij}/C_i^{\cdot}C_j, \quad \text{for } i, j = K, L, E, \tag{15}$$

where the subscripts refer to first and second order derivatives with respect to input prices. Using (15) these partial elasticities can be computed from the generalized Box-Cox cost function as follows:

$$\sigma_{ij} = 1 - \lambda + \gamma_{ij} \frac{p_i}{S_i^2} \left[\frac{C}{y^{\beta(y,p,\pi)} e^{T(t,p,\pi)}} \right]^{-\lambda} + \lambda \left[\frac{\varphi_i \log y + r_i t + \alpha_{i\pi}\pi}{S_i} \right] +$$

$$+ \lambda \left\{ 1 - \frac{\varphi_i \log y + r_i t + \alpha_{i\pi}\pi}{S_i} \right\} \frac{\varphi_i \log y + r_i t + \alpha_{i\pi}\pi}{S_i} + \tag{16}$$

$$+ \frac{\lambda}{2} \left\{ 1 - \frac{\varphi_i \log y + r_i t + \alpha_{i\pi}\pi}{S_i} \right\} \frac{1}{S_i} - \frac{1}{S_i}, \quad \text{for } i = K, L, E,$$

where the S_i and S_j refer to the cost share of i or j input.

The Allen partial elasticities of substitution are related to input demand elasticities by:

$$\varepsilon_{ij} = \frac{\partial x_i}{\partial p_j} \frac{p_j}{x_i} = S_j \sigma_{ij}, \quad \text{for } x_i = K, L, E. \tag{17}$$

From (17) follows that, if $\sigma_{ij} > 0$, the inputs x_i and x_j are substitutes, thus implying that $\varepsilon_{ij} > 0$. Conversely, if $\sigma_{ij} < 0$, the inputs x_i and x_j are complements, thus implying $\varepsilon_{ij} < 0$.

In addition, the generalized Box-Cox cost function provides the growth rate of total factor productivity. Following Denny, Fuss and Waverman (1981), and Baltagi and Griffin (1988), the rate of total productivity growth (henceforth $T\dot{F}P$) is given by:

$$T\dot{F}P = (1 - \varepsilon_{cy})\dot{y} - \varepsilon_{ct} - \varepsilon_{c\pi}\dot{\pi}, \tag{18}$$

where:

$$\varepsilon_{cy} = \frac{\partial \log C}{\partial \log y} = \beta + \theta \log y + \sum \varphi_i \log p_i + \alpha_{y\pi} \pi \log y \tag{19}$$

$$\varepsilon_{ct} = -\frac{\partial \log C}{\partial t} = -(\alpha_t + \sum r_i \log p_i), \tag{20}$$

$$\varepsilon_{c\pi} = \alpha_\pi + \alpha_{y\pi} \log y + \alpha_{y\pi} (\log y)^2 + \Sigma \alpha_{i\pi} \log p_i. \tag{21}$$

Equation (18) decomposes the total factor productivity growth, $\dot{TFP}$, into three components: (i) the scale effect, which depends on ε_{cy} and $\dot{y}$, (ii) the effect of technological change, ε_{ct}, and (iii) the effect of inflation $\varepsilon_{c\pi}\dot{\pi}$. This expression will be especially useful in looking at the effect of increased inflation on total factor productivity growth.

II. Data, definitions and measurement of variables

Our data comprise observations from the two-digit Standard Industrial Classification of manufacturing industries in Greece and span the period from 1964 to 1980. Aside from the fact that we wished to compare our results with those reported earlier in Bitros and Panas (2001), the observation period had to be limited to 1980 for three reasons. The first of them was that the data provided by the National Statistical Service of Greece in its *Annual Industrial Survey* after 1980 are not compatible with those before 1980. Up to 1980 the National Statistical Service of Greece reported employment in manufacturing enterprises with an average employment of at least 10 persons. But after 1980 it started reporting employment by all manufacturing enterprises with an average employment of at least 20 persons and manufacturing establishments with an average employment of 10 to 19 persons.

The second reason emanated from the lack of capital stock series at the two-digit level after 1980. Due to the aforementioned incompatibility in the available data, even if we had the resources to construct capital stock series beyond 1980, they would not be internally consistent. Thus, we were compelled to use the capital stock series computed by Kintis (1986).

Finally, the third reason was that, if we had to choose between the period before and the period after 1980, we would have opted for the former. This is because the period 1964-1980 consists of two sub-periods: one of low inflation (1964-1972) and another of high inflation (1973-1980). Hence, it is more suitable for our study than the period since 1980.

Unless indicated otherwise, all data come from two publications of the National Statistical Service of Greece. These are the *Annual Industrial Survey* and the *Statistical Yearbook of Greece.* All variables are measured in 1975 prices and are defined as follows:

C = sum of input costs.

y = value-added.

L = man-hours per year.

E = kilowatt-hours of energy consumption.

K = capital stock as indicated above.

p_L = real wage rate. This was calculated with data from the *Annual Industrial Survey* as the ratio of the deflated wage bill to man-hours worked.

p_K = user cost of capital. This variable was constructed as $q_K(r+\delta)$, where q_K is the investment deflator, r = the interest rate, and δ = depreciation rate of the capital stock.

p_E = real price of energy obtained by dividing the deflated nominal energy expenditure by the energy consumption in physical units.

π = relative change in output price.

The investment deflator for the construction of p_K was the implicit price deflator for gross investment in manufacturing and was extracted from the *National Income Accounts of Greece*. The interest rate came from the *Monthly Statistical Bulletin* of the Bank of Greece. And δ was calculated as the ratio of depreciation reserves over the value of undepreciated physical assets, excluding the value of land.

IV. Results

To estimate the parameter of interest, we conceived of (12), (13) and (14) as comprising a three-equation system. Also, following Berndt and Khaled (1979), we added to each equation a stochastic term to account for the errors that occur in cost minimisation. So the general form of the non-linear system that resulted was:

$$\begin{aligned}\xi_{it} = {} & [(2/\lambda)\sum_j \gamma_{ij}(p_{jt}/p_{it})^{\lambda/2}]\cdot y^{\lambda[(\beta+(\theta/2)\log y_t+\alpha_{y\pi}\pi\log y_t+\alpha_\pi\pi+\sum\varphi_i\log p_{it})-1]} \\ & \cdot\exp\{\lambda t[\alpha_t+\Sigma r_i\log p_{it}+\Sigma\alpha_{i\pi}\pi\log p_{it}\} \\ & \cdot\left(\frac{C_t}{p_{it}}\right)^{(1-\lambda)}+(\varphi_i\log y_t+r_i t+\alpha_{i\pi}\pi)\frac{C_t}{y_t p_{it}}+u\end{aligned} \tag{22}$$

where i, j = K, L, E and t = 1, 2, ..., 17 and

ξ_{it} = observed input-output value;

C_t = observed unit cost;

u_{it} = error term which is assumed to be distributed as $u_{it}\sim N(0,\sigma^2)$.

All the parameters of the generalized Box-Cox cost function (11) are contained in (22). Spitzer (1981) has shown that it is possible to employ non-linear least-squares procedures to obtain the parameter estimates of a non-linear system. In this study we use the non-linear three-stage least-squares method. From (22) it follows that the number of parameters to be estimated is very large in relation to the number of observations (problem of degrees of freedom). However, according to Amemiya (1977) and Gallant (1977), the non-linear three-stage least-squares technique permits using instrumental variables. So, to overcome the problem of degrees of freedom we adopted this estimating technique.[3] Table 1 presents the estimates of the generalised Box-Cox cost functions for the twenty two-digit manufacturing industries. These were obtained in the following manner. In order to apply the non-linear three-stage-least-squares estimator it was necessary to provide starting values for each and every parameter in (22). Initially, the starting values chosen were the parameter estimates that we obtained in Bitros and Panas (1998) using the same data set in conjunction with a translog cost function. However, convergence failed in all industries and we

Please insert Table 1 here

had to adopt an indirect approach. If (22) satisfied the condition of integrability, the Hessian would be symmetric. So to reduce the number of estimable parameters we fixed the values of γ_{11}, γ_{22}, and γ_{33} to the values shown in the table and went ahead with the estimation. This appeared to improve convergence but not totally. For this reason we then fixed the values of γ_{13} to the ones shown and achieved convergence in all industries.

Moreover, since we had fixed the values of parameters γ_{11}, γ_{22}, and γ_{33} to achieve convergence, from 6(ii) it is clear that we had imposed the condition of linear homogeneity of degree one on the cost function, with respect to input prices. So the remaining question was whether the estimates satisfied the conditions of monotonicity and concavity.

With regards to the former, this required that:

[3] In addition to the time trend and the constant, the instrumental variables included: the number of establishments, the average annual employment, the numbers of working proprietors, salaried employees and wage earners, the gross value of production, the amounts paid in salaries and wages, and the values of gross investment in machinery, buildings and transport equipment.

$$\frac{\partial C}{\partial p_i} > 0 \quad \text{for all } i = K, L, E. \tag{23}$$

By using the parameter estimates in Table 1 and substituting each observation, it was found that all predicted values for all industries are non-negative. Thus, the monotonicity condition was satisfied for all data points.

As to the concavity of the cost functions, this would be satisfied if the Hessian matrix $\partial^2 C / \partial p_i p_j$, for all i, j, turned out to be negative semi-definite at each observation. The estimates in Table 1 confirmed the negative semi-definiteness of the Hessian matrix. So, given that the symmetry conditions are satisfied a priori, the estimated conditional demand functions (11), (12), and (13) are integrable, and hence the generalized Box-Cox cost function is well behaved for the observed data.

Now let us look closer at the estimates in Table 1. Clearly, the overwhelming majority of coefficients are significantly different from zero. The parameters of main interest in this table are the estimates of λ because they indicate how close the generalized Box-Cox specification comes to one of the three special cases. That is, the estimates of λ permit statistical tests for the cases of translog, generalized Leontief, and generalized square-root quadratic. For example, in industry 21, using the estimate for λ of 1.4431, with asymptotic t-statistic of 5.48, it is clear that the translog and generalized square-root quadratic cases are rejected, while the generalized Leontief is not rejected at any conventional level of significance. Out of a total of twenty estimates for λ, eight –i.e., for industries 21, 25, 26, 32, 34, 36, 37, and 39- are statistically different from one at the 5% level. Therefore, the generalized Leontief specification is not rejected in 40% of the cases. The generalized square-root quadratic model is not rejected in 10% of the cases, i.e. industries 27 and 30. And, finally, the estimates for λ are different from zero, one, or two in ten industries or 50% of the cases. As a result, in 50% of the industries investigated none of these three flexible functional forms is supported by the data. In view of these findings it is clear that, if any of the less general functional forms had been used to represent the cost function, the estimates would be biased in unknown directions and magnitudes.

To highlight the nature of biases that would result from a misspecification of the functional form of the cost function, it suffices to contrast the values of certain crucial parameters under the Box-Cox and the translog specifications. Recall from above that the non-homotheticity coefficients φ_2 and φ_3 measure the existence of input i-using or input i-saving scale economies accordingly as $\varphi_2, \varphi_3 > 0$ or $\varphi_2, \varphi_3 < 0$. Therefore, given from Table 1 that φ_2 and φ_3 are generally positive and statistically different from zero, all two-digit industries experienced labour and energy-using scale economies. So the question arose as to what might have happened if, instead of the Box-Cox specification, we had used the translog. The results from Bitros and Panas (1998), are quite revealing. In those industries in which the proper specification was another functional form, the adoption of a translog cost function led to significantly different estimates of the bias in scale economies. For an example, consider industry 21 in which the adoption of a translog specification was inappropriate. According to our earlier results, industry 21 experienced labour and energy-saving scale economies, and hence the bias was exactly opposite to that from Table 1. And, of course, similar inconsistencies with regard to the bias of scale economies would arise in all those industries in which none other generalised flexible functional form than the Box-Cox was appropriate.

Next consider the parameters r_2 and r_3, which indicate the nature of technical change. From Table 1 we see that all estimates of r_2 are negative and statistically significant. This confirms that technical change was labour saving in all industries. By contrast, our earlier results using a translog specification of the cost function showed that industry 24 experienced labour-using technical change and that the inconsistencies were even wider with regard to r_3. For, as the results from Table 1 indicate, technical change was energy saving in 14 out of 20 industries, whereas by our earlier results, energy-saving bias prevailed only in 10 out of 20 industries and, indeed, not the same ones.

Finally, it should be pointed out that the adverse effects on the estimates from the misspecification of the cost function were not limited to the sign reversals just mentioned, because in many cases that the parameters preserved their signs, the misspecification distorted their values significantly. Two characteristic examples in this respect are represented by industries 27 and 29. From Table 1 we see that the coefficients of, say, technical change are: (27) $r_2 = -0.03344$, $r_3 = -0.00166$ and (29) $r_2 = -0.01711$, $r_3 = 0.00145$. But the same coefficients from our earlier study using the translog specification turned out to be the following: (27) $r_2 = -0.012$, $r_3 = -0.053$ and (29) $r_2 = -0.028$, $r_3 = 0.002$. Therefore, while the misspecification did not affect the signs of the coefficients, it did distort their magnitudes by leading, in both industries, to serious underestimation or overestimation of the input bias in technical change.

In the light of the above findings we surmised that the estimates in our earlier study regarding the relation between inflation and total factor productivity growth needed revision. To this effect we divided the data again into two sub-periods, characterised by low (1964-1972) and high inflation (1973-1980) respectively, and calculated for each the three components in equation (18) at the mean values of the variables. Table 2 below gives the results from these calculations. In comparison to those reported in our earlier study, several interesting differences have emerged. For one, observe that the acceleration of inflation from the one period to the other accelerated the slowdown of total factor productivity growth in all industries. On the contrary, according to our earlier results only in 8 out of 20 two-digit industries the acceleration of inflation between the two periods led to acceleration in total factor productivity growth. So the importance of adopting the most general flexible functional form available for representing the cost function should be obvious.

Please insert Table 2 here

Another interesting finding is that there was not a single industry where, from the one period to the other, the acceleration of inflation did not accelerate the slowdown of total factor productivity significantly. To obtain an estimate of this relationship at the overall manufacturing level, we used (18) to compute the following expression

$$\eta = \frac{\partial \dot{\mathrm{TFP}}}{\partial \dot{\pi}} \frac{\hat{\dot{\pi}}}{\hat{\dot{\mathrm{TFP}}}} = -\left(\frac{\partial \varepsilon_{c\hat{\pi}}}{\partial \dot{\pi}} \hat{\dot{\pi}} + \varepsilon_{c\hat{\pi}}\right) \frac{\hat{\dot{\pi}}}{\hat{\dot{\mathrm{TFP}}}} \tag{24}$$

where η is the elasticity of total factor productivity growth with respect to inflation and the hat over a variable denotes its sample mean value during the period 1964-1972. The results of the calculations gave $\eta \approx -1{,}02$ and this meant that a 10% increase in inflation, *ceteris paribus*, would reduce total factor productivity growth in this sector by 10.2%. Clearly, this is a noteworthy finding because it indicates that the losses in total factor productivity growth may increase (decrease) faster than the rate by which inflation increases (decreases).

Lastly, it may not be superfluous to point out that a misspecification of the cost function leads to overestimation or underestimation of total factor productivity growth. This is so because the biases introduced in the estimation of the components in the right-hand side of equation (18) will cancel out only by chance. In the present case, the estimates of total factor productivity growth that are exhibited in Table 2 differ significantly from those that we reported in our earlier study.

IV. Conclusions

The primary purpose in this paper was to test the robustness of the relation between inflation and total factor productivity growth to the specification of the model adopted for its investigation. To do so we estimated a generalized Box-Cox cost function and compared the results with those from Bitros and Panas (1998) where we used the same set of data but in conjunction with a translog specification of the cost function. The results showed that the adoption of the wrong functional form leads to substantial biases. More specifically, using the translog specification of the cost function in industries, where a generalised Box-Cox would be appropriate, caused sign reversals for several key parameters, whereas for those that retained their signs, it led to serious over or under estimations. For this reason, in future research efforts in this area it is advisable to adopt the most general flexible functional form available.

In addition, the results confirmed that for a precise estimation of the relation under investigation the effect of inflation on total factor productivity growth must be separated from those of scale economies and technical change. The reason for this being that otherwise there is the risk of attributing to inflation effects that may be due to these sources.

Finally, our revised estimates showed that a 10% increase in inflation, *ceteris paribus*, could reduce total factor productivity growth by as much as 10.2%. This finding established firmly the importance of the relationship under investigation and left no doubt about the substantial gains associated with the controlling of inflation.

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Table 1: Estimates of Generalized Box-Cox Parameters

Parameters	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
λ	0,5849	1,4431	1,5956	2,1575	0,6501	0,8842	1,0129	2,7487	2,2547	0,4554	1,6647	3,4564	0,789	7,4583	0,8794	1,5796	0,7762	1,1255	0,5859	0,8078
	(4,4)	(-5,5)	(-8,5)	(-10,8)	(-5,3)	(-3,5)	(-2,4)	(-3,2)	(-7,8)	(-2,8)	(-5,6)	(-5,1)	(-6,5)	(-13,3)	(-7,9)	(-11,2)	(-4,3)	(-5,7)	(-5,2)	(-7,0)
γ_{11}	2,043	2,9927	2,6117	1,7632	2,4395	3,0789	37.769	0,9193	1,2353	1,8085	1,688	1,6689	2,1779	2,3787	2,0119	2,1197	3,1801	4,6775	2,7531	2,9022
γ_{12}	0,0168	0,0126	0,0284	0,013	-0,0056	0,014	0,0013	0,035	-0,0038	0,0131	0,0197	0,0666	-0,015	0,0219	0,0754	0,0128	-0,0005	-0,0041	0,0096	-0,0332
	(-8,6)	(-3,6)	(-10,6)	(-7,2)	(-4,6)	(-4,0)	(-0,6)	(-13,9)	(-1,8)	(-4,1)	(-2,7)	(-2,4)	(-0,2)	(-8,5)	(-7,0)	(-8,3)	(-0,3)	(-1,4)	(-7,6)	(-1,1)
γ_{13}	0,5135	0,6877	0,6649	0,7176	1,2361	1,6542	0,5399	6,1524	6,6331	5,7982	5,8556	5,7917	8,0179	6,1407	6,2875	6,3399	5,7016	5,9022	5,9941	6,2542
γ_{22}	6,1055	5,9172	5,4541	5,9829	5,3664	5,7136	5,4474	6,0249	5,2714	6,9472	5,6908	5,6644	4,8672	5,4711	6,1055	5,7376	5,9019	5,7298	5,456	5,5314
γ_{23}	0,1724	0,1901	0,053	0,1636	0,148	0,1134	0,113	0,0939	0,1399	0,092	0,2961	-0,2245	1,1516	0,1217	0,1628	0,1738	0,2349	0,212	0,1132	0,4784
	(-9,3)	(-6,4)	(-1,9)	(-8,1)	(-14,9)	(-4,4)	(5,3)	(-3,6)	(-4,1)	(-3,6)	(-3,8)	(-0,7)	(-0,7)	(-4,5)	(-1,7)	(-10,8)	(-15,6)	(-5,9)	(-9,7)	(-2,21)
γ_{33}	7,0384	6,6971	5,8971	6,051	6,7764	5,7744	5,8913	5,5985	6,7956	5,8411	6,4541	6,5439	5,1149	6,3882	5,607	6,0325	6,3965	6,378	6,5954	6,21438
$\alpha_{2\pi}$	-0,1434	-0,1168	-0,045	-0,1328	-0,1499	-0,0205	-0,0676	-0,0536	-0,0422	-0,129	-0,2221	0,1594	0,0198	-0,0778	0,0515	-0,137	-0,1822	-0,0961	-0,0895	-0,2925
	(-8,2)	(-5,2)	(-1,9)	(-5,7)	(-9,0)	(-1,6)	(-6,1)	(-3,1)	(-1,3)	(-7,5)	(-2,3)	(-1,3)	(-0,0)	(-4,7)	(-1,6)	(-7,8)	(-10,3)	(-3,7)	(-7,2)	(-6,2)
$\alpha_{3\pi}$	0,0209	0,0088	0,002	0,002	0,012	-0,0056	0,0052	0,0439	0,001	0,0023	-0,0284	0,0036	0,0392	-0,001	-0,0319	-0,0016	0,0026	0,008	-0,0012	-0,0051
	(-8,3)	(-3,4)	(-1,4)	(-0,3)	(-7,5)	(-0,6)	(-4,9)	(-1,8)	(-0,3)	(-0,5)	(-0,6)	(-0,1)	(-1,2)	(-0,1)	(-0,7)	(-0,3)	(-1,2)	(-2,1)	(-0,4)	(-0,3)
$\alpha_{y\pi}$	0,0015	3,3852	0,8929	0,6312	0,9887	1,1954	3,8315	1,5951	0,5404	3,316	4,5011	1,2548	0,6449	2,386	1,4665	2,2975	2,6798	1,074	1,4201	3,4946
	(-2,0)	(-2,8)	(-2,6)	(-3,3)	(-1,9)	(-3,5)	(-5,3)	(-4,6)	(-2,6)	(-4,6)	(-5,3)	(-3,2)	(-5,5)	(-4,9)	(-4,6)	(-4,6)	(-4,3)	(-5,8)	(-6,3)	(-2,6)
α_{π}	0,1268	0,1459	0,158	0,185	0,0991	0,7373	0,6023	0,1856	0,1271	1,2009	1,4841	0,5292	1,0067	0,6463	0,6787	1,0832	0,7553	0,5121	0,7477	0,4509
	(-3,5)	(-4,1)	(-2,2)	(-3,6)	(-2,5)	(-4,6)	(-3,0)	(-2,5)	(-2,2)	(-4,7)	(-2,6)	(-1,9)	(-2,7)	(-1,7)	(-1,5)	(-3,1)	(-2,1)	(-3,6)	(-3,9)	(-1,8)
α_{t}	0,0053	0,0094	0,0227	0,0084	0,004	0,0161	0,0128	0,0105	0,0091	0099	-0,0123	0,0302	0,0986	0,0119	-0,0246	0,0053	0,00001	0,009	0,0087	-0,0204
	(-2,6)	(-2,8)	(-8,1)	(-3,8)	(-5,1)	(-3,9)	(-5,4)	(-2,6)	(-2,0)	(-4,4)	(-1,7)	(-1,3)	(-0,5)	(-4,4)	(-2,9)	(-3,2)	(-0,9)	(-2,3)	(-3,6)	(-1,2)
β	0,4571	0,8632	0,8769	0,7465	0,8698	0,7558	0,7923	0,8933	0,9782	0,8753	0,9421	0,9339	0,853	0,7666	0,963	0,5157	0,7517	0,9784	0,7639	0,8263
	(-5,1)	(-6,4)	(-4,7)	(-6,6)	(-1,8)	(-3,7)	(-5,3)	(-2,8)	(-1,6)	(-3,7)	(-3,3)	(-1,5)	(-4,9)	(-2,6)	(-2,1)	(-2,8)	(-2,6)	(-1,2)	(-3,8)	(-4,1)
θ	-0,3609	2,2573	-1,5886	4,6259	-0,3835	2,185	2,5331	1,4866	-0,1526	1,2321	1,6635	-0,0961	0,5083	0,5999	4,5211	3,3773	3,0182	-0,8519	0,7121	0,4946
	(-1,3)	(-3,6)	(-1,4)	(-5,92)	(-1,11)	(-5,8)	(-3,8)	(-2,5)	(-1,6)	(-3,3)	(-3,9)	(-1,1)	(-4,2)	(-3,8)	(-8,9)	(-4,1)	(-6,7)	(-1,0)	(-2,9)	(-2,6)
φ_2	0,1018	0,1342	0,1119	0,1045	0,1672	0,1533	0,1731	0,1056	0,1488	0,1667	0,1235	0,0711	0,1172	0,0942	0,0549	0,01243	0,1563	0,1377	0,1344	0,2034
	(-55,0)	(-46,3)	(-49,9)	(-52,1)	(-87,7)	(-69,2)	(-71,4)	(-42,5)	(-63,9)	(-79,4)	(-15,1)	(-7,0)	(-3,2)	(-56,3)	(-16,5)	(-72,9)	(-84,0)	(-62,1)	(-46,6)	(-35,2)
φ_3	0,0097	0,0072	0,0019	0,0071	0,0026	0,0052	0,0016	0,0201	0,0021	0,0033	0,0122	0,0152	0,0124	0,0188	0,0209	0,0067	0,0033	0,0041	0,0017	0,0005
	(-35)	(-26,8)	(-13,6)	(-10,8)	(-11,4)	(-2,8)	(-4,2)	(-3,6)	(-4,0)	(-5,1)	(-6,3)	(-8,2)	(-3,4)	(-12,6)	(-4,6)	(-11,9)	(-11,5)	(-9,2)	(-2,5)	(-2,4)
r_2	-0,017	-0,0313	-0,0263	-0,0234	-0,0276	-0,0494	-0,0334	-0,0241	-0,0305	-0,0171	-0,0104	-0,0448	0,0521	-0,0265	-0,0264	-0,023	-0,0183	-0,0327	-0,0266	-0,0128
	(-6,6)	(-9,5)	(-9,1)	(-7,4)	(-14,6)	(-17,6)	(-12,8)	(-6,8)	(-5,6)	(-8,2)	(-1,0)	(-3,9)	(-0,6)	(-11,7)	(-7,6)	(-9,9)	(-7,4)	(-9,2)	(-6,9)	(-2,6)
r_3	-0,0056	-0,0025	-4E-05	-0,0001	-0,0008	-0,0033	-0,0017	-0,0101	0,0008	0,0014	0,0026	-0,0028	-0,0084	-0,0018	0,0063	-0,2876	-0,0001	-0,001	0,0009	0,003
	(-13,4)	(-8,1)	(-3,2)	(-0,1)	(-2,8)	(-4,1)	(-5,1)	(-2,7)	(-1,0)	(-1,9)	(-0,4)	(-3,1)	(-3,4)	(-2,9)	(-0,9)	(-2,4)	(-2,2)	(-2,7)	(-0,7)	(-1,3)
R_1^2	0,6491	0,8035	0,825	0,4097	0,4382	0,8847	0,8546	0,8376	0,8514	0,5691	0,3885	0,4429	0,1718	0,4706	0,9482	0,5095	0,7727	0,9233	0,9200	0,0175
R_2^2	0,9656	0,9413	0,9772	0,9717	0,9928	0,9796	0,9457	0,9151	0,9718	0,9898	0,9016	0,9046	0,466	0,9749	0,9548	0,9837	0,9808	0,956	0,8706	0,9041
R_3^2	0,9714	0,9811	0,9866	0,9661	0,9916	0,9456	0,9985	0,9177	0,9692	0,9502	0,7686	0,7761	0,9352	0,9646	0,7968	0,9444	9826	0,9753	0,862	0,6656

Note: the numbers in parentheses are asymptotic t-statistics

Table 2: Influence of Inflation on total factor productivity growth

SOURCES	20			21			22			23			24		
	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80
1.SCALE	0,0637	0,0422	0,0536	0,0728	0,0256	0,0506	0,0152	0,0233	0,0190	0,0355	0,0266	0,0313	0,0575	0,0538	0,0557
2.INFLATION	0,0012	0,0028	0,0087	0,000699	0,0199	0,0098	0,0006	0,0167	0,0082	0,0015	0,0213	0,0108	0,0002	0,0165	0,0078
3.TECHNICAL CHANGE	0,0231	0,0223	0,0227	0,0568	0,0397	0,0487	0,0596	0,0419	0,0513	0,0495	0,0361	0,0432	0,0540	0,0388	0,0469
4.TOTAL	0,0394	0,0171	0,0222	0,0153	-0,0340	-0,0079	-0,0451	-0,0352	-0,0405	-0,0155	-0,0308	-0,0227	0,0033	-0,0015	0,0010

SOURCES	25			26			27			28			29		
	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80
1.SCALE	0,0694	0,0121	0,0425	0,0452	0,0130	0,0301	0,0452	0,0064	0,0269	0,0388	0,0314	0,0353	0,0146	0,0428	0,0279
2.INFLATION	0,0046	0,0306	0,0168	0,0013	0,0116	0,0061	0,0045	0,0311	0,0170	0,0011	0,0128	0,0066	0,0007	0,0195	0,0095
3.TECHNICAL CHANGE	0,0810	0,0475	0,0652	0,0561	0,0314	0,0445	0,0214	-0,0014	0,0107	0,1398	0,1146	0,1279	0,0353	0,0221	0,0291
4.TOTAL	-0,0162	-0,0660	-0,0396	-0,0122	-0,0300	-0,0206	0,0193	-0,0234	-0,0008	-0,1020	-0,0960	-0,0992	-0,0214	0,0012	-0,0107

SOURCES	30			31			32			33			34		
	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80
1.SCALE	0,0759	0,0301	0,0543	0,0632	0,0198	0,0428	0,0219	0,0635	0,0415	0,0334	0,0207	0,0274	0,0477	-0,0226	0,0146
2.INFLATION	-0,0009	0,0076	0,0031	0,0009	0,0263	0,0129	0,0013	0,0082	0,0046	0,0039	0,0311	0,0167	0,0154	0,0174	0,0899
3.TECHNICAL CHANGE	0,0190	0,0137	0,0165	0,0916	0,0624	0,0779	0,0178	0,0150	0,0165	0,0550	0,0476	0,0515	-0,0196	-0,0289	-0,0240
4.TOTAL	0,0578	0,0087	0,0347	-0,0293	-0,0689	-0,0480	0,0028	0,0403	0,0205	-0,0256	-0,0580	-0,0408	0,0519	-0,0111	-0,0513

SOURCES	35			36			37			38			39		
	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80	1964-72	1973-80	1964-80
1.SCALE	0,0520	0,0346	0,0438	0,0409	0,0211	0,0316	0,0637	0,0091	0,0380	0,0406	0,0319	0,0319	0,0280	0,0429	0,0350
2.INFLATION	0,0016	0,0231	0,0117	-0,0002	0,0167	0,0077	0,0004	0,0126	0,0062	0,0029	0,0258	0,0026	-0,0370	0,0283	-0,0063
3.TECHNICAL CHANGE	0,0411	0,0263	0,0341	0,0336	0,0225	0,0284	0,0531	0,0325	0,0434	0,0134	0,0112	0,0112	0,0135	0,0108	0,0122
4.TOTAL	0,0093	-0,0147	-0,0020	0,0076	-0,0180	-0,0045	0,0102	-0,0361	-0,0116	0,0242	-0,0051	0,0181	0,0514	0,0038	0,0290