The inflation-productivity trade-off revisited

By

George C. Bitros[*]
Professor of Economics
and
Epaminondas E. Panas
Professor of Statistics and Econometrics
Communication: George C. Bitros
Athens University of Economics and Business
76 Patision Street, Athens 10434, Greece
Tel. 8223545, Fax: 8203301, E-mail: Bitros@aueb.gr

Abstract

Our aim in this paper is threefold. First, to test the robustness of the relation between total factor productivity growth and inflation to the specification of the estimating model; second, to test the stability of their relationship in the short run and in the long run, and third, to investigate the direction of causality between these two variables. To accomplish the first objective, 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 show that: a) 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, and b) 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. With respect to the second objective, somewhat to our surprise, we find that the inflation-productivity trade-off prevails even in the long run. And, finally, regarding the third objective, it emerges that in the great majority of two-digit manufacturing industries the causality runs from inflation to productivity. On these grounds we conclude that for a precise estimation of the relationship under consideration it is imperative to sort out the three effects involved, do so by adopting the most general flexible functional form for the cost function, and run the appropriate stability and causality tests.

---

1. 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 might 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. So our first objective in this paper 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.

A second objective is to study the dynamics of the trade-off between inflation and productivity using appropriate data and econometric techniques. This is motivated by at least two reasons. The first is that if the trade-off does not remain stable over time, its usefulness will be limited, whereas the second reason is the following. At the macroeconomic level the empirical evidence is that an increase in the rate of inflation reduces economic growth in the short-run, but has no long-run effect either on the rate of economic growth or on the level of real per capita output. Yet at the sector or industry level our knowledge is at most scanty. So by focusing on the dynamics of the trade-off at the two-digit manufacturing industries we may be able to shed some light on the microfoundations of the so-called principle of superneutrality of money.

Finally, a third objective is the following. Since inflation is not exogenous, the most an empirical model without enough macroeconomic structure like ours may be expected to identify would be an association between changes in prices and productivity. To be sure even this much of evidence provides valuable guidance. But in the absence of tests regarding the direction of causality between these two variables the results would not be exploitable by policy makers. Consequently, to enhance the usefulness of our estimates and at the same time to stay clear from attributing to them more significance for policy applications than they deserve, we shall run a series of causality tests.

With respect to our first objective the estimates 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 and did so in

a way that was both statistically significant and sizeable. Moreover, the estimates 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. Regarding the second objective, much to our surprise the inflation-productivity trade-off survives even in the long run, thus suggesting that the principle of superneutrality of money may not hold in this sector. Finally, with respect to the third objective, we find that, while in the short run inflation Granger causes productivity, in the long run the causality between these two variables is bi-directional. On these grounds 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, do so by adopting for the cost function the most general flexible functional form, and perform the appropriate stability and causality tests.

In the next Section we do three things. We explain the model adopted to assess the impact of inflation on total factor productivity growth. We describe the data and the definition and the construction of the variables entering the estimations; and, lastly, we present and comment on the results. In Section 3 we describe the data and the tests performed to investigate the existence and stability of the inflation-productivity trade-off in the long run. Our interpretations of the results from these tests are included in the same section. The tests, the results, and our comments regarding the direction of causality in the inflation-productivity trade-off as well as its dynamic properties are contained in Section 4. And, finally, in Section 5, we summarise the conclusions.

2. The inflation-productivity trade-off

In this section we derive a generalized Box-Cox cost function, we estimate it using the same data as in Bitros and Panas (1998), and test the robustness of the results to the proposed new specification of the model.

2.1 The 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 func-

tional 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, and p_3 are respectively the input prices of K, L, and E.

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

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

---

[1]   See Christensen, Jorgenson and Lau (1971, 1973, and 1975).
[2]   See also Diewert (1971).

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

$$p_i(\lambda) = (p_i^{\lambda/2} - 1)/(\lambda/2), \quad \text{for} \quad i, j = K, L, E, \tag{i}$$

$$\beta(y,p,\pi) = \beta + (\theta/2)\log y + \sum \varphi_i \log p_i + \alpha_{y\pi}\pi\log\pi. \tag{ii}$$
(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:

$$\sum_i \alpha_i = 1 + \lambda\alpha_0 \tag{i}$$

$$\sum_j \gamma_{ij} = (\lambda/2)\alpha_i \tag{ii}$$
(6)

$$\sum_i \phi_i = 0. \tag{iii}$$

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:

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

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

$$\sum_i r_i = 0 \tag{i}$$

$$\sum_i \alpha_{i\pi} = 0. \tag{ii}$$
(10)

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

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

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 $\lambda=1$, (11) is equivalent to the generalized Leontief cost function, b) when $\lambda=2$, (11) is equivalent to the generalized square root quadratic, and c) when $\lambda\to0$, (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 $\varphi_i = 0$ for all i, the production structure is homothetic. If in addition $\theta=0$ the production is homogeneous of degree $1/\beta$. The parameter $\theta(=\partial^2 \ln C/\partial \ln y^2)$ carries information regarding the slope of the cost curve of the industry. When $\theta > 0$ 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:

$$\frac{K_t}{y_t} = \{(2/\lambda)[\gamma_{12}(p_{2t}/p_{1t})^{\lambda/2} + \gamma_{11} + \gamma_{13}(p_{3t}/p_{1t})^{\lambda/2}]\}\cdot$$
$$y_t^{\lambda\cdot((\beta+(\theta/2)\log y\, +\alpha_\pi\pi+\alpha_{y\pi}\pi\log y+\varphi_2(p_{2t}/p_{1t})+\varphi_3(p_{3t}/p_{1t})\,-1)\cdot}$$
$$e^{\lambda(\alpha_t t+r_2 t(p_{2t}/p_{1t})+r_3 t(p_{3t}/p)+\alpha_{2\pi}\pi(p_{2t}/p_{1t})+\alpha_{3\pi}\pi(p_{3t}/p_{1t}))}$$
$$(C_t/y_tp_{1t})^{1-\lambda}+\;\;((C_t/y_tp_{1t})(\varphi_1\log y + r_1 t + \alpha_{1\pi}\pi),\tag{12}$$

$$\frac{L_t}{y_t} = \{(2/\lambda)[\gamma_{22} + \gamma_{12}(p_{1t}/p_{2t})^{\lambda/2} + \gamma_{23}(p_{3t}/p_{2t})^{\lambda/2}]\}\cdot$$
$$y^{\lambda((\beta+(\theta/2)\log y\, +\, \alpha_\pi\pi+\alpha_{y\pi}\pi\log y+\varphi_2(p_{2t}/p_{1t})+\varphi_3(p_3/p_1)\,-1)\,\cdot}$$
$$e^{\lambda(\alpha_t t+r_2 t(p_2 t/p_{t1})+r_3 t(p_{3t}/p_{1t})+\alpha_{2\pi}\pi(p_{2t}/p_{1t})+\alpha_{3\pi}\pi(p_{3t}/p_{1t}))}$$
$$(C_t/y_tp_{2t})\cdot + (C_t/y_tp_{2t})(\varphi_2\log y + r_2 t + \alpha_{2\pi}\pi),\tag{13}$$

$$\frac{E_t}{y_t} = \{(2/\lambda)[\gamma_{23}(p_{2t}/p_{3t})^{\lambda/2} + \gamma_{31}(p_{1t}/p_{3t})^{\lambda/2} + \gamma_{33}]\}\cdot$$

$$y^{\lambda((\beta+(\theta/2)\log y+\alpha_{y\pi}+\alpha_{y\pi}\pi\log y+\varphi_2(p_{2t}/p_{1t})+\varphi_3(p_{3t}/p_{1t})-1)}\cdot$$

$$e^{\lambda(\alpha_t t+r_2 t(p_{2t}/p_{1t})+r_3 t(p_{3t}/p_{1t})+\alpha_{2\pi}\pi(p_{2t}/p_{1t})+\alpha_{3\pi}\pi(p_{3t}/p_{1t}))}\cdot$$

$$(C_t/y_t p_{2t})^{1-\lambda} + (C_t/y_t p_{3t})(\varphi_3\log y + r_3 t + \alpha_{3\pi}\pi). \tag{14}$$

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:

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

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 $\dot{TFP}$) is given by:

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

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

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

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

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.

2.2 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.

2.3 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:

$$\xi_{it} = [(2/\lambda)\sum_j \gamma_{ij}(p_{jt}/p_{it})^{\lambda/2}] \cdot y^{\lambda[(\beta+(\theta/2)\log y_t + \alpha_{y\pi}\pi\log y_t + \alpha_\pi\pi + \sum\varphi_i\log p_{it})-1]}$$

$$\cdot \exp\{\lambda t[\alpha_t + \Sigma r_i\log p_{it} + \Sigma\alpha_{i\pi}\pi\log p_{it}\} \tag{22}$$

$$\cdot \left(\frac{C_t}{p_{it}}\right)^{(1-\lambda)} + (\varphi_i\log y_t + r_i t + \alpha_{i\pi}\pi)\frac{C_t}{y_t p_{it}} + u_{it}$$

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

```
Please insert Table 1 here
```

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 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

---

[3]   In addition to the time trend and the constant, the set of 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.

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 conditions, this required that:

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

By using the parameter estimates in Table 1 and substituting each observation, it was found that all predicted values for all industries were 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 re-

sult, in 50% of the industries investigated none of these three flexible functional forms is supported by the data. In view of these findings it was 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 generalized 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 generalized 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 in-

dustries 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), 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,

Please insert Table 2 here

observe that the acceleration of inflation from the one period to the other accelerated the slowdown in total factor productivity growth in all industries. On the contrary, according to our earlier results only in 8 out of 20 two-digit industries did the acceleration of inflation between the two periods result in a deceleration of total factor productivity growth. So the importance of adopting the most general flexible functional form available for representing the cost function should be obvious.

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 in total factor productivity in a statistically significant way. To obtain an estimate of this relationship at the overall manufacturing level, we used (18) to compute the following expression:

$$\eta = \frac{\partial T\dot{F}P}{\partial \dot{\pi}} \frac{\hat{\dot{\pi}}}{\hat{T\dot{F}P}} = -(\frac{\partial \varepsilon_{c\hat{\pi}}}{\partial \dot{\pi}} \hat{\dot{\pi}} + \varepsilon_{c\hat{\pi}}) \frac{\hat{\dot{\pi}}}{\hat{T\dot{F}P}} \tag{24}$$

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.

3. The inflation-productivity trade-off in the long run

In this section we examine the relationship between inflation and productivity in the long run using cointegration techniques. The Index of Industrial Production (IP) for each two-digit manufacturing industry is used as a proxy for productivity and the Consumer Price Index (CPI) as an indicator of inflation. The data come from the *National Statistical Service of Greece* and span the period from 1988: 1 to 2004: 12.

3.1 Stationarity of the series IP and CPI

As a preliminary step to the formal tests, it is necessary to determine the stationary characteristics of the time series. This requires an investigation for the existence of unit roots in the level of the variables as well as in their first differences. The test employed for this purpose is the Augmented Dickey Fuller (ADF) test, which is based on the following regression:

$$\Delta Y_t = \alpha + \beta \cdot t + \gamma \cdot Y_{t-1} + \sum_{i=1}^{k} \varphi_i \cdot \Delta Y_{t-i} + u_t \, , \tag{25}$$

where Δ is the first difference operator, Y_t is the time series under consideration, t is a time trend and u_t is a random error. The Akaike Information Criterion (AIC) determines the length of the lag for the ADF test. The results of this test for log levels and first differences showed that all variables are nonstationary in the levels. If a time series has a unit root, the first-order difference of the series is stationary. A series that is stationary after being differenced d times is said to be integrated of order d or $I(d)$. The results of the unit root tests show $R_i \sim I(1)$ and $RCPI \sim I(1)$, where $R_i = \log(IP_{it}/IP_{i,t-1})$, $RCPI = \log(CPI_t/CPI_{t-1})$ and $i = 20, 21, ..., 37$. Hence, since the variables are integrated of order one, i.e., they are all $I(1)$, the question now is whether they are cointe-

grated. A cointegration between two variables means that they display common trends in the long run. As stressed by Edders (1995, p.359), cointegration only shows the existence of a long run ex post stable relationship between the variables in question.

3.2 Cointegration

Since $R_i = \log(IP_{it}/IP_{i,t-1})$ and $RCPI = \log(CPI_t/CPI_{t-1})$ are $I(1)$, cointegration tests may be used to assess whether these variables share common trends. There are many possible tests for cointegration. The most commonly used is the residual-based Engle-Granger technique. The test of cointegration involves two steps. The first step requires estimating a cointegration regression using variables having the same order of integration.

$$\log(IP_{it}/IP_{i,t-1}) = \beta_0 + \beta_1 \cdot \log(CPI_t/CPI_{t-1}) + \varepsilon_t, \qquad i = 20, 21, ..., 37 \ . \qquad (26)$$

In the second step the estimated residuals ($\hat{\varepsilon}_t$) from the cointegration regression are subjected to the stationarity test based on ADF test:

$$\Delta \hat{\varepsilon}_t = \alpha_1 \cdot \hat{\varepsilon}_{t-1} + \sum_{j=1}^{m} \delta_j \cdot \Delta \hat{\varepsilon}_{t-j} + u_t \qquad (27)$$

If the residual variable is stationary, i.e., $\hat{\varepsilon}_t \sim I(0)$, then there is a long run relationship between the two variables. The results of the unit root tests showed that all series, $\hat{\varepsilon}_t$, are $I(0)$. That is true cointegrating residuals confirm stationary relationship on the one hand between productivity and inflation, R= f (RCPI), and on the other between inflation and productivity, RCPI = g (R). Furthermore, the cointegration coefficient, β_1, is negative and indicates that in the long run productivity and inflation move in opposite direction.

In conclusion, the results of the tests presented in this section ascertained that at the two-digit SIC level of Greek manufacturing industries, there existed during the 1988-2004 period (a) a stable relationship between inflation and productivity, and (b) this relationship was negative.

4. The causality between inflation and productivity

We turn now to the issue of causality between inflation and productivity. To highlight it we shall adopt the Error Correction Model (ECM). Our basis for doing so is that, according to the Granger representation theorem, the existence from the above of a stable long run relationship

between the variables $R_i = \log(IP_{it}/IP_{i,t-1})$ and $RCPI = \log(CPI_t/CPI_{t-1})$ renders the estimation of this model a consistent and effective choice.

4.1 Causality tests

Granger (1988) has noted that cointegration between two variables is a sufficient but not necessary condition for the presence of causality in at least one direction. Since our variables are cointegrated, an error-correction term must be included in the causality test. The presence of cointegration provides a dynamic framework in which an error-correction variable represents deviations from a long run cointegration relationship, and the lagged difference terms represent short run dynamics. Error Correction Models are useful because they reconcile the short and long run behaviour of the variables under investigation.

The next step is to test for the causality between the cointegrated variables. The procedure is described by the following equations:

$$\Delta y_t = \alpha_0 + \alpha_y \cdot ECT_{y,t-1} + \sum_{i=1}^{m} \alpha_{y,i} \cdot \Delta y_{t-i} + \sum_{j=1}^{n} \beta_{y,j} \cdot \Delta x_{t-i} + u_t, \qquad \text{(i)}$$

$$\Delta x_t = \beta_0 + \beta_x \cdot ECT_{x,t-1} + \sum_{i=1}^{\kappa} \alpha_{x,i} \cdot \Delta y_{t-i} + \sum_{j=1}^{l} \beta_{x,j} \cdot \Delta x_{t-i} + u_t, \qquad \text{(ii)}$$

$$\tag{28}$$

where y and x are $R_i = \log(IP_{it}/IP_{i,t-1})$ and $RCPI = \log(CPI_t/CPI_{t-1})$; Δ is the difference operator; and $ECT_{y,t-1}$ and $ECT_{x,t-1}$ are the error correction terms; m, n, κ and l are the optimal number of lags of the first differences chosen according to the AIC criterion. Short run dynamic adjustments are captured by nonzero values for the $\alpha_{y,i}$'s, $\alpha_{x,i}$'s, $\beta_{y,i}$'s and $\beta_{x,i}$'s. In the ECM framework causation comes from two sources: (i) the error-correction terms, i.e. α_y's and α_x's and (ii) the lagged dynamic terms, i.e. $\beta_{y,j}$'s and $\beta_{x,j}$'s. The error-correction terms are related with the long run causation while the lagged dynamic terms capture short run causation. Long run causality now can be ascertained by the significance of the parameters α_y and β_x. The hypothesis of long run causality from inflation to productivity is accepted if α_y is significantly different from zero. If β_x is significantly different from zero then productivity causes inflation in the long run. If α_y as well as β_x are significant then there is evidence of long-run causality in both directions. Tables 3 and 4 summarize the findings from the estimates of equations 28(i) and 28(ii).

The error correction terms turn out to be negative and statistically significant for both equations 28(i) and 28(ii). It is noted that the ECT_{t-1} coefficients are statistically significant. This implies that inflation did long run Granger cause productivity and vice versa. Hence, the empirical results indicate the existence of a long run bi-directional Granger causality relationship between inflation and productivity.

The error correction term indicates the speed with which deviations from long run equilibrium will be corrected. In our case, the magnitude of the coefficient of ECT_{t-1} implies that this would take place quite fast with over 100 percent of deviation being eliminated after a month. Equation 28(i) shows the impact of price changes (measured by $DRCPI's$) on productivity (see Table 3). The sign and the size of the lagged coefficients of the DRCPI variables give an indication of the impact. In all cases inflation initially has a negative impact on productivity. Similarly, the estimation of equation 28(ii) provides information on the impact of productivity on inflation in the Greek manufacturing sector (see Table 4). With the exception of two industries, the coefficients of DR_{t-1} are negative and statistically significant. These results suggest that productivity changes have an adverse impact on inflation in the long run.

For short run Granger causality we examine the following null hypothesis:

$$H_0 : \beta_{y,1} = \beta_{y,2} = \cdots = \beta_{y,n} = 0 \tag{29}$$

In testing H_0, the standard F-test is used. Failing to reject the null hypothesis, H_0 implies that inflation does not short run Granger cause productivity. In the same way, if the null hypothesis $H_0 : \alpha_{x,1} = \alpha_{x,2} = \cdots = \alpha_{x,n} = 0$ is rejected, we can say that productivity does not short run Granger cause inflation. The results from these tests indicated the existence in all cases of a one-directional short run causal link from inflation and productivity.[4] This is an important finding since it indicates that in the case of Greek manufacturing, inflation and productivity do not inter-

---

[4] The results of the tests based on the equations (25), (27), and (29) at the two-digit Standard Industrial Classification of Greek manufacturing industries over the 1988-2004 period are available on request from the authors.

act causally in the short-run, except in four cases. Hence, in the short-run there seems to be a relation between inflation and productivity in which inflation impacts productivity in a negative way.

5. Conclusions

In this paper we pursued tree objectives. The first of them 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.

The results confirmed also 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.

Our second objective was to inquire about the existence and stability of the relationship between inflation and productivity in the long run. To this effect we run cointegration tests at the two-digit SIC manufacturing industries and found that during the 1988-2004 period there existed a stable negative relationship between inflation and productivity, thus suggesting that the principle of superneutrality of money may not hold in this sector. Lastly, with respect to our third objective, the estimates of the error correction model showed that, while in the log run there existed a strong bi-directional trade-off between inflation and productivity, in the short run inflation Granger reduced productivity in all but four industries. As a result, we concluded that a spell of inflation reduces productivity in the short run, but in the long run inflation and productivity losses reinforce each other.

References

Amemiya, T., (1977), "The maximum likelihood and the nonlinear three-stage-least-squares estimator in the general nonlinear simultaneous system", *Econometrica*, 45, 955-968.

Appelbaum, E., (1979), "On the choice of functional forms", *International Economic Review,* 20, 449-458.

Baltagi, B.H. and Griffin, J. M., (1988), "A General Index of Technical Change", *Journal of Political Economy*, 96, 1, 20-41.

Barro, R., (1995), "Inflation and economic growth", *Bank of England Economic Bulletin*, 1-11.

Berndt, E. R. and Khaled, M. S., (1979), "Parametric Productivity Measurement and Choice Among Flexible Functional Forms", *Journal of Political Economy*, 81, 1220-1245.

Bitros G. C. and Panas, E. E., (1998), "Is there an Inflation-Productivity trade off? Some evidence from the manufacturing sector in Greece", *Applied Economics*, 33, 1961-1969.

Buck, A. J. and Fitzroy, F., (1988), "Inflation and Productivity Growth in the Federal Republic of Germany", *Journal of Post Keynesian Economics*, X, N.3, 428-444.

Christensen, L. R., Jorgenson, D. W., and Lau, L. J., (1975), "Transcendental Logarithmic Utility Functions", *American Economic Review*, 65, 367-383.

----------------, (1973) "Transcendental Logarithmic Production Frontiers", *Review of Economics and Statistics*, 55, 28-45.

----------------, (1971) "Conjugate Duality and the Transcendental Logarithmic Production Function", *Econometrica*, 39, 255-256.

Clark T.E., (1997) "Cross-country evidence on long run growth and inflation", *Economic Inquiry*, xxxv, 70-81.

Cozier, B. and Selody, J., (1992) "Inflation and macroeconomic performance: some cross-country evidence", *Working Paper 92-6*, Bank of Canada.

Denny, M., Fuss, M., and Waverman, L., (1981), "The Measurement and Interpretation of Total Factor productivity in Regulated Industries with an Application to Canadian Telecommunication", in T. G. Cowing and R. E. Stevenson (Eds.) *Productivity Measurement in Regulated Industries*, New York, Academic Press

Diewert, W. E., (1974), "Applications of Duality Theory" in Intrilligator, M. D. and D. A. Kendrick, (Eds.), *Frontiers of Quantitative Economics*, North-Holland, Amsterdam.

Diewert, W. E., (1971), "An Application of the Shephard Duality Theorem: Generalized Leontief Production Function", *Journal of Political Economy*, 70, 481-501.

Enders, W., (1995), *Applied Econometric Time Series,* J. Wiley and Sons, New York.

Fischer, S., (1993), "The role of macroeconomic factors in growth", National Bureau of Economic Research, *Working Paper 4565*.

Gallant, A. R., (1977), "Three-stage-least-squares estimators for a system of simultaneous nonlinear implicit equations", Journal of Econometrics, 5, 71-88.

Granger, C.W.J., (1988), "Some recent Developments in a Concept of Causality," *Journal of Econometrics*, 38, 199-211.

Grimes, A., (1991), "The effects of inflation on growth: some international evidence", *Weltwirtschftliches Archiv*, 127, 631-644.

Hanoch, G., (1975), "The elasticity of scale and the shape of average costs", *American Economic Review*, 65, 492-497.

Hurwicz, L., (1971), "On the Problem of Integrability of Demand Functions", in J. Chipman (ed.) *Preferences, Utility and Demand*, New York, Harcourt Brace.

Hurwicz, L. and Uzawa, H., (1971), "On the Integrability of Demand Functions", in J. Chipman (ed.) *Preferences, Utilities and Demand*, New York, Harcourt Brace.

Kintis, A. (1986), "Estimates of Capital Stock and Capital Utilisation Rate", Centre of Economic Research, Athens University of Economics and Business, mimeo.

Levine, R. and Renelt, D., (1992), "A sensitivity analysis of cross-country growth regressions", *American Economic Review*, 82, 942-963.

Motley, B., (1998), "Growth and inflation: a cross-country study", *Economic Review*, 1, Federal Reserve Bank of San Francisco, 15-28.

Smyth, D. J., (1995), "The supply side effects of Inflation in the United States: evidence from multifactor productivity", *Applied Economics Letters*, **2**, 482-483.

Spitzer, A, (1982), "A primer on Box-Cox Estimation", *Review of Economics and Statistics*, 64, 307-313.

Varian, A., (1978), *Microeconomic Analysis*, Norton and Company New York.

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 (4,4)	1,4431 (-5,5)	1,5956 (-8,5)	2,1575 (-10,8)	0,6501 (-5,3)	0,8842 (-3,5)	1,0129 (-2,4)	2,7487 (-3,2)	2,2547 (-7,8)	0,4554 (-2,8)	1,6647 (-5,6)	3,4564 (-5,1)	0,789 (-6,5)	7,4583 (-13,3)	0,8794 (-7,9)	1,5796 (-11,2)	0,7762 (-4,3)	1,1255 (-5,7)	0,5859 (-5,2)	0,8078 (-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 (-8,6)	0,0126 (-3,6)	0,0284 (-10,6)	0,013 (-7,2)	-0,0056 (-4,6)	0,014 (-4,0)	0,0013 (-0,6)	0,035 (-13,9)	-0,0038 (-1,8)	0,0131 (-4,1)	0,0197 (-2,7)	0,0666 (-2,4)	-0,015 (-0,2)	0,0219 (-8,5)	0,0754 (-7,0)	0,0128 (-8,3)	-0,0005 (-0,3)	-0,0041 (-1,4)	0,0096 (-7,6)	-0,0332 (-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 (-9,3)	0,1901 (-6,4)	0,053 (-1,9)	0,1636 (-8,1)	0,148 (-14,9)	0,1134 (-4,4)	0,113 (5,3)	0,0939 (-3,6)	0,1399 (-4,1)	0,092 (-3,6)	0,2961 (-3,8)	-0,2245 (-0,7)	1,1516 (-0,7)	0,1217 (-4,5)	0,1628 (-1,7)	0,1738 (-10,8)	0,2349 (-15,6)	0,212 (-5,9)	0,1132 (-9,7)	0,4784 (-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 (-8,2)	-0,1168 (-5,2)	-0,045 (-1,9)	-0,1328 (-5,7)	-0,1499 (-9,0)	-0,0205 (-1,6)	-0,0676 (-6,1)	-0,0536 (-3,1)	-0,0422 (-1,3)	-0,129 (-7,5)	-0,2221 (-2,3)	0,1594 (-1,3)	0,0198 (-0,0)	-0,0778 (-4,7)	0,0515 (-1,6)	-0,137 (-7,8)	-0,1822 (-10,3)	-0,0961 (-3,7)	-0,0895 (-7,2)	-0,2925 (-6,2)
$\alpha_{3\pi}$	0,0209 (-8,3)	0,0088 (-3,4)	0,002 (-1,4)	0,002 (-0,3)	0,012 (-7,5)	-0,0056 (-0,6)	0,0052 (-4,9)	0,0439 (-1,8)	0,001 (-0,3)	0,0023 (-0,5)	-0,0284 (-0,6)	0,0036 (-0,1)	0,0392 (-1,2)	-0,001 (-0,1)	-0,0319 (-0,7)	-0,0016 (-0,3)	0,0026 (-1,2)	0,008 (-2,1)	-0,0012 (-0,4)	-0,0051 (-0,3)
$\alpha_{y\pi}$	0,0015 (-2,0)	3,3852 (-2,8)	0,8929 (-2,6)	0,6312 (-3,3)	0,9887 (-1,9)	1,1954 (-3,5)	3,8315 (-5,3)	1,5951 (-4,6)	0,5404 (-2,6)	3,316 (-4,6)	4,5011 (-5,3)	1,2548 (-3,2)	0,6449 (-5,5)	2,386 (-4,9)	1,4665 (-4,6)	2,2975 (-4,6)	2,6798 (-4,3)	1,074 (-5,8)	1,4201 (-6,3)	3,4946 (-2,6)
α_{π}	0,1268 (-3,5)	0,1459 (-4,1)	0,158 (-2,2)	0,185 (-3,6)	0,0991 (-2,5)	0,7373 (-4,6)	0,6023 (-3,0)	0,1856 (-2,5)	0,1271 (-2,2)	1,2009 (-4,7)	1,4841 (-2,6)	0,5292 (-1,9)	1,0067 (-2,7)	0,6463 (-1,7)	0,6787 (-1,5)	1,0832 (-3,1)	0,7553 (-2,1)	0,5121 (-3,6)	0,7477 (-3,9)	0,4509 (-1,8)
α_{t}	0,0053 (-2,6)	0,0094 (-2,8)	0,0227 (-8,1)	0,0084 (-3,8)	0,004 (-5,1)	0,0161 (-3,9)	0,0128 (-5,4)	0,0105 (-2,6)	0,0091 (-2,0)	0099 (-4,4)	-0,0123 (-1,7)	0,0302 (-1,3)	0,0986 (-0,5)	0,0119 (-4,4)	-0,0246 (-2,9)	0,0053 (-3,2)	0,00001 (-0,9)	0,009 (-2,3)	0,0087 (-3,6)	-0,0204 (-1,2)
β	0,4571 (-5,1)	0,8632 (-6,4)	0,8769 (-4,7)	0,7465 (-6,6)	0,8698 (-1,8)	0,7558 (-3,7)	0,7923 (-5,3)	0,8933 (-2,8)	0,9782 (-1,6)	0,8753 (-3,7)	0,9421 (-3,3)	0,9339 (-1,5)	0,853 (-4,9)	0,7666 (-2,6)	0,963 (-2,1)	0,5157 (-2,8)	0,7517 (-2,6)	0,9784 (-1,2)	0,7639 (-3,8)	0,8263 (-4,1)
θ	-0,3609 (-1,3)	2,2573 (-3,6)	-1,5886 (-1,4)	4,6259 (-5,92)	-0,3835 (-1,11)	2,185 (-5,8)	2,5331 (-3,8)	1,4866 (-2,5)	-0,1526 (-1,6)	1,2321 (-3,3)	1,6635 (-3,9)	-0,0961 (-1,1)	0,5083 (-4,2)	0,5999 (-3,8)	4,5211 (-8,9)	3,3773 (-4,1)	3,0182 (-6,7)	-0,8519 (-1,0)	0,7121 (-2,9)	0,4946 (-2,6)
φ_{2}	0,1018 (-55,0)	0,1342 (-46,3)	0,1119 (-49,9)	0,1045 (-52,1)	0,1672 (-87,7)	0,1533 (-69,2)	0,1731 (-71,4)	0,1056 (-42,5)	0,1488 (-63,9)	0,1667 (-79,4)	0,1235 (-15,1)	0,0711 (-7,0)	0,1172 (-3,2)	0,0942 (-56,3)	0,0549 (-16,5)	0,01243 (-72,9)	0,1563 (-84,0)	0,1377 (-62,1)	0,1344 (-46,6)	0,2034 (-35,2)
φ_{3}	0,0097 (-35)	0,0072 (-26,8)	0,0019 (-13,6)	0,0071 (-10,8)	0,0026 (-11,4)	0,0052 (-2,8)	0,0016 (-4,2)	0,0201 (-3,6)	0,0021 (-4,0)	0,0033 (-5,1)	0,0122 (-6,3)	0,0152 (-8,2)	0,0124 (-3,4)	0,0188 (-12,6)	0,0209 (-4,6)	0,0067 (-11,9)	0,0033 (-11,5)	0,0041 (-9,2)	0,0017 (-2,5)	0,0005 (-2,4)
r_{2}	-0,017 (-6,6)	-0,0313 (-9,5)	-0,0263 (-9,1)	-0,0234 (-7,4)	-0,0276 (-14,6)	-0,0494 (-17,6)	-0,0334 (-12,8)	-0,0241 (-6,8)	-0,0305 (-5,6)	-0,0171 (-8,2)	-0,0104 (-1,0)	-0,0448 (-3,9)	0,0521 (-0,6)	-0,0265 (-11,7)	-0,0264 (-7,6)	-0,023 (-9,9)	-0,0183 (-7,4)	-0,0327 (-9,2)	-0,0266 (-6,9)	-0,0128 (-2,6)
r_{3}	-0,0056 (-13,4)	-0,0025 (-8,1)	-4E-05 (-3,2)	-0,0001 (-0,1)	-0,0008 (-2,8)	-0,0033 (-4,1)	-0,0017 (-5,1)	-0,0101 (-2,7)	0,0008 (-1,0)	0,0014 (-1,9)	0,0026 (-0,4)	-0,0028 (-3,1)	-0,0084 (-3,4)	-0,0018 (-2,9)	0,0063 (-0,9)	-0,2876 (-2,4)	-0,0001 (-2,2)	-0,001 (-2,7)	0,0009 (-0,7)	0,003 (-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

	CONSTANT	ECT_{t-1}	DR_{t-1}	DR_{t-2}	DR_{t-3}	$DRCPI_{t-1}$	$DRCPI_{t-2}$	$DRCPI_{t-3}$	$\overline{R}^2$	D.W
20	0.000141	-1.46604	0.35528	0.251967	0.130491	-0.602554	-1.242427	-1.311614	0.55	2.04
	(0.01)	(-9.67)	(2.8)	(2.54)	(1.96)	(-1.44)	(-0.94)	(-0.97)		
21	-0.002458	-1.11924	0.013491	-0.00231	-0.13072	-0.18287	-0.952991	0.686982	0.58	1.94
	(-0.22)	(-7.6)	(2.11)	(-0.02)	(-1.99)	(-1.23)	(-1.26)	(0.88)		
22	-0.001939	-0.87823	0.066085	0.139126	0.212605	-0.049609	-1.931643	1.408342	0.44	2.06
	(-0.15)	(-8.31)	(0.69)	(2.67)	(3.22)	(-1.05)	(-2.07)	(1.5)		
23	-0.001072	-1.80116	0.458884	0.163671	-0.03517	-1.751108	-2.877833	1.882184	0.65	1.93
	(-0.08)	(-9.2)	(2.87)	(1.4)	(-0.51)	(-2.47)	(-2.68)	(1.83)		
24	-0.00009	-1.43988	0.00562	0.08154	-0.06368	-0.826636	-3.021796	1.619915	0.73	1.97
	(-0.01)	(-7.46)	(0.03)	(-0.66)	(-0.92)	(-2.58)	(-2.33)	(1.4)		
25	0.00135	-2.02293	0.409149	0.05145	-0.0701	-1.694937	-3.937473	3.061107	0.79	1.95
	(0.09)	(-9.15)	(2.24)	(0.4)	(-1.06)	(-1.97)	(-2.65)	(2.4)		
26	-0.002249	-2.15824	0.594394	0.359519	0.270538	-4.194284	-5.563333	1.556472	0.75	1.76
	(-0.14)	(-10.55)	(3.36)	(2.74)	(3.86)	(-2.27)	(-3.45)	(1.22)		
27	0.0018	-1.66867	0.292824	0.035845	-0.08258	-1.915006	-3.065531	0.744683	0.7	2.04
	(0.17)	(-8.91)	(2.01)	(0.36)	(-1.66)	(-2.73)	(-3.4)	(0.9)		
28	-0.001695	-1.84398	0.322067	0.013532	0.019974	-1.002408	-0.201471	3.424705	0.72	1.86
	(-0.17)	(-9.37)	(1.99)	(0.11)	(0.29)	(-1.88)	(-0.2)	(4.22)		
29	-0.000717	-2.56316	0.933546	0.433349	0.202084	-7.132078	-5.608495	1.353731	0.72	1.83
	(-0.04)	(-11.01)	(4.83)	(3.18)	(2.76)	(-4.2)	(-3.82)	(1.13)		
30	-0.002297	-1.94368	0.629972	0.261774	0.21281	-11.01554	-11.99172	-0.681642	0.66	2.07
	(-0.05)	(-10.69)	(4.14)	(2.38)	(3.19)	(-2.87)	(-3.36)	(-0.19)		
31	-0.000357	-1.94688	0.300777	0.054671	0.030361	-0.310476	-2.815798	3.016302	0.8	1.88
	(-0.02)	(-9.15)	(1.86)	(1.42)	(0.45)	(-0.16)	(-1.68)	(2.21)		
32	-0.000839	-2.12362	0.547048	0.179546	0.127045	-4.126211	-5.557017	1.715441	0.76	1.99
	(-0.03)	(-10.29)	(3.15)	(1.46)	(1.92)	(-2.1)	(-3.04)	(0.97)		
33	-0.001592	-1.64404	0.027867	0.161658	-0.03831	-0.367194	-1.778056	1.568244	0.8	1.99
	(-0.1)	(-8)	(0.16)	(1.24)	(-0.57)	(-0.28)	(-1.48)	(1.38)		
34	-0.003447	-2.21678	0.597246	0.319986	0.177036	-2.86103	-3.43298	2.88536	0.76	1.93
	(-0.16)	(-10.86)	(3.46)	(2.55)	(2.64)	(-1.52)	(-1.97)	(1.79)		
35	-0.0000186	-1.2347	0.125853	0.16061	-0.12716	-2.724719	-1.214685	3.572477	0.71	1.92
	0	(-7.14)	(0.85)	(2.39)	(-1.87)	(-1.85)	(-0.89)	(2.84)		
36	-0.001299	-2.23113	0.649821	0.274303	0.187049	-5.234769	-4.135267	3.895291	0.71	1.69
	(-0.07)	(-10.55)	(3.59)	(2.04)	(2.55)	(-2.27)	(-2.07)	(2.56)		
37	-0.0000899	-1.88945	0.319343	0.070231	0.033696	-1.13091	-3.331409	3.503257	0.75	1.83
	(-0.01)	(-9.05)	(1.8)	(0.54)	(0.49)	(-2.61)	(-2.04)	(2.58)		

Table 3: Estimates of Error Correction Models: Dependent Variable DR

	CONSTANT	ECT$_{t-1}$	DR$_{t-1}$	DR$_{t-2}$	DR$_{t-3}$	DRCPI$_{t-1}$	DRCPI$_{t-2}$	DRCPI$_{t-3}$	$\overline{R}^2$	D.W
20	-0.00000976	-1.08253	-0.00357	-0.00449	0.00533	0.40842	0.06316	0.34559	0.51913	1.72465
	(-0.13)	(-9.55)	(-1.56)	(-1.71)	(-2.33)	(-4.04)	(-0.81)	(-5.52)		
21	-0.00000812	-1.10171	-0.0047	-0.00469	-0.00287	0.41155	0.06661	0.33543	0.5152	1.69242
	(-0.1)	(-9.84)	(-1.23)	(-1.02)	(-0.75)	(4.12)	(0.86)	(5.39)		
22	-0.00000736	-1.03706	-0.00634	-0.01384	-0.0012	0.37651	0.07391	0.3179	0.52524	1.680585
	(-0.09)	(-9.53)	(-2.88)	(-3.69)	(-0.35)	(3.87)	(0.97)	(5.14)		
23	-0.00000782	-1.07551	-0.00923	-0.0082	-0.00576	0.38584	0.05056	0.34757	0.49794	1.66256
	(-0.1)	(-9.32)	(-2.74)	(-2.14)	(-1.86)	(3.71)	(0.61)	(5.28)		
24	-0.00000763	-1.0254	-0.01328	-0.00914	-0.00161	0.36158	0.02865	0.30571	0.47579	1.68093
	(-0.09)	(-8.65)	(-3.6)	(-2.01)	(-0.49)	(3.37)	(0.32)	(4.28)		
25	-0.00000834	-1.06816	-0.01225	-0.01288	-0.00519	0.40806	0.1065	0.37307	0.4962	1.62712
	(-0.1)	(-9.17)	(-4.36)	(-3.7)	(-2.05)	(3.9)	(1.24)	(5.43)		
26	-0.0000072	-1.04357	-0.01056	-0.00898	-0.00314	0.36664	0.04145	0.32412	0.47684	1.67172
	(-0.09)	(-8.51)	(-3.09)	(-2.09)	(-1.04)	(3.26)	(0.44)	(4.61)		
27	-0.00013	-1.08072	-0.00908	-0.00355	0.00101	0.39647	0.04134	0.30059	0.49617	1.69379
	(-0.17)	(-9.23)	(-2.28)	(0.79)	(0.37)	(3.78)	(0.48)	(4.38)		
28	-0.00000523	-0.96724	-0.02145	-0.02525	-0.01027	0.3589	0.095	0.35332	0.48202	1.71414
	(-0.06)	(-8)	(-4.48)	(-4.45)	(-2.31)	(3.26)	(1.09)	(5.2)		
29	-0.00000798	-1.06953	-0.01104	-0.01108	-0.00134	0.40364	0.07678	0.31176	0.50587	1.6719
	(-0.1)	(-9.08)	(-3.69)	(-3.16)	(-0.49)	(3.82)	(0.91)	(4.82)		
30	-0.00000819	-1.0809	-0.00255	-0.00191	0.0003	0.40275	0.06308	0.31991	0.50617	1.68364
	(-0.1)	(-9.52)	(-2.8)	(-1.88)	(0.35)	(3.98)	(0.8)	(5.04)		
31	-0.00000595	-1.05646	-0.01366	-0.01292	-0.00411	0.41297	0.11658	0.3619	0.48703	1.64845
	(-0.07)	(-8.88)	(-4.56)	(-3.32)	(-1.52)	(3.84)	(1.27)	(5.03)		
32	-0.00000776	-1.07497	-0.00385	-0.00378	0.0009	0.4128	0.0707	0.32421	0.52037	1.67699
	(-0.1)	(-9.66)	(-2.31)	(-1.78)	(0.54)	(4.16)	(0.91)	(5.21)		
33	-0.00000664	-1.06885	-0.01029	-0.0118	-0.00404	0.40297	0.0908	0.33478	0.51708	1.67968
	(-0.08)	(-9.59)	(-3.72)	(-3)	(-1.45)	(4.04)	(1.16)	(5.36)		
34	-0.00000732	-1.06538	-0.00532	-0.00653	-0.00181	0.40534	0.07979	0.33862	0.50953	1.68998
	(-0.09)	(-9.43)	(-2.78)	(-2.55)	(-0.96)	(4)	(1)	(5.37)		
35	-0.00000508	-1.03742	-0.01449	-0.01333	-0.00629	0.38931	0.08255	0.35705	0.48366	1.69147
	(-0.06)	(-8.87)	(-4.56)	(-3.38)	(-2.16)	(3.68)	(0.95)	(5.11)		
36	-0.00000627	-0.99122	-0.0104	-0.01168	-0.00461	0.34387	0.0614	0.32872	0.47372	1.70891
	(-0.08)	(-7.94)	(-3.38)	(-3.19)	(-1.73)	(2.97)	(0.64)	(4.6)		
37	-0.00000745	-1.05762	-0.0115	-0.0131	-0.00597	0.40058	0.10519	0.3718	0.4959	1.63059
	(-0.09)	(-9.03)	(-3.98)	(-3.59)	(-2.29)	(3.77)	(1.2)	(5.47)		

Table 4: Estimates of Error Correction Models: Dependent Variable DRCPI