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The endogeneity of the natural rate of growth

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The aim of this paper is to estimate the sensitivity of the natural rate of growth to the actual rate of growth for 15 OECD countries over the period 1961–95, on the hypothesis that the natural rate of growth is not exogenously given. To do this, we estimate the natural rate of growth and, then, how it changes when the actual growth rate is different from the natural rate. As a side test of the endogeneity hypothesis, we also test for the direction of causality between national output and factor inputs for the same set of countries. Our results support the idea that the natural rate of growth is not independent of the actual rate of growth and bring to the fore the importance of focusing on demand as well as supply for an understanding of long-run growth-rate differences between countries.

Key words: Natural rate of growth, Actual rate of growth, Endogeneity, Causality, Inputs, Output
JEL classifications: O40, E23, E10

1. Introduction

The main purpose of this paper is to estimate the sensitivity of the natural rate of growth to the actual rate of growth for a series of developed countries over the period 1961–95, on the hypothesis that the natural rate of growth is not exogenously given, as it is assumed to be in orthodox growth theory (including 'new' growth theory). To do this, we first estimate the natural growth rate as defined by Harrod (1939) for the various countries. We then see how the natural growth rate varies when the actual growth rate is different from the natural rate, and give reasons why this is to be expected. As a side test of the endogeneity hypothesis, we also test for the direction of causality between national output and factor inputs for the same countries.

The question of whether the natural growth rate is exogenous or endogenous to demand, and whether it is input growth that causes output growth or vice versa, lies at the heart of the debate between neoclassical growth economists on the one hand, who treat the rate of growth of the labour force and labour productivity as exogenous to the actual rate of growth, and economists in the Keynesian/post-Keynesian tradition, who maintain that growth is primarily demand driven because labour force growth and productivity

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growth respond to demand growth, both foreign and domestic. The latter view does not imply, of course, that demand growth determines supply growth without limit; rather, that aggregate demand determines aggregate supply over a range of full employment growth rates, and that in most countries demand constraints (related to excessive inflation and balance of payments disequilibrium) tend to bite long before supply constraints are ever reached.

There is a relatively simple way to answer the question above and to discriminate between the competing hypotheses. Following the work of Okun (1962), one of the present authors (Thirlwall, 1969) has shown an easy way to estimate the natural rate of growth. Since the natural rate of growth is the sum of the rate of growth of the labour force and the rate of growth of labour productivity (or what Harrod originally called the rate of growth of the labour force in efficiency units), if the actual growth rate falls below the natural rate, the unemployment rate will rise, and if it rises above it, the unemployment rate will fall. Thus, the natural rate of growth is the actual rate of growth that keeps unemployment constant. Okun specifies the change in the percentage level of unemployment ($\Delta\% U$) as a linear function of the growth of output (g):

$$\Delta\% U = a - b(g) \qquad (1)$$

From equation (1), when $\Delta\% U=0$, the natural rate of growth is defined as a/b. It is possible, of course, that because of labour hoarding the estimate of b is biased downwards, leading to an overestimate of the natural rate. Equally, however, when there is no growth, there are likely to be drop-outs from the labour force, biasing the estimate of a downwards. It is difficult to know, a priori, what the relative (offsetting) strengths of the biases are likely to be.

An alternative approach which overcomes these particular problems of bias is to reverse the dependent and independent variables of equation (1) giving:

$$g = a_1 - b_1(\Delta\% U) \qquad (2)$$

where the constant term (a_1) in equation (2) now defines the natural rate of growth; that is, the growth rate consistent with no change in the percentage level of unemployment. Since $\Delta\% U$ is not exogenous, however, the coefficient estimates of equation (2) will be statistically biased, although to what extent is also difficult to know a priori. In Thirlwall (1969), estimates of the natural rate of growth for the UK and the US were made using both approaches over the period 1950–67, and the results were not significantly different. For the US, the OLS estimation of equation (1) gave an estimate of 3·60%, and equation (2), 3·63%. For the UK, equations (1) and (2) gave the same estimate of 2·90%.

Once the natural rate of growth has been estimated, deviations of the actual growth rate from the natural rate can be calculated, and equation (2) can be estimated introducing a dummy variable (D = 1) for periods when the actual rate of growth is above the natural rate and zero otherwise, as in equation (3).

$$g = a_2 + b_2 D - c_2(\Delta\% U) \qquad (3)$$

If the coefficient on the dummy (b_2) plus the constant (a_2) is significantly higher than the original constant (a_1) in equation (2), this means that the rate of growth to keep unemployment constant in booms must have risen. In other words, the actual rate of growth must have pulled up the natural rate.

To illustrate the point, consider Figure 1. The growth of output is measured on the vertical axis, and the change in the percentage level of unemployment on the horizontal

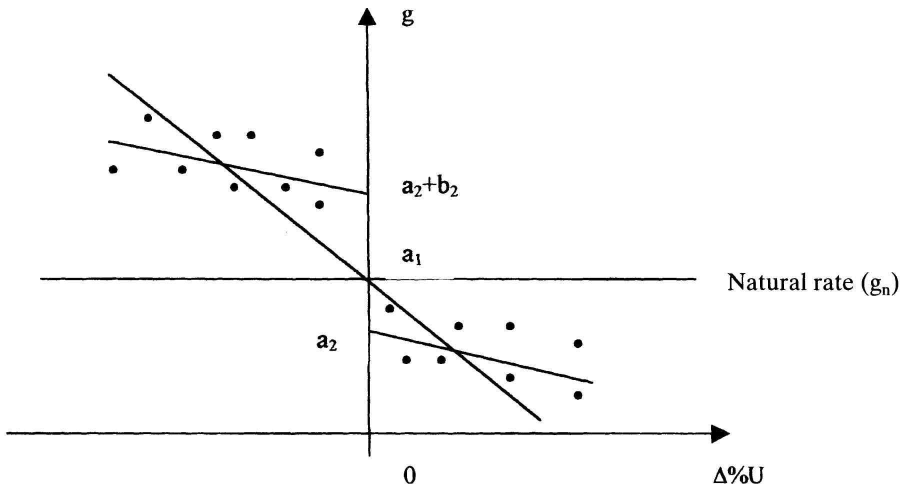

Fig. 1. *Relation between growth and change in unemployment.*

axis. Fitting equation (2) to observations of g and $\Delta\% U$ defines the natural rate of growth (g_n) at a_1 where $\Delta\% U = 0$. *Theoretically*, if $g>g_n$, $\Delta\% U<0$; and if $g<g_n$, $\Delta\% U>0$, and all observations should lie in the top left-hand and bottom right-hand quadrants (as depicted). The question is: is the intercept (a_1) the same for both samples of $g>g_n$ and $g<g_n$, or does a spline relationship fit the data more accurately, so that the natural rate of growth (a_2+b_2) when $g>g_n$ is significantly greater than the natural rate of growth (a_2) when $g<g_n$?

In practice, of course, the relationship between g and $\Delta\% U$ is a stochastic one, and observations of g and $\Delta\% U$ in the top right and bottom left quadrants are possible, which may bias the estimates of a_2 and b_2. We shall deal with the issue of bias in Section 4, when we come to the empirical testing, but it may be said at the outset that, for most of the countries we take, fewer than 35% of the observations lie in the top right and bottom left quadrants, and that using a test suggested by Maddala (1992) for 'abnormal' observations suggests no evidence of bias.

2. Theoretical considerations

The issue of the endogeneity of the natural rate of growth is of great theoretical and practical importance. It was Harrod (1939) who first formally introduced the concept of the natural rate of growth into economic theory, although, interestingly, Keynes alluded to the idea two years previously in a lecture to the Eugenics Society in 1937 on the economic consequences of a declining population (Keynes, 1937). There, he expressed the view that if the growth of population fell to zero, the growth of demand for savings (with a given capital–output ratio) may not match the supply of savings (given the propensity to save), leading to a demand deficiency. This is a clear anticipation of the idea in Harrod that the natural rate of growth may fall below what Harrod called the warranted growth rate, leading to secular stagnation.[1]

In Harrod, and in mainstream growth theory, the natural growth rate fulfils two important functions. First, it sets the ceiling to the divergence between the actual and the

[1] For a fuller discussion, see Thirlwall (1987).

warranted rate of growth, and turns cyclical booms into slumps. It is thus important for generating cyclical behaviour in trade cycle models that rely on first-order difference equations. Second, it gives the maximum long-run rate of growth which is attainable—what Harrod called the social optimum rate of growth, but without any discussion of its determinants. That is why Harrod's growth theory is not really a theory of growth at all, but a dynamic theory of the trade cycle around an unexplained trend (Besomi, 1998). The natural growth rate is treated as strictly exogenous, made up of the growth of the labour force and the growth of labour productivity, without any recognition that both may be endogenous to demand.

In Harrod's model, there was also no mechanism for bringing the warranted rate of growth into line with the natural rate. It was this (pessimistic) conclusion that started the neoclassical versus Keynesian growth debate in the 1950s that engaged some of the greatest minds in the economics profession for more that two decades (see Hacche, 1979; Jones, 1975, for a summary). Cambridge, Massachusetts, USA, represented by Samuelson, Solow and Modigliani, was pitched against Cambridge, England, represented by Kaldor, Joan Robinson, Khan and Pasinetti. Both camps, however, by and large treated the natural rate of growth as given. Virtually all the discussion centred on the various mechanisms by which the warranted rate might converge on the natural rate, giving a long-run equilibrium growth path. The Cambridge, Massachusetts, neoclassical school, as is well known, concentrated on adjustments to the capital–output ratio through capital–labour substitution. The Cambridge, England, Keynesian school concentrated on adjustments to the savings ratio through changes in the distribution of income between wages and profits.

If the natural rate of growth is not exogenously given, however, but is endogenous to economic conditions, both approaches are considerably weakened. Likewise, the endogeneity of the natural rate has serious implications for neoclassical growth theory that views the long-run growth rate (the natural rate) as determined by exogenously given factor inputs and technical progress.

First, consider the short-run cyclical problem of divergence between the actual and warranted growth rates. If the natural rate increases as the actual growth rate diverges further from the warranted rate in the upward direction, this will perpetuate the cyclical upturn which is then eventually brought to an end, not necessarily by reaching a full employment ceiling, but by inflationary conditions and/or balance of payments problems before the natural rate is ever reached. This, indeed, may be one explanation why cyclical peaks of activity are very often accompanied in many countries by continued under-utilisation of labour and capacity. The boom has generated its own supply, but the supply cannot be utilised before various demand constraints bite.

Second, consider the secular problem of divergence between the warranted and the natural growth rates. If the warranted rate exceeds the natural rate, it means that the growth of the capital stock exceeds the growth of the labour force in efficiency units. The neoclassical adjustment mechanism is the substitution of capital for labour, increasing the capital–output ratio. The Keynesian adjustment mechanism is a fall in the savings ratio through a redistribution of income from profits to wages. But in conditions of depression, the natural rate of growth is likely to be adversely affected so that the natural rate falls as the warranted rate falls, making adjustment more difficult. Conversely, if the natural rate exceeds the warranted rate, the growth of the labour force in efficiency units exceeds the growth of capital. The warranted rate must rise to the natural rate, but if boom conditions raise the natural rate, the adjustment of the two rates is again made more difficult.

There are a number of mechanisms through which the natural rate of growth may be endogenous to the actual growth rate. First, there are a variety of ways, well documented, by which the growth of labour inputs increases when output growth is buoyant. Hours worked increase; participation rates increase, particularly among females; reallocation of labour from low to high productivity sectors takes place, which is a very important factor in the early stages of industrialisation (see Cornwall, 1977), and immigration may also occur (as in Germany in the 1950s and 1960s). Second, there is a host of ways in which labour productivity growth may be enhanced as output growth increases: micro (static) economies of scale; macro-economies of scale [in the Allyn Young (1928) sense], and dynamic economies of scale associated with induced capital accumulation; embodied technical progress; and learning-by-doing. All these mechanisms play a part in the determination of the Verdoorn relation (Verdoorn, 1949), resurrected by Kaldor (1966), which shows a strong positive relation between the growth of output in manufacturing as the independent variable and the growth of labour productivity. This relationship can, in turn, be derived (see Dixon and Thirlwall, 1975) from Kaldor's technical progress function (Kaldor, 1957), which postulates a relation between the rate of growth of output per head and the rate of growth of capital per head. If the extent of the market, and not relative factor prices, is the fundamental variable determining different production techniques and the introduction of new inventions and production processes, the actual growth of output becomes the major determinant of labour productivity growth. As Cornwall and Cornwall (1997) comment in their analysis of the difference in long-run growth performance of capitalist economies between the golden-age 1950–73 and post-1973, 'strong sustained demand pressures were a necessary condition not only for low unemployment rates but also for high rates of growth of productivity, per capita incomes and output during the golden age, primarily because of their impact on the rates of growth of the labour force, capital and technical progress'.

If labour force growth and productivity growth are endogenous to output growth, then the natural growth rate will be endogenous to output growth, and this has serious implications for the neoclassical theory of growth which attempts to understand the growth process in terms of the growth of factor inputs and technical progress, the growth of which are determined outside the model. With an exogenously determined production frontier, it is always possible to assume that the economy will move towards the full employment of resources. If it can be shown, however, that the buoyancy of demand affects positively the natural rate of growth, and that output growth induces input growth, the notion of a full employment production frontier is no longer tenable. There needs to be much more focus on the components of demand, and constraints on demand, for an understanding of the growth process. It should be noted at this point that so-called 'new' growth theory, or endogenous growth theory, provides no help in this regard, since the long-run steady-state growth rate is still determined by the exogenous growth of the labour force in efficiency units. Indeed, the main purpose of 'new' growth theory seems to be to rehabilitate the neoclassical growth model by explaining growth rate divergences between countries in terms of various forms of externalities to investment (see Barro, 1991; Lucas, 1988; Romer, 1986, 1987, 1991). Growth is only endogenous in the sense that the ratio of investment to output matters for growth because the capital–output ratio does not fall as the capital–labour ratio rises. This is attributed to external effects associated with investment in education and research and development, and with foreign direct investment. Thus, by investing in these inputs, a country is able to sustain its growth rate independently of the exogenous rate of technical progress. However, the natural rate of growth is still independent of the actual rate of growth and, in this regard, is exogenously given by the parameters of the production function. There is no room for demand, or demand constraints, in the model. All saving is invested; supply creates its own demand, and there are no constraints on demand associated with inflation or the balance of payments. In relation to the latter, which would be a representative modern neoclassical view, Krugman (1989) has summed up the position very well when he says '*we all know* (our italics) that differences in growth rates among countries are primarily determined by the rate of growth of total factor productivity . . . it is hard to see what channel links balance of payments . . . to total factor productivity growth.' In other words, he fails to appreciate that total factor productivity, just like labour productivity, is very much a function of rates of growth of aggregate demand and may be affected unfavourably by constraints on demand imposed by poor balance of payments performance (or other factors for that matter) and could impact unfavourably on productivity growth. Long-run growth is *exogenously* determined.

Given this brief theoretical background to the importance of the question of the endogeneity of the natural growth rate, we now turn to empirical estimation of (i) the natural growth rate, (ii) the endogeneity of the natural growth rate, and (iii) the direction of causality between inputs and output, for our sample of countries.

3. Estimation of the natural rate of growth

In order to test the hypothesis of the endogeneity of the natural rate of growth, we shall first obtain estimates of the natural rate as given by equations (1) and (2) and compare the results of both procedures. The analysis is carried out with a set of 15 OECD developed countries: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Greece, Italy, Japan, the Netherlands, Norway, Spain, the UK and the US. This selection of countries has the advantage of embracing different economic contexts, i.e., European and non-European, big and small economies, northern and southern development experiences, fast and slow growth, high and low unemployment levels, etc. The period over which the estimates are made is 1961–95 and the database used is the *OECD Statistical Compendium, 1960–1995*, provided by the OECD (1997). The homogeneity of this database allows us to compare with some confidence the results obtained for the different countries considered.

The results of the ordinary least squares (OLS) estimation of Okun's equation (1) are reported in Table 1. For many of the countries, correction for autocorrelation of the errors was necessary; thus, the Cochrane–Orcutt iterative method of generalised least squares is reported. The results show, in general, low values of the R^2, but, except for the case of two countries, the model is jointly significant at the 95% confidence level, and most of the parameters are significantly different from zero. The natural rate of growth is obtained as a/b from equation (1), and is reported together with a Wald test for testing the significance of the value obtained. The estimate of the natural growth rate is significant in all but two countries and its value (for those significantly different from zero) ranges from 7·25% for Japan to 2·99% for the US. In one of the two remaining cases (France) the results obtained indicate a very low sensitivity of changes in unemployment to the growth of GDP (and is even positive) making the results unreliable.

Though the results obtained seem to be reasonable given what we know of the growth experience of these countries, we also use the Thirlwall (1969) method of estimating the natural rate of growth given in equation (2). The estimates are reported in Table 2 and, in

Table 1. *Estimation of the natural rate of growth using Okun's equation. 1961–95*

Country	Constant	Coefficient on GDP growth	R^2	DW	Natural rate[a]
Australia	0·8205 (2·524)*	−0·1514 (−2·064)*	0·118*	1·939	5·42 (16·195)*
Austria[b]	0·0850 (0·385)	−0·0433 (−0·8737)	0·265*	–	1·97 (0·302)
Belgium[a]	0·8613 (2·640)*	−0·1538 (−3·488)*	0·605*	–	5·60 (6·660)*
Canada[b]	1·3263 (3·693)*	−0·3435 (−7·789)*	0·689*	–	3·86 (16·381)*
Denmark	0·9508 (3·102)*	−0·2864 (−3·423)*	0·262*	1·743	3·32 (22·265)*
France[b]	0·0341 (0·150)	0·0877 (1·167)	0·145	–	−0·39 (0·014)
Germany[b,c]	0·8769 (5·329)*	−0·2192 (−6·047)*	0·664*	–	3·99 (4,635)*
Greece	0·5059 (3·022)*	−0·0930 (−3·085)*	0·224*	1·278	5·43 (19·716)*
Italy	0·3822 (2·352)*	−0·0567 (−1·469)	0·061	1·755	6·74 (5·986)*
Japan	0·1849 (3·728)*	−0·0255 (−3·461)*	0·266*	1·445	7·25 (37·255)*
Netherlands[b]	0·7591 (2·384)*	−0·1656 (−2·669)*	0·408*	–	4·58 (9·039)*
Norway	0·7191 (3·980)*	−0·1622 (−3·726)*	0·296*	1·733	4·43 (80·441)*
Spain[b]	1·8654 (4·371)*	−0·3539 (−4·566)*	0·611*	–	5·27 (28·532)*
UK[b]	0·8197 (2·584)*	−0·2681 (−3·137)*	0·468*	–	3·05 (9·737)*
USA	1·1735 (8·089)*	−0·3919 (−9·892)*	0·748*	1·563	2·99 (194·542)*

Notes: *Denotes significant at the 95% confidence level; **denotes significant at the 90% confidence level. The significance of the model reported together with the R^2 is based on an F-test of joint significance.

[a]The number in parentheses is a Wald test for the significance of the natural rate of growth, distributed as a $\chi^2(1)$. The natural rate is obtained as a/b.

[b]Estimated using Cochrane-Orcutt AR(1) iterative method since evidence of autocorrelaton was found. For Austria, AR(2) errors were used. In the case of Greece, though evidence of autocorrelation was found, the estimations converged after six iterations, and the results obtained give implausible values for the parameters; the OLS estimation therefore is given in the table and the results must be interpreted with caution.

[c]For Germany, a dummy variable for the re-unification in the period 1990–91 was included and is significantly positive at the 95% confidence level.

general, give more reliable results for the natural rate of growth. All the estimations except for Austria are jointly significant, and most of the variables are significant at the 95% confidence level. Correction for autocorrelation was also necessary in several cases. Regarding the estimates of the natural rate of growth obtained, these are significantly different from zero in all cases and, again, the values obtained seem reasonable on the basis of the growth performance of the different countries considered. The natural growth rate now ranges from 4·57% for Japan to 2·54% for the UK. Except for the cases of Austria, Canada and France, the estimate of the natural rate of growth (i.e., a_1) is lower than that obtained using equation (1), and it is important to note that, for those countries that gave unreliable estimates of the natural growth rate in Okun's equation, the values obtained from the reversal test are positive and make economic sense.

As mentioned earlier, since we are hypothesising the endogeneity of input growth to output growth, the change in the percentage level of unemployment should be regarded as an endogenous variable which will bias the coefficient estimates in equation (2). However, when performing an instrumental variables estimation of equation (2), using the lags of the variables as instruments, the values obtained for the intercept term (i.e., the natural growth rate) were not different from those obtained using simple OLS and, in some cases, the lags of the variables did not seem to be appropriate instruments.[1] The bias that could arise from this sort of problem, therefore, does not seem to be important. We also tried a dynamic

[1] The results are not reported here but are available from the authors on request.

Table 2. *Estimation of the natural rate of growth using Thirlwall's reversal*

Country	Constant	Coefficient on Δ%*U*	R^2	DW	Natural rate
Australia	3·9985 (10·324)*	−0·7763 (−2·064)*	0·118*	1·878	3·999
Austria[a]	3·1358 (6·653)*	−0·5482 (−1·163)	0·136	–	3·136
Belgium	3·5239 (10·281)*	−1·4702 (−3·893)*	0·328*	1·467	3·524
Canada[a]	3·8352 (4·735)*	−1·9982 (−8·160)*	0·705*	–	3·835
Denmark	2·9424 (8·309)*	−0·9149 (−3·423)*	0·262*	1·835	2·942
France[a]	2·8270 (7·891)*	0·4838 (1·178)*	0·176*	–	2·827
Germany[b]	3·5054 (13·631)*	−2·4150 (−6·946)*	0·738*	1·627	3·505
Greece	4·5089 (8·103)*	−2·4064 (−3·085)*	0·224*	1·785	4·509
Italy[a]	3·3439 (5·412)*	−0·4581 (−0·604)	0·173**	–	3·344
Japan[a]	4·5671 (2·066)*	−5·0503 (−1·735)**	0·582*	–	4·567
Netherlands[a]	3·2817 (3·645)*	−1·2423 (−4·015)*	0·523*	–	3·282
Norway	3·9722 (15·472)*	−1·8259 (−3·726)*	0·296*	1·709	3·972
Spain[a]	4·0623 (4·995)*	−1·0793 (−4·365)*	0·733*	–	4·062
UK	2·5438 (9·119)*	−1·1083 (−4·457)*	0·376*	1·577	2·544
USA	2·9911 (16·114)*	−1·9078 (−9·892)*	0·748*	1·407	2·991

Notes: *Denotes significant at the 95% confidence level; **denotes significant at the 90% confidence level. The significance of the model reported together with the R^2 is based on an F-test of joint significance.

[a]Estimated using Cochrane-Orcutt AR(1) iterative method since evidence of autocorrelaton was found. For Austria, AR(2) errors were used. In the case of Greece, though evidence of autocorrelation was found, the estimations converged after six iterations, and the results obtained give implausible values for the parameters; the OLS estimation therefore is given in the table and the results must be interpreted with caution.

[b]For Germany, a dummy variable for the re-unification in the period 1990–91 was included and is significantly positive at the 95% confidence level.

specification of equation (2) including lags of the variables[1] in order to test the robustness of the static OLS estimations presented in Table 2. The results of these dynamic specifications did not change the estimates of the natural rate obtained from the static equation. Only in the cases of Belgium and Italy were some differences detected, but they were never more than one percentage point higher. The estimates of the natural rate of growth in Table 2 are therefore taken as reliable enough to use this specification for testing the endogeneity of the natural rate to the actual rate of growth. This is done in the next section.

4. Testing for the endogeneity of the natural rate of growth

As outlined in Section 1, the procedure used to test for the endogeneity of the natural growth rate consists of introducing a dummy variable for the periods of growth buoyancy when the actual rate is above the natural rate. If the coefficient of the dummy variable is significantly positive, this means that the natural rate of growth experiences an upward shift (see Figure 1). In other words, the higher growth of output has induced a higher growth of the labour force in efficiency units owing to increases in labour supply and productivity growth. We also test for the possibility that our estimates of the endogeneity of natural rate of growth are biased owing to theoretically 'abnormal' observations (as indicated in Section 1).

Two alternative procedures are used to identify the booming periods of each economy for which the dummy variable takes the value of one: (i) those years for which the actual

[1] Selected using the Swartz Bayesian Criterion and the Akaike Information Criterion.

Table 3. *Estimation of the change in the natural rate of growth using a dummy for the years when actual growth is above the natural rate of growth*

Country	Constant	Dummy	$\Delta\%U$	R^2	DW
Australia	2·1900 (6·886)*	3·5231 (7·492)*	−0·2345 (−1·928)**	0·648*	1·899
Austria	1·6837 (6·895)*	3·2726 (9·315)*	−0·3958 (−1·609)	0·742*	1·833
Belgium	1·3172 (4·528)*	3·5930 (8·615)*	−1·0653 (−1·917)**	0·707*	2·529
Canada	2·5349 (7·301)*	2·7264 (5·454)*	−1·0653 (−4·162)*	0·734*	1·529
Denmark	1·1907 (3·199)*	3·5919 (6·201)*	−0·1668 (−0·761)	0·665*	1·831
France	1·8228 (8·976)*	2·1115 (8·235)*	0·0265 (0·109)	0·684*	1·839
Germany[b]	2·2997 (8·177)*	2·4094 (5·654)*	−1·4790 (−4·959)*	0·871*	1·839
Greece	1·8101 (4·146)*	5·8610 (8·713)*	−0·7280 (−1·540)	0·769*	1·966
Italy	1·6954 (4·803)*	4·2150 (7·937)*	0·4783 (1·003)	0·684*	1·693
Japan[a]	3·6593 (5·001)*	5·0606 (6·256)*	−1·3917 (−0·713)	0·802*	–
Netherlands	2·0397 (7·787)*	3·2754 (8·077)*	−0·7109 (−3·122)*	0·732*	2·358
Norway	2·5662 (10·541)*	2·4432 (7·539)*	−1·0775 (−3·423)*	0·746*	1·444
Spain[a]	3·2446 (7·126)*	2·8482 (5·286)*	−0·8474 (−4·612)*	0·866*	–
UK	1·4503 (4·940)*	2·3519 (5·263)*	−0·6982 (−3·480)*	0·665*	1·703
USA	2·2738 (7·739)*	1·3904 (2·967)*	−1·4014 (−5·759)*	0·802*	1·776

Notes: *Denotes significant at the 95% confidence level; ** denotes significant at the 90% confidence level. The significance of the model reported together with the R^2 is based on an F-test of joint significance.

[a]Estimated using Cochrane-Orcutt iterative method because of residual autocorrelation. All the estimations were done using AR(1) errors.

[b]For Germany, a dummy variable for the re-unification in the period 1990–91 was included and is significant at the 95% confidence level.

rate of growth is higher than the natural rate of growth as estimated in equation (2); and (ii) those years in which a three to five year moving average of the growth of output is above the average growth, since the first procedure may not capture longer-run effects associated with increasing returns. This second procedure is also independent of the estimation obtained in equation (2).

Tables 3 and 4 report the results of introducing the dummy variable in equation (2) using both procedures. All the estimations are jointly significant at the 95% confidence level. The dummy variable is significantly positive in all cases, and the sum of the constant and the dummy show that, for some countries, the natural rate of growth in boom periods is nearly twice as high as the average natural rate in Table 2. The extreme cases are Japan, Greece and Italy, while in other countries, such as the US, France, Germany and the UK, the natural rate is less sensitive. Table 5 gives the difference between the natural growth rate in high growth periods and that for the period overall (given in Table 2). For the 15 countries as a whole, the average difference between the natural rate in boom periods and the average natural rate is 1·83 and 1·42 percentage points, using the alternative methods proposed. This represents an average elasticity of 51·7% and 40·1%, respectively. The fact that Greece, Italy and Japan have a higher elasticity than the US, the UK, Germany and France is not surprising. The former countries have a lower participation of the labour force, especially among females, and higher reserves of labour in general. Also, the relationship between productivity growth and output growth, as represented by the Verdoorn relationship, is likely to be stronger in countries undergoing more rapid structural change which are not already industrially 'mature'.[1] It is important to stress here that

[1] See Setterfield (1997) for a similar argument based on the concept of lock-in specialisation.

Table 4. *Estimation of the change in the natural rate of growth using a dummy for the medium run cycles*

Country	Constant	Dummy	$\Delta\%U$	R^2	DW
Australia	2·0023 (3·847)*	2·8761 (4·299)*	0·0037 (0·022)	0·386*	2·162
Austria	1·6699 (5·224)*	2·9462 (6·782)*	−0·4527 (−1·494)	0·607*	2·162
Belgium	1·9217 (4·118)*	2·6782 (4·252)*	−0·6258 (−1·726)**	0·581*	2·401
Canada	2·2318 (5·204)*	2·6136 (4·891)*	−1·2040 (−4·634)*	0·707*	1·712
Denmark	1·5393 (2·775)*	2·3324 (3·078)*	−0·4354 (−1·529)	0·431*	2·273
France	1·9313 (8·386)*	1·9684 (6·657)*	−0·0515 (−0·184)	0·587*	1·815
Germany[b]	2·5753 (8·234)*	1·8967 (4·037)*	−1·7615 (−5·359)*	0·828*	2·209
Greece	1·3060 (2·040)*	5·4864 (6·219)*	−0·3915 (−0·628)	0·649*	2·050
Italy[a]	1·3241 (2·386)*	4·0784 (5·912)*	0·2969 (0·561)	0·626*	–
Japan	3·5405 (7·215)*	5·4377 (7·423)*	−6·2043 (−3·178)*	0·730*	1·685
Netherlands	1·9699 (5·704)*	2·8363 (5·845)*	−0·6976 (−2·509)*	0·606*	2·116
Norway	2·1516 (5·568)*	2·6207 (8·574)*	−1·2575 (−3·407)*	0·642*	2·141
Spain[a]	2·8693 (4·779)*	2·8428 (3·619)*	−0·8356 (−3·649)*	0·805*	–
UK	0·7143 (1·426)	2·4791 (4·108)*	−0·4874 (−1·917)**	0·591*	1·785
USA	2·1341 (5·577)*	1·3010 (2·508)*	−1·4495 (−5·666)*	0·789*	1·606

Notes: *Denotes significant at the 95% confidence level; ** denotes significant at the 90% confidence level. The significance of the model reported together with the R^2 is based on an F-test of joint significance.

[a]Estimated using Cochrane-Orcutt iterative method because of residual autocorrelation. All the estimations were done using AR(1) errors.

[b]For Germany, a dummy variable for the re-unification in the period 1990–91 was included and is significant at the 95% confidence level.

these results are not measuring simply the *cyclical* effect of demand on output growth because this is captured by the coefficient c_2 in equation (3). The results are capturing the longer lasting effects that sustained demand expansion has had on the growth of productive potential over the period under study.

To ascertain whether the results are biased owing to 'abnormal' observations in the top right and bottom left quadrants of Figure 1, we apply the Maddala (1992) test and include a dummy for each set of theoretically inconsistent observations, taking the value 1 for the 'abnormal' points. If the dummy is significant, then the observations in the upper right and bottom left quadrants are relevant and significantly drive our results.[1] If not, the existence of 'abnormal' observations does not have a significant impact on the results. The percentage of 'abnormal' observations for each country is as follows: Australia (35%); Austria (32%); Belgium (34%); Canada (25%); Denmark (20%); France (50%); Germany (20%); Greece (34%); Italy (31%); Japan (25%); Netherlands (43%); Norway (23%); Spain (25%); the UK (32%); the US (17%). Only in the case of Italy is the bottom left dummy for abnormal observations significant at the 90% significance level (but not at the 95% level), which may bias the intercept downwards. The case of France, with 50% of 'abnormal' observations, shows again the weak relationship between growth and changes in the level of unemployment in this country, as already commented on in Section 3. For the rest of the countries, the dummies for the 'abnormal' observations are not significant, and the estimates of the endogeneity of the natural rate remain unaffected.[2]

[1] The coefficient on the dummy is the 'forecast' error of omitting the 'abnormal' observations, and its associated t-statistic is a measure of significance of this error

[2] The results of these estimations are available on request from the authors.

Table 5. *Sensitivity of the natural rate of growth to the actual rate of growth*

	Natural rate	Natural rate in boom periods		Increase in natural rate in boom periods			
Country	(1) Table 2	(2) Table 3	(3) Table 4	Absolute difference (2)–(1)	% increase	Absolute difference (3)–(1)	% increase
Australia	3·9985	5·7131	4·8784	1·7146	42·9	0·8799	22·0
Austria	3·1358	4·9563	4·6161	1·8205	58·1	1·4803	47·2
Belgium	3·5239	4·9102	4·5999	1·3863	39·3	1·0760	30·5
Canada	3·8352	5·2613	4·8454	1·4261	37·2	1·0102	26·3
Denmark	2·9424	4·7826	3·8717	1·8402	62·5	0·9293	31·6
France	2·8270	3·9343	3·8997	1·1073	39·2	1·0727	38·0
Germany	3·5054	4·7091	4·4720	1·2037	34·3	0·9666	27·6
Greece	4·5089	7·6711	6·7924	3·1622	70·1	2·2835	50·6
Italy	3·3439	5·9104	5·4025	2·5665	76·8	2·0586	61·6
Japan	4·5671	8·7199	8·9782	4·1528	90·9	4·4111	96·6
Netherlands	3·2817	5·3151	4·8127	2·0334	62·0	1·5310	46·7
Norway	3·9722	5·0094	4·7723	1·0372	26·1	0·8001	20·1
Spain	4·0623	6·0928	5·7121	2·0305	50·0	1·6498	40·7
UK	2·5438	3·8022	3·1934	1·2584	49·5	0·6496	25·5
USA	2·9911	3·6642	3·4351	0·6731	22·5	0·4440	14·8
Average	3·5359	5·3634	4·9521	1·8275	51·7	1·4162	40·1

Thus, our results strongly support the hypothesis of the endogeneity of the natural growth rate to the actual growth rate. Growth creates its own resources in the form of increased labour force availability and higher productivity of the labour force. If this is so, the orthodox theory of growth, which assumes that it is factor input growth that *causes* output, needs to be substantially revised. The evidence here shows that there is no such thing as an exogenously determined production frontier. The production frontier moves with each movement of the actual growth rate. In the next section, we focus directly on the causal relationship between inputs and outputs for the same set of countries, complementing the empirical results already obtained.

5. Granger causality analysis between inputs and output

The causal relationship between factor inputs and output will be carried out using Granger's (1969) procedure for testing the temporal causality between two economic time series. Despite the fact that causality between economic variables cannot be completely identified using this technique, it gives a first hint of what the direction of causation is between the two variables considered. Our two variables will be the log of GDP ($LGDP_t$) and the log of total factor inputs ($LTFI_t$). Total factor input is taken, instead of labour and capital separately, in order to simplify the analysis that otherwise would require the use of vector error correction models for the causality tests. The $LTFI_t$ is obtained as

$$LTFI_t = wL_t + (1-w)K_t \tag{4}$$

where L_t and K_t are the logarithms of the levels of labour and the capital stock, and w is the weight of employees' compensation in the national accounts. Given the fact that most of the human capital and new inventions are introduced in the production process through labour and capital inputs, and their respective returns, the *LTFI* variable is capturing most of the inputs used to obtain the aggregate output. Note that the procedure used to weight the inputs does not imply assuming a constant returns to scale production function. What the procedure does is to use the share of labour and capital returns in the national accounts to weight the inputs (not to assume that output is exhausted by the marginal productivity times that the levels of labour and capital used). This variable thus gives an accurate measure of the combined inputs used in the production process at each moment of time without making any a priori assumption about the technical characteristics of the production process.

The database used in the estimations is the same as that used in estimating the natural rate of growth, namely the *OECD Statistical Compendium*. However, for some countries, the capital stock series are not available from this source or are incomplete, while for other countries the data on capital stock only correspond to a limited set of manufacturing industries. For this reason, when the OECD data on the capital stock are not available, we have used the estimations provided by Nehru and Dhareshwar (1993), which range from 1960 to 1990. The causality tests are not run, therefore, for the same period in all the countries. These estimates are based on the perpetual inventory method of accumulated investment and, since they are not obtained as a residual, they avoid accounting identity problems in our econometric test.

The standard Granger causality tests between two economic time series, x_t and y_t, are based on the following regression:

$$x_t = a_0 + \sum_{i=1}^{p} a_{xi} x_{t-i} + \sum_{i=1}^{p} a_{yi} y_{t-i} + e_t \quad (5)$$

If the joint F-test of significance of the lagged values of y_t rejects the null hypothesis of zero coefficients, we reject the hypothesis that y_t does not Granger cause x_t. Replacing x_t by y_t on the left-hand side of the equation, we would obtain the Granger causality relation from x_t to y_t. However, as pointed out by Granger (1988), based on the developments of the co-integration and error correction theory, the causality tests carried out with equation (5) do not take into account the problems arising when $I(1)$ variables are being used. If two $I(1)$ variables are co-integrated, there must exist a causality relation at least in one direction, independently of the significance of the values of the parameters of the lagged variables in equation (5). Two co-integrated variables are generated by the error correction model

$$\Delta x_t = a_0 + \sum_{i=1}^{p} a_{xi} \Delta x_{t-i} + \sum_{i=1}^{p} a_{yi} \Delta y_{t-i} + b_1 \mu_{t-1} + e_t \quad (6)$$

where μ_{t-1} is the lagged value of the error term of the co-integration equation of x_t on y_t, b_1 is the velocity of adjustment of x_t to its equilibrium relationship with y_t and Δx_t and Δy_t are the first differences of the $I(1)$ variables x_t and y_t. The introduction of μ_{t-1} (the error correction term) in equation (5) provides another channel through which causality can be tested. In the error-correction model (6), Granger causality from y_t to x_t will emerge not only if the lagged values of y_t are jointly significant, but also if μ_{t-1} is significant. Reversing the left- and right-hand side variables, and using the error term of the co-integration vector of y_t on x_t, we would test for causality from x_t to y_t.[1]

On the hypothesis that the natural rate of growth is endogenous to the actual rate of growth, we should not expect factor inputs to cause output unidirectionaly as is the case in the neoclassical and 'new' neoclassical growth theories. If output growth creates its own inputs, and the economy does not reach the full employment of its resources because of demand constraints, demand growth would lead output growth. Output growth does not meet supply constraints and, thus, it is output growth that leads input growth. However, we cannot discard the possibility of bi-directional causality between inputs and output for two reasons. First, though demand growth may lead output growth, in order to increase production it is clearly necessary to hire capital and labour. Depending on the time lag structure of the process of demand growth/hiring factors of production/output growth sequence, we should also presume that some temporal causality from inputs to output will arise. And second, the introduction of new capital embodies technical progress that will increase the productivity of the economy, leading to increased price and non-price competitiveness. Thus, increased capital inputs can lead to increased demand through the effects on export performance and, in turn, to increased output.[2] In this case, causality from inputs to output is also a plausible result, although through a very different channel from that proposed by the orthodox neoclassical growth theory. Summarising, although bi-directional causality is consistent with the demand-led approach to economic growth,

[1] A related concept is that of weak and strong exogeneity. If both the error-correction term and the lagged values of the independent variable are significant, the variable considered is *strongly exogenous*, while if the error-correction term is significant but the lagged values are not significant, the variable is *weakly exogenous*. See Urbain (1992).

[2] This is the mechanism of cumulative growth proposed by Kaldor (1970) and later formalised by Dixon and Thirlwall (1975). See also Targetti and Foti (1997) for an empirical illustration of this kind of model.

the finding of causality from output to inputs would be enough to reject the neoclassical view that the growth of output is always constrained by supply and is a consequence of the growth of inputs.

The Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests for the order of integration of the variables are presented in Table A1 in the Appendix.[1] Most of the time series for the different countries analysed are $I(1)$, i.e., first-difference stationary, and we carry out the co-integration analysis assuming $I(1)$ variables, since in at least one of the tests this hypothesis is not rejected.

The co-integration vectors are obtained using an autoregressive distributed lags (ARDL) model, to take into account the dynamic nature of the relationship between inputs and output.[2] The ARDL procedure consists of the OLS estimation of a dynamic model that includes the lagged values of the dependent and independent variables. Once this estimation is obtained, selecting an appropriate number of lags,[3] the long-run co-integration relationship is obtained solving the dynamic model for its static solution. In order to test for co-integration, DF and ADF tests of the residuals of the dynamic models were carried out. Note that, since this estimation accounts for the dynamic nature of the data, it is not pushing the dynamic terms into the residuals as would be the case in the static Engle–Granger procedure.[4] For this reason, also, the DF tests for the residuals are more reliable, since the autocorrelation of the residuals has already been accounted for.[5] The results in Table A2 of the Appendix indicate that inputs and output are co-integrated in the long-run for all the countries and show the long-run elasticities of the co-integration equations of *LGDP* on *LTFI* and *LTFI* on *LGDP*. Except for the cases of Italy, Japan and the US, the elasticity of output with respect to total factor inputs is greater than one. This indicates the existence of increasing returns to scale, one of the causes of the endogeneity of the natural rate of growth.[6] The values of the long-run co-integration equations therefore support the Kaldorian hypothesis of increasing returns to scale as a source of the endogeneity of the natural rate of growth found in the preceding section.

Once the co-integration vectors have been obtained, we estimate equation (6) for each country assuming, first, that $\Delta LGDP$ is the dependent variable—with the causal relation running from *LTFI* to *LGDP* (*LTFI*→*LGDP*)—and, second, that $\Delta LTFI$ is the dependent variable, i.e., *LGDP*→*LTFI*. The *F*-tests for the joint significance of the lagged values of the first differences of the independent variable and the *t*-test of significance of the error-correction terms are reported in Table 6. Out of the 15 countries, 13 show bi-directional causality between output and total factor inputs, two of them (Australia and Denmark) show causality running only from output to inputs, and none of them shows

[1] Both tests are carried out for the levels and the first differences of the variables. In many cases, the technique proposed by Perron (1989, 1990), allowing for structural breaks in the time series, was used. Following Granger (1997), when $I(2)$ variables were found, we tested for structural breaks and, if this is confirmed by the data, Perron's procedure was applied.

[2] The ARDL procedure proposed by Pesaran and Shin (1995) also allows for testing long-run relationships between variables with different order of integration. We have not included this step in our procedure since all the variables seem to be $I(1)$.

[3] The number of lags chosen in our estimations was based on the information provided by the Swartz Bayesian Criterion (SBC) and Akaike Information Criterion (AIC).

[4] The ARDL procedure has two further advantages put forward by Pesaran (1997). First, it does not depend on which variable is assumed to be exogenous, whether inputs or output. Second, the *t*-tests have good size and power properties and, thus, it allows for making inferences over the parameters of the co-integration vector obtained.

[5] In all these cases, the SBC and AIC criteria for the selection of the appropriate number of lags in the DF and ADF tests indicates that the preferred test is the DF.

[6] Analysing the reverse estimation, we can see that this hypothesis is confirmed in most of the cases.

Table 6. *Granger causality tests*

Country	Causal relation	F-test of lagged differences	T-test of error-correction term
Australia	*LTFI→LGDP*	0·294	−1·307
	LGDP→LTFI	6·100*	−2·148*
Austria	*LTFI→LGDP*	3·271**	2·819*
	LGDP→LTFI	0·420	−2·069*
Belgium	*LTFI→LGDP*	6·506*	−1·788**
	LGDP→LTFI	0·131	−2·156*
Canada	*LTFI→LGDP*	8·383*	−3·895*
	LGDP→LTFI	10·567*	−0·548
Denmark	*LTFI→LGDP*	1·197	−1·332
	LGDP→LTFI	3·722*	−5·149*
France	*LTFI→LGDP*	1·327	−3·413*
	LGDP→LTFI	2·368	−2·408*
Germany	*LTFI→LGDP*	1·434	−3·136*
	LGDP→LTFI	18·726*	1·767**
Greece	*LTFI→LGDP*	0·713	−2·722*
	LGDP→LTFI	0·385	−12·612*
Italy	*LTFI→LGDP*	6·305*	−3·684*
	LGDP→LTFI	6·584*	−2·222*
Japan	*LTFI→LGDP*	10·070*	−4·732*
	LGDP→LTFI	0·392	−3·647*
Netherlands	*LTFI→LGDP*	2·259	−5·461*
	LGDP→LTFI	1·858	−3·698*
Norway	*LTFI→LGDP*	0·885	−4·010*
	LGDP→LTFI	0·641	−2·615*
Spain	*LTFI→LGDP*	9·179*	−3·723*
	LGDP→LTFI	2·597**	−4·600*
UK	*LTFI→LGDP*	0·025	5·756*
	LGDP→LTFI	15·839*	−2·151*
USA	*LTFI→LGDP*	8·484*	−0·226
	LGDP→LTFI	13·581*	−1·639

Notes: *Denotes that the joint test of the lagged values of the first differences of the independent variable in equation (5) or the error-correction terms are significant at the 95% confidence level.
** Denotes significance at the 90% confidence level.

causality running *only* from inputs to output. This result can be derived by analysing the significance of the lagged values, the error-correction term or both. In most of the cases the error-correction term is significant, showing that both inputs and output adapt endogenously to their long-run relationship.

6. Conclusions

In mainstream growth theory, the natural rate of growth is treated as exogenously determined. We have shown in this paper that for a sample of 15 developed countries over the post-war period, it is a mistake to regard the natural rate of growth as exogenously given. The rate of growth necessary to keep the percentage level of unemployment constant rises in boom periods and falls in recession because the labour force and productivity growth are elastic to demand and output growth.

This is also confirmed using causality tests between input and output growth. The orthodox and 'new' growth theories that assume that it is input growth that *unidirectionally* causes output growth find no support from the evidence presented here. The implication for growth theory and policy is that it makes little economic sense to think of growth as supply constrained if, within limits, demand can create its own supply. If factor inputs (including productivity growth) react endogenously, the process of growth, and growth rates differences between countries, can only be properly understood in terms of differences in the strength of demand, and constraints on demand. This is not to say, of course, that input growth is not important for output growth, but it is not *causal* in the neoclassical sense. Demand constraints are also likely to be related to supply bottlenecks which cause inflation and balance of payments difficulties for countries. It is this aspect of supply, and not the growth of inputs in a production function, that should be the main focus of enquiry in any supply-orientated theory of economic growth.

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Appendix

Table A1. *DF and ADF tests for the order of integration*

Country	Variable	DF	ADF	Country	Variable	DF	ADF
Australia	*LGDP*	−2·958	−2·918	Italy	*LGDP*	−1·365	−1·364
(1966–94)	*LTFI*	−2·074	−2·203	(1960–90)	*LTFI*	−0·685	−0·760
	Δ*LGDP*	−4·159*	−2·905**		Δ*LGDP*	−4·147*	−3·325*
	Δ*LTFI*	−3·580*	−3·686*		Δ*LTFI*	−3·288*	−3·185*
Austria	*LGDP*	−1·297	−1·422	Japan	*LGDP*[a]	−2·704	−2·401
(1960–90)	*LTFI*	−1·836	−1·835	(1960–94)	*LTFI*[a]	−1·714	−2·282
	Δ*LGDP*	−3·567*	−1·353		Δ*LGDP*[a]	−5·155*	−4·270*
	Δ*LTFI*	−4·841*	−3·686*		Δ*LTFI*[a]	−4·298*	−4·576*
Belgium	*LGDP*[a]	−2·529	−2·401	Netherlands	*LGDP*[a]	−2·435	−3·123
(1960–95)	*LTFI*[a]	−4·066*	−2·055	(1960–90)	*LTFI*[a]	−2·580	−2·527
	Δ*LGDP*[a]	−6·859*	−4·255*		Δ*LGDP*[a]	−5·814*	−3·275**
	Δ*LTFI*[a]	−3·829*	−3·484*		Δ*LTFI*[a]	−3·975*	−3·091**
Canada	*LGDP*	−1·048	−1·156	Norway	*LGDP*	0·116	−0·932
(1960–95)	*LTFI*	−0·067	−0·708	(1960–90)	*LTFI*[a]	−0·617	−1·279
	Δ*LGDP*	−3·961*	−2·742**		Δ*LGDP*	−3·229*	−2·993*
	Δ*LTFI*	−2·883**	−2·444		Δ*LTFI*[a]	−3·740*	−3·174**
Denmark	*LGDP*	−2·529	−2·753	Spain	*LGDP*[a]	−1·802	−1·608
(1965–92)	*LTFI*	−1·845	−2·475	(1960–90)	*LTFI*[a]	−1·625	−1·761
	Δ*LGDP*	−3·961*	−3·704*		Δ*LGDP*[a]	−4·508*	−3·037
	Δ*LTFI*	−3·232*	−2·880**		Δ*LTFI*[a]	−5·122*	−3·726**
France	*LGDP*	−0·188	−0·346	UK	*LGDP*	−2·196	−3·232
(1960–90)	*LTFI*[a]	−2·460	−2·378	(1960–91)	*LTFI*	−1·821	−2·965*
	Δ*LGDP*	−3·654*	−2·364		Δ*LGDP*	−3·118*	−3·574*
	Δ*LTFI*[a]	−5·145*	−4·836*		Δ*LTFI*	−2·745**	−3·509*
Germany	*LGDP*	−1·990	−2·418	USA	*LGDP*	−3·023	−3·430
(1960–94)	*LTFI*	−1·625	−1·978	(1960–93)	*LTFI*	−0·134	−1·051
	Δ*LGDP*	−4·121*	−4·423*		Δ*LGDP*	−4·021*	−4·149*
	Δ*LTFI*	−5·004*	−3·907*		Δ*LTFI*	−3·270*	−3·582*
Greece	*LGDP*	−1·494	−1·467				
(1960–90)	*LTFI*[a]	0·867	0·883				
	Δ*LGDP*	−3·083*	−2·276				
	Δ*LTFI*[a]	−4·359*	−4·029*				

Notes: [a]Unit root tests and critical values used are provided in Perron (1989, 1990), since a structural break was found in the series in the form of additive outliers.

*The null hypothesis of the existence of a unit root is rejected at the 95% confidence level.

**Denotes rejection at the 90% confidence level.

Table A2. *Long-run co-integration elasticities of the estimated ARDL models*

Country	Dependent variable	Constant	*LTFI*	*LGDP*	DF	ADF
Australia	*LGDP*	−0·698 (−0·812)	1·233 (16·318)*	–	−4·103*	−3·900**
	LTFI	1·228 (8·922)*	–	0·763 (81·19)*	−5·338*	−4·105
Austria	*LGDP*	−1·631 (−1·105)	1·441 (10·988)*	–	−5·258 [n.a.]	−4·029 [n.a.]
	LTFI	1·398 (1·168)	–	0·684 (8·059)*	−5·258*	−3·998
Belgium	*LGDP*	−1·842 (−3·594)*	1·978 (34·295)*	–	−5·016*	−3·100
	LTFI	1·175 (6·327)*	–	0·490 (41·51)*	−5·064*	−3·495*
Canada	*LGDP*	−0·630 (−0·102)	1·312 (2·188)*	–	−6·152*	−4·484
	LTFI	1·234 (0·719)	–	0·721 (5·163)*	−5·875*	−4·047
Denmark	*LGDP*	−2·826 (−0·857)	1·606 (5·036)*	–	−5·612*	−4·346
	LTFI	3·015 (13·24)*	–	0·532 (31·46)*	−6·215*	−3·903
France	*LGDP*	−0·396 (−0·216)	1·140 (8·165)*	–	−5·428*	−4·794*
	LTFI	2·937 (2·571)*	–	0·703 (8·740)*	−5·494*	−4·497**
Germany[a]	*LGDP*	−8·887 (−7·050)*	1·936 (18·62)*	–	−4·431 [n.a.]	−2·743 [n.a.]
	LTFI	5·910 (54·40)*	–	0·429 (56·63)*	−2·276	−4·159*
Greece	*LGDP*	0·431 (1·111)*	1·133 (41·64)*	–	−5·049*	−2·800
	LTFI	0·023 (0·073)*	–	0·859 (44·66)*	−4·286*	−2·782
Italy	*LGDP*	−3·655 (−0·349)	1·117 (1·743)**	–	−5·361*	−3·395
	LTFI	7·712 (30·65)*	–	0·592 (33·91)*	−4·850*	−6·569*
Japan	*LGDP*	3·069 (1·429)*	0·936 (4·797)*	–	−5·377 [n.a.]	−4·542 [n.a.]
	LTFI	0·559 (0·769)	–	0·859 (14·19)*	−4·721**	−5·690*
Netherlands	*LGDP*	−5·664 (−0·886)	1·768 (2·847)*	–	−4·626*	−4·159
	LTFI	6·182 (8·904)*	–	0·332 (5·917)*	−6·167*	−4·959
Norway	*LGDP*	−1·202 (−1·207)*	1·381 (15·24)*	–	−4·718*	−4·284*
	LTFI	1·617 (8·537)*	–	0·672 (47·07)*	−4·986*	−3·328
Spain	*LGDP*	−7·464 (−20·48)*	1·299 (50·05)*	–	−5·500*	−4·104
	LTFI	5·824 (44·04)*	–	0·763 (61·80)*	−5·238*	−5·230*
UK	*LGDP*	−12·870 (−11·27)*	2·276 (22·77)*	–	−5·193**	−3·899
	LTFI	5·375 (25·30)*	–	0·458 (27·84)*	−4·788*	−3·062
USA	*LGDP*	2·009 (2·886)*	1·037 (19·42)*	–	−4·541**	−1·890
	LTFI	−1·371 (−2·542)*	–	0·930 (26·37)*	−5·404*	−2·287

Notes: [a]For Germany, a dummy variable to take account for the re-unification process was included.

*Denotes significant at the 95% confidence level. In the case of the DF and ADF tests, it denotes that we can reject the hypothesis of the existence of a unit root in the residuals at the 95% confidence level.

**Denotes significance at the 90% confidence level.

[n.a.]Denotes that the DF and ADF tests' critical values for the number of regressors chosen in the ARDL model are not available.