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Macroeconomic performance and convergence in OECD countries

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Abstract

This paper investigates the robustness of the correlation between growth and a set of variables which comprises accumulation rates in human and physical capital and medium term macroeconomic indicators in OECD countries. We include these variables as additional regressors in the standard growth equation that comes from the human capital-augmented Solow model. Our results show that variables related to medium term macroeconomic performance affect both growth and convergence. In some periods these variables even outperform the explanatory power of the conventional growth variables such as the accumulation rates. Our results also suggest that it is difficult to analyse the contribution to growth of any particular macroeconomic indicator in an isolated way. Rather, these effects should be studied in a framework that accounts for the macroeconomic performance of a country.

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1. Introduction

Convergence equations derived from the enlarged Solow model (Solow, 1956) seem to provide an adequate framework for the analysis of growth and convergence in cross-section samples of countries (Mankiw et al., 1992). However, a closer look at the robustness of the estimates of the basic parameters of these equations reveals that they are very unstable across subperiods and subsamples of

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countries in the OECD (Andrés et al., 1996). There are, at least, two alternative explanations for these results. First, this instability of the human capital-augmented Solow model may be due to the omission of some medium term macroeconomic variables which could explain the performance of these countries in periods of slow growth and macroeconomic turbulence. The second explanation is simply that the augmented Solow model does not explain very well the growth experience of this sample of countries, and that a better approach could be that of the endogenous growth models. This paper explores the first alternative. Its aim is to investigate the robustness in OECD countries of the correlation between growth and a set of variables which includes the accumulation rates of the Solow model and medium term macroeconomic indicators.

The analysis of the correlation between growth and macroeconomic indicators has a short but rich tradition in the literature. Although the theoretical framework which describes the relationships between such variables is still incomplete, the empirical work on growth has paid an increasing attention to the role of macroeconomic variables such as inflation, public spending and others upon the long run prospects of different economies (Fischer, 1991, 1993). Most papers in this field have dealt with specific issues, but it is difficult to compare their findings. The paper by Levine and Renelt (1992) is a remarkable exception to this norm because they study the correlation between growth and a large set of variables. They conclude that the significance of these correlations depends on the set of regressors included in the model. However, as Sala-i-Martín (1994) has argued, the implications of the extreme-bounds analysis applied by Levine and Renelt may be too strong, since there will always be possible to find a set of regressors that makes a variable non-significant in growth equations.

Our work differs from the study of Levine and Renelt in three aspects. First, our methodology for testing is different. We follow a conventional specification search and try all possible combinations between the most representative macroeconomic indicators in our data set, searching for variables that are significant in most of the cases. Second, since we exploit the time dimension of our data set using pooled data, we also evaluate the robustness of these correlations to changes in the sample period. Finally, we restrict our analysis to the OECD countries for homogeneity reasons.

The structure of the paper is as follows. In Section 2 we present the results of the estimation of standard convergence equations augmented with macroeconomic variables. After a brief discussion of the reasons to include such variables in convergence equations and a concise summary of the data used, we present the results of cross-section regressions using time averages from 1960 to 1990. Next, we exploit the time dimension of the data set and estimate convergence equations with a pooled sample of five years averages of the variables. We then analyse the stability across periods of parameter estimates, splitting the sample in two periods that reflect the break in the pattern of convergence among OECD countries between 1975 and 1985. This section ends with an analysis of the robustness of macroeconomic variables and accumulation rates to changes in the conditioning set of variables and in the sample period.

The main findings of this paper, summarized in Section 3, are as follows. First, macroeconomic variables have a significant and robust impact on growth, not only in the short run but also in the medium and long run, and they help to improve the explanatory power of the Solow model. The relative importance of macroeconomic factors is higher in periods of slow growth and macroeconomic turbulence than in periods of rapid and stable growth, which helps to explain the slowdown of growth after the mid 70s. Second, growth rates seem to be positively correlated with exports and monetary growth and negatively so with inflation and the variability of money growth and inflation. Unlike other studies, we find that the lack of correlation between the size of the public sector and growth is robust to the specification of the model. Third, contrary to the results of Levine and Renelt, we find that the influence of these macroeconomic factors is robust to changes in the set of conditioning variables or changes in the sample period. In fact, the coefficients of some macroeconomic variables are more robust than those of the basic variables of the Solow model. Finally, the instability of the coefficients of accumulation rates of physical and human capital discussed in Andrés et al. (1996) does not disappear with the inclusion of macroeconomic indicators, and we also find that some OECD countries present a lack of convergence in recession periods that cannot be explained by these macroeconomic variables. These results raise some doubts about the 'mechanics' of growth in the augmented Solow model, and about the interpretation of the estimated coefficients of accumulation rates as technological parameters of a common underlying production function for OECD countries, and suggest the need for further research in this field.

2. Empirical results

Our starting point is the well known convergence equation popularized by Barro and Sala-i-Martín (1991) and Mankiw et al. (1992) among others. The main implication of the augmented Solow model with constant returns to scale is the so called *conditional convergence proposition*, which states that the rate of growth of per capita income (y) between periods T and $T+\tau$ is a decreasing function of the distance to the steady state. The steady state is given by the share of output devoted to accumulate physical (s_{k}) and human (s_{h}) capital, the population growth rate (n), the exogenous rate of technical progress (ϕ), the depreciation rates (δ_{k} and δ_{h} assumed to be equal), and the parameters of the underlying technology. The rate of growth of income per capita between T and $T+\tau$ for country i is given by

$$
\begin{aligned}
y^i_{T+\tau} - y^i_T = {} & \phi_i\tau + \left(1 - \exp\{-\lambda_i\tau\}\right) \\
& \times\left[B_i - y^i_T + \phi_i T + \beta_i^{-1}\left\{\alpha_i s^{i*}_{\mathrm{k}} + \gamma_i s^{i*}_{\mathrm{h}} - (\alpha_i + \gamma_i) s^{i*}_n\right\}\right] \\
& + \Sigma_j A_j M_{ji} \qquad (1)
\end{aligned}
$$

where α and γ are the coefficients of physical and human capital in the production function, $\beta = 1 - \alpha - \partial$ the labour share, and A_j the coefficient associated with the macroeconomic variable M_{ji}. All variables are in logs and s_n^{i*} is the log of $(n^{i*} + \phi_i + \delta_i)$. Steady state values are denoted by starred variables, B_i is a constant (a function of the initial technology level) and λ is the convergence rate which can be written as

$$\lambda_i = \beta_i(n_i^* + \phi_i + \delta_i). \tag{2}$$

There are several reasons to include some macroeconomic indicators (M_{ji}) in the otherwise traditional convergence regression. Since the basic growth model performs poorly in periods of macroeconomic imbalances in OECD countries (Andrés et al., 1996), it seems natural to think that the inclusion of variables related to macroeconomic shocks or policy actions may improve its explanatory power. Following the work of Kormendi and Meguire (1985), different authors have used accumulation rates and medium term macroeconomic indicators to explain long run growth. [1] We shall consider three sets of macroeconomic indicators: fiscal variables, such as public spending and the budget surplus, [2] nominal variables, such as the inflation rate, the rate of growth of the money supply and the variance of money growth and inflation, [3] and some trade-related variables. [4]

2.1. The data

When making international real income comparisons, we must be aware of a number of problems in the properties of the data used for that purpose (Kravis et al., 1982). The more transitive we want our comparisons to be, the more the

[1] See Grier and Tullock (1989), Barro (1989), Levine and Renelt (1992), De Gregorio (1993), Easterly (1993), Artus and Kaabi (1993) and Sala-i-Martín (1994) among others.

[2] Different components of public spending might have different effects upon growth depending on whether they enter into private production functions (Barro, 1989) and on the relevance of the tax induced price distortions they generate (Singh, 1992). The budget deficit is expected to have negative effects on growth (Fischer (1993), Easterly and Rebelo (1993)), although Artus and Kaabi (1993) find the opposite for the OECD.

[3] The evidence is mixed in this area. Grimes (1991) and Clark (1993) argue that inflation and growth might be positively correlated. Nevertheless a significant and negative incidence of inflation on growth cannot be denied, according to the work of De Gregorio (1993), Barro (1995) and many others. Similarly, De Long and Summers (1992) have studied the relationship between Central Bank independence and productivity growth. They find that Central Bank independence is negatively correlated with inflation and positively correlated with growth (once the effect of initial conditions has been discounted). Rajhi and Villieu (1993) present a model of endogenous growth to explain negative correlation between the acceleration of inflation and growth found in a cross-section of 61 countries and in the USA from 1950 to 1987.

[4] Greenaway and Sapsford (1994) survey the empirical literature on the relationship between openness and growth. There is a widespread consensus about the superior performance of countries more actively involved in international trade (see Easterly et al. (1993) and Lee (1993) on this issue), although Levine and Renelt (1992) find that this correlation is not robust to alternative specifications.

reference basket of goods has to depart from being the most representative sample of items for each country, and vice versa. This is the main reason why we have not used in this paper the *Penn World Table 5.6*, a new version of *PWT 5* (Summers and Heston, 1991), which constitutes a standard in the empirical growth literature. As we restrict the analysis to the OECD, there is a potential loss in representativeness that would come with a data set constructed for a much larger sample of countries. A second reason for using a specific OECD data set is that some of the variables we use are not included in the *PWT*, and have to be drawn from National Accounts. For the sake of homogeneity, it may be better to make a fresh start from the OECD National Accounts.

Our data set is described in Dabán et al. (1995). We use the OECD 1990 purchasing power parities (OECD, 1992a) to homogenize OECD National Accounts from 1960 to 1991 (OECD, 1992b). Human capital indices (average years of schooling of the labour force) have been taken from Kyriacou (1991). Following Mankiw et al. (1992), we could work with the fraction of total output devoted to accumulate human capital. This variable, however, is not available for all OECD countries in different benchmark years covering our sample period. Assuming that economies with a higher level of this indicator also have a higher preference for human capital accumulation, we can use Kyriacou's variable as a proxy. Finally, money supply (M1) and budget surplus figures have been taken from the IMF. [5]

Comparisons between the data set used in this paper and the *Penn World Table Mark 5* (*PWT 5*) and its new version (*PWT 5.6*) reveal some significant differences in terms of economic growth and convergence, as Dabán et al. (1995) have pointed out. The pattern of σ-convergence displayed by each of these data sets differs substantially from the mid-seventies onwards, whit both versions of *PWT* showing a higher dispersion of GDP per capita than our data set. Moreover, there are important differences in the ranking of OECD countries according to their per capita incomes and in the evolution across time of the distribution of this variable. Convergence equations estimated with OECD data yield a better fit than those obtained with *PWT* data. However, there are also some relevant differences between *PWT 5* and *PWT 5.6*, since conditional and unconditional convergence seem to be much lower in the former. Nevertheless, other parameters of interest such as the coefficients of physical and human capital in the production function are not significantly affected by the use of these different data sets.

2.2. Cross-section estimation

Basic model. We have estimated the non-linear version of the convergence Eq. (1) setting T to 1960 and τ equal to 30. This means that we consider only the

[5] *International Financial Statistics*. We have eliminated all break points using rates of growth contained in various issues of this publications. The only exception is New Zealand for which we use OECD rates of growth of M1 in 1987 and 1988.

Table 1

Dependent variable: $\log(y^i_{90}/y^i_{60})$. Sample i: 1,…,24 [a]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
B	−6.82	−7.57	−6.59	−3.15	−10.1	−6.97	−6.01	−5.08
	(5.05)	(5.27)	(5.50)	(1.63)	(3.08)	(4.61)	(2.87)	(1.89)
α	0.30	0.31	0.28	0.31	0.37	0.31	0.27	0.33
	(4.41)	(4.60)	(3.89)	(4.51)	(4.18)	(3.70)	(3.31)	(3.56)
∂	0.33	0.34	0.35	0.19	0.33	0.32	0.34	0.26
	(6.90)	(7.43)	(6.61)	(2.11)	(4.69)	(5.61)	(4.58)	(2.82)
λ	0.025		0.026	0.026	0.016	0.024	0.023	0.013
	(5.12)		(4.93)	(5.92)	(3.53)	(3.72)	(5.49)	(4.29)
ϕ	0.02 *	0.031	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *
		(2.49)						
Public consumption			−0.571					
			(1.32)					
ΔM1 growth				−0.725				−0.869
				(2.16)				(4.04)
Inflation							−0.064	−0.048
							(1.24)	(1.87)
M1 growth							0.062	0.069
							(1.65)	(2.93)
Exports growth					0.149			0.173
					(1.67)			(3.39)
Budget surplus						−0.006		
						(0.23)		
R^2 Adj.	0.807	0.821	0.817	0.839	0.839	0.797	0.807	0.906
σ	0.109	0.105	0.106	0.100	0.099	0.112	0.109	0.076
β_{imp}	0.37	0.36	0.37	0.50	0.30	0.37	0.39	0.41
λ_{imp}	0.021	0.021	0.022	0.029	0.017	0.021	0.023	0.024
$\chi_1^{(\lambda)}$	0.44	–	0.56	0.21	0.35	0.26	0.02	4.3

[a] Estimation method: nonlinear least squares with robust errors. t-statistics shown in parentheses. λ_{imp} is equal to $(1-\hat{\alpha}-\hat{\gamma})(\bar{n}+\phi+\delta)$ where $\phi=0.02$ and $\delta=0.03$. β_{imp} is equal to $(1-\hat{\alpha}-\hat{\gamma})$. Test for restriction $\lambda=(1-\alpha-\gamma)(\bar{n}+\phi+\delta)$ is a $\chi_{(1)}$ (critical value = 3.84). Coefficients for macroeconomic indicators have been multiplied by 10^2.

cross-section variability to analyse the convergence hypothesis over the long run. Steady-state values of the variables are then approximated by their thirty year averages. [6] The results are presented in Table 1, columns (1) and (2). The convergence rate implied by these estimates is in the range of values found in

[6] This procedure (common to much of the work in this field) also mitigates the endogeneity problem in estimating the convergence equation. Lagged values of the variables could be used as instruments if the sample were cut at some intermediate date. The reasons for not proceeding in this way will become clear later. As we will show, splitting the sample is not a trivial decision because the differences across subperiods are large enough.

previous work (Barro and Sala-i-Martín, 1991), about 2%–2.5%. The estimates of the implicit labour share (β), and the physical (α) and human (γ) capital shares are also quite similar to the values reported in Mankiw et al. (1992), Durlauf and Johnson (1992) and Holtz-Eakin (1992). The convergence rate (λ) is fairly robust to alternative specifications. In column (2), the parameter ϕ is estimated to be 0.031, slightly higher than the value of 0.02 which is usually imposed (the null hypothesis that $\phi = 0.02$ cannot, however, be rejected). Our direct estimate of λ, in column (1), is 0.025. When we use the estimates of α and γ, the implicit λ given by expression (2) is 0.021 as column (2) shows. It is worth noting that the data accept fairly well the theoretical restriction imposed by Eq. (2) with a χ_1 equal to 0.44.

Macroeconomic performance. The main results for the whole period are summarized in Table 1, cols. (3) to (8). The public sector size (the ratio of public consumption to GDP) and the public surplus (as percentage of GDP) are found to be weakly correlated with growth in the OECD sample. Both variables have a low t-ratio in most specifications. Public consumption is insignificant in every specification. Grier and Tullock (1989) found significant effects of public consumption for the OECD countries, but their model does not include the investment rate. [7] Similarly, the Barro (1989) results show a strong negative correlation between public consumption and growth in the Summers and Heston data set. However Levine and Renelt (1992) have found that this correlation is non-robust to the inclusion of other macroeconomic indicators. [8] The results presented in columns (3) and (6) show that public consumption and the public surplus add very little to the overall significance of the Solow model, and that the partial correlation between these variables and growth is not robust to the inclusion of additional regressors.

Out of the several nominal variables we tried, only the first difference of inflation is significant for different combinations of regressors. The inflation rate and money supply growth are significant when exports and the first difference of inflation are included, but their variances are excluded. While our results are consistent with those of Kormendi and Meguire (1985), Fischer (1991) finds a strong negative effect of inflation on growth in both cross-section and pooling models using the Summers and Heston data set, and so do Grimes (1991) and De Gregorio (1993), who also report a negative influence of inflation growth. It is interesting to note that inflation and money growth have similar coefficients but of opposite signs. In fact, both coefficients are equal in absolute value when White's standard errors are not used.

Different measures of competitiveness and openness, such as the balance of

[7] In fact they obtain this result in a pooled model. As we shall see later this weak correlation between growth and public spending carries over our pooled sample model.

[8] The same is true for any other indicator of the size of public sector.

trade, real and nominal exports plus imports, etc., have been tried. Only the rate of growth of exports (and to a lesser extent this rate weighted by the share of exports in GDP) is robust to alternative specifications. This result is stronger than those reported in other studies such as Kormendi and Meguire (1985) and Levine and Renelt (1992) who found this positive correlation to be non-robust.

2.3. Pooling

Basic Model. We have chosen to split the sample into five year periods starting in 1960. Such a procedure cancels out some uninteresting cyclical movements and still leaves some room for time varying shocks to affect the growth process. There are several advantages to exploiting the time series dimension of our data set. Pooled data improves our understanding of the relationship between growth and medium term macroeconomic performance. By their nature, the information given by long-run averages of macroeconomic indicators about their impact on growth is very limited. The correlation between public spending, inflation, and the openness of the economy with the rate of growth is unlikely to remain stable over the cycle. Inflation, for instance, may be an undesired consequence of demand impulses to growth or the result of negative supply shocks leading to an economic slowdown. Consequently, it is difficult to attach a particular interpretation to the relationship between short-run macroeconomic indicators and long-run growth if we average over long time periods. This procedure hides the different stages of development achieved by OECD economies from 1960 to 1990 and also cancels out the large variations in the average rate of growth during the sample period.

A second advantage of the pooled sample is the possibility to carry out tests of structural stability on the convergence equation. Growth rates in the OECD have been far from homogeneous during the sample period. Many countries grew very fast until 1973 and entered in a deep recession from then until 1986. This raises two related issues as far as the Solow model is concerned. The first one is to what extent it is legitimate to expect the Solow model (or in general any model based on labour market equilibrium) to hold during periods of high unemployment. Second, we can also ask whether the rate of convergence remains stable regardless of average growth.

We have estimated the equations by non-linear instrumental variables. Instru-

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Notes to Table 2:

[a] Estimation method: non linear instrumental least squares with robust errors. t-statistics shown in parentheses. λ_{imp} is equal to $(1-\hat{\alpha}-\hat{\gamma})(\bar{n}+\phi+\delta)$ where $\phi = 0.02$ and $\delta = 0.03$. β_{imp} is equal to $(1-\hat{\alpha}-\hat{\gamma})$. Test for restriction $\lambda = (1-\alpha-\gamma)(\bar{n}+\phi+\delta)$ is a $\chi(1)$ (critical value = 3.84). Coefficients for macroeconomic indicators have been multiplied by 10^2. Instruments: constant, time dummies, lagged values of growth rates, investment rate, population growth, budget surplus to GDP, inflation, exports and money growth and variance of money growth, current values of initial GDP per capita, human capital, exports and money growth and variance of money growth.

[b] Equation includes time dummies.

Table 2
Dependent variable: $\log(y^i_{t+5}/y^i_t)$. Sample i: 1,...,24; t: 1965, 70, 75, 80 and 1985 [a]

	(1)	(2) [b]	(3) [b]	(4) [b]	(5) [b]	(6) [b]	(7) [b]	(8) [b]	(9) [b]	(10)
B	−5.36	−5.80	−6.41	−5.23	−5.65	−8.05	−6.23	−4.93	11.2	−6.72
	(3.89)	(4.05)	(4.82)	(3.25)	(4.05)	(3.69)	(3.84)	(2.70)	(2.21)	(2.38)
α	0.41	0.33	0.32	0.31	0.36	0.38	0.35	0.28	0.40	0.42
	(4.87)	(4.41)	(5.35)	(4.10)	(4.72)	(4.36)	(4.15)	(3.40)	(3.71)	(3.51)
γ	0.18	0.28	0.30	0.29	0.24	0.27	0.27	0.30	0.30	0.19
	(2.13)	(3.57)	(4.37)	(3.71)	(2.92)	(3.17)	(3.25)	(4.03)	(3.33)	(2.09)
λ	0.027	0.026		0.027	0.025	0.019	0.025	0.026	0.012	0.017
	(4.95)	(5.48)		(5.37)	(5.44)	(4.27)	(4.53)	(5.68)	(2.52)	(3.36)
ϕ	0.02 *	0.02 *	0.033	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *
			(2.57)							
Public consumption				−0.342						
				(0.75)						
Variance of M1 growth					−0.002				−0.006	−0.005
					(1.51)				(3.22)	(2.58)
Inflation								−0.138	−0.119	−0.140
								(1.38)	(3.42)	(3.76)
M1 growth								0.061	0.168	0.128
								(1.37)	(3.81)	(3.32)
Exports growth						0.136			0.123	0.145
						(2.38)			(3.05)	(3.32)
Budget surplus							−0.027		−0.072	−0.001
							(0.62)		(1.90)	(0.02)
R^2 Adj.	0.377	0.462	0.457	0.461	0.480	0.521	0.460	0.494	0.627	0.586
σ	0.060	0.055	0.056	0.055	0.054	0.052	0.055	0.054	0.046	0.049
β_{imp}	0.41	0.39	0.38	0.40	0.40	0.35	0.38	0.42	0.31	0.39
λ_{imp}	0.024	0.023	0.022	0.023	0.023	0.020	0.022	0.024	0.018	0.023
$\chi_1(\lambda)$	0.26	0.37	–	0.46	0.14	0.03	0.21	0.09	2.77	2.48

ments are first lags of endogenous variables as well as some current and lagged macroeconomic variables. The results are summarized in Table 2. The fit of the convergence equation is worse than in the cross-section case, and the parameter estimates are far from the values obtained there (1/3, 1/3, 1/3), as can be seen in col. (1). Labour and physical capital shares are around 0.4, while the share of human capital takes the value 0.2, although it is significantly different from zero. On the other hand, the restriction on the estimated λ is still accepted.

How could this discrepancy be accounted for? Our conjecture is that the convergence model specification is incomplete if we do not allow for the changing macroeconomic performance of OECD economies during the sample period. In columns (2) and (3) a similar exercise is presented, but with the inclusion of time dummies to control for the large differences in average growth across subperiods. The six periods in which the sample has been split display large variations in terms of growth and macroeconomic performance. Including time dummies improves the overall fit of the model (with a 10% fall in the standard error). The parameter values are closer to the (1/3, 1/3, 1/3) set we found in the cross-section. The implicit convergence rate is fairly similar to the one found in the cross-section model (between 2.3% and 2.4%). Our point estimate of ϕ is 0.033 (col. (3)), but again the null hypothesis that $\phi = 0.02$ cannot be rejected. The fit and the estimated values of α and γ, and the implicit λ are similar to col. (2).

Macroeconomic variables. The variables we have used to measure short-run macroeconomic performance are, to a large extent, endogenous to the growth process. This characteristic is evident in the case of inflation and the ratio of public surplus to GDP, suggesting that at least some macroeconomic indicators should be instrumented. We do so using current exogenous and lagged endogenous variables. [9] The best specifications of the augmented convergence equation with pooled data are presented in Table 2, cols. (4) to (10). In all these estimations the parameter ϕ is exogenously restricted to 0.02.

A common feature of all the specifications tried is the absence of correlation between the rate of growth of per capita income and the indicators of public sector size. Such results are obtained regardless of the time period considered and the inclusion of other regressors. The estimated coefficient of public consumption turned out to be positive in some specifications and negative in others but with a t-statistic always below one, which corroborates the cross-section model results.

[9] In practice, most of the macroeconomic indicators have been taken as being simultaneously determined with output growth, and hence endogenous. The exceptions are the rate of growth and variance of the money supply (which might be considered as policy variables) and the rate of growth of exports. As the economy grows, the presence of economies of scale may increase competitiveness and exports. However, considering that this effect takes time, we can safely assume export growth as exogenous in the convergence equation. Since exports are a component of GDP, the convergence equation has also been estimated using lagged export growth as an instrument for current growth obtaining very similar results in most of the specifications. In particular, when the rate of growth of exports is instrumented in the equation of col. (7), Table 3, the t-ratio for this variable is 2.03.

The budget surplus has in some specifications a negative and significant influence on growth, although it depends on the inclusion of other macroeconomic indicators. It is the lagged value of this variable which enters in the regressions, pointing out the positive influence that current stabilization policies might have on future growth.

The effect of nominal variables shows up more clearly than in the cross-section model. The impact of inflation is negative, as expected, in all the specifications we tried, which is in accordance with the results reported by Fischer (1991), Kormendi and Meguire (1985), and Grimes (1991) among others. Contrary to Levine and Renelt's results, the significance of inflation seems to be robust to alternative choices of macroeconomic policy indicators. It should be pointed out that, as long as we include money supply growth in our equations, there should not be much ambiguity in the interpretation of this negative coefficient. Phillips curve type effects should be captured by money growth and hence, the negative impact of inflation reflects the effect of price distortions and uncertainty, which may induce misallocations of resources.

Money growth, on the other hand, is positively correlated with growth. This effect has also been reported in the literature (Kormendi and Meguire, 1985), and its coefficient keeps its significant positive value in most estimations regardless of the set of regressors included. We should keep in mind that this positive influence of money upon growth cannot be understood as implying non-neutrality of money in the long run. It depends on how nominal GDP impulses are split between inflation and real GDP changes over the long run which, in turn, depends largely on income distribution conflicts and economic institutions. Inflation and money supply growth enter in all specifications with roughly the same coefficient and opposite signs (the same results as in the 'base' coefficients reported by Levine and Renelt (1992)). [10] If inflation had a unit elasticity with respect to changes in the money supply, nominal shocks would have no effect whatsoever upon real per capita growth. At this stage no conclusions can be drawn on whether long run neutrality will hold, [11] although the results in Table 2 do not rule out such a possibility.

Second moments of nominal variables appear significant in the convergence equation. As shown in Table 2 in cols. (9) and (10), the variance of money growth enters significantly in the equation with the expected negative sign. Although we do not show in Table 2 the results of the variance of inflation, this variable appears strongly significant (as in Grier and Tullock, 1989) in equations that do not include other nominal variables. However, when inflation and money supply growth are included, the t-ratio of the coefficient of the variance of inflation becomes almost non-significant. Unlike the results reported by Levine and Renelt

[10] See Table 11 in their paper.

[11] Real growth models of this kind are not well suited to test this hypothesis.

(1992), the variance of money growth or the variance of money accelerations is strongly significant regardless of the set of regressors. The rationale for these results can be found in the endogenous nature of price variability, which is the results of both the exogenous shocks and the way monetary policy responds to them. Perhaps the variance of the money supply is a better proxy of the erratic nature of monetary policy and of the increased uncertainty which harms long run growth through relative price distortions.

The positive correlation between growth and exports that we found in the cross-section model carries over to the pooled sample. As in the cross-section, the rate of growth of exports is the best indicator to capture the relationship between trade and growth. Its significance is very robust to alternative specifications and to the estimation method. The ability to sell abroad seems to have affected positively the rate of growth of OECD countries. Nevertheless, this variable has a negative effect on the estimated λ. Some of the OECD countries with a high rate of growth, which have converged from lower GDP per capita, have a high growth of exports, as in the case of Japan. Once such relationship is taken into account, the speed of convergence diminishes.

The statistical contribution of these macroeconomic indicators is non-negligible. When they are introduced, the standard error of the regression falls by about 20 per cent. The estimated λ also changes to some extent, but an important feature of these regressions is that in all cases the theoretical restriction on λ given by Eq. (2) can be accepted.

2.4. Stability across periods

As it has been mentioned before, one of the advantages of pooled data is that the stability of parameter estimates can be tested. Our sample period can be split into two subperiods characterized by very different average growth of OECD economies. These periods capture the changing performance of OECD economies in the postwar era better than a set of macroeconomic variables: sustained and balanced growth until 1974 and a long-lasting recession thereafter until 1985. Since then, OECD economies have grown rather fast again, although their macroeconomic performance is somehow different from that observed during the previous period of rapid growth.

We carry out the study of growth and convergence by splitting the sample into two periods. Period I covers the first years of the sample, from 1965 until 1975, [12] and the last period 1985–1990. Period II covers 1975 to 1985. Given that our interest is mainly the analysis of the relation between growth and convergence, this splitting has been chosen in order to isolate fast growth and low growth periods. Table 3 shows the estimates of Eq. (1) for each period. Comparing cols.

[12] Notice we need observations over the years 1960–65 to instrument some variables.

Table 3
Dependent variable: $\log(y^i_{t+5}/y^i_t)$. Sample i: 1,...,24 [a]

	(1)	(2) [b]	(3) [b]	(4)	(5)	(6) [b]	(7) [b]	(8) [b,c]
	1965–70, 1970–75 and 1985–90				1975–80 and 1980–85			
B	−3.27	−3.64	−5.34	−4.24	−12.7	−13.4	−64.9	−5.52
	(2.66)	(2.53)	(1.93)	(1.95)	(3.01)	(3.18)	(0.50)	(1.95)
α	0.33	0.34	0.39	0.39	0.39	0.34	0.30	0.10
	(3.45)	(3.58)	(3.56)	(3.32)	(2.72)	(2.97)	(2.33)	(1.34)
γ	0.19	0.20	0.18	0.14	0.35	0.40	0.62	0.51
	(2.22)	(2.30)	(1.67)	(1.28)	(2.94)	(3.92)	(7.33)	(9.60)
λ	0.031	0.030	0.019	0.020	0.019	0.017	0.004	0.032
	(4.65)	(5.04)	(4.00)	(4.34)	(2.17)	(2.33)	(0.48)	(2.75)
ϕ	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *	0.02 *
Variance of M1 growth			−0.008	−0.007			−0.005	−0.005
			(3.99)	(3.52)			(2.65)	(2.47)
Inflation			−0.103	−0.104			−0.111	−0.152
			(2.81)	(2.91)			(2.10)	(3.10)
M1 growth			0.117	0.100			0.181	0.209
			(2.77)	(2.79)			(3.28)	(4.01)
Exports growth			0.135	0.162			0.159	0.152
			(2.28)	(2.89)			(5.50)	(5.81)
Budget surplus			−0.045	−0.028			−0.037	
			(0.94)	(0.90)			(0.98)	
R^2 Adj.	0.468	0.493	0.676	0.673	0.225	0.323	0.557	0.632
σ	0.058	0.056	0.045	0.045	0.052	0.048	0.039	0.036
β_{imp}	0.48	0.487	0.43	0.47	0.26	0.26	0.08	0.39
λ_{imp}	0.029	0.028	0.025	0.028	0.015	0.014	0.004	0.022
$\chi_1(\lambda)$	0.12	0.10	1.37	1.50	0.312	0.24	0.03	1.27

[a] Estimation method: non linear instrumental least squares with robust errors. t-statistics shown in parentheses. λ_{imp} is equal to $(1-\hat{\alpha}-\hat{\gamma})(\bar{n}+\phi+\delta)$ where $\phi = 0.02$ and $\delta = 0.03$. β_{imp} is equal to $(1-\hat{\alpha}-\hat{\gamma})$. Test for restriction $\lambda = (1-\alpha-\gamma)(\bar{n}+\phi+\delta)$ is a $\chi(1)$ (critical value = 3.84). Coefficients for macroeconomic indicators have been multiplied by 10^2. Instruments: constant, time dummies, lagged values of growth rates, investment rate, population growth, budget surplus to GDP, inflation, exports and money growth and variance of money growth, current values of initial GDP per capita, human capital, exports and money growth and variance of money growth.
[b] Equation includes time dummies.
[c] Equation includes a dummy for Spain, Greece, Ireland, Portugal and Turkey.

(1) and (5) we see that the fit of this equation is worse in period II than in period I. The direct and implicit estimates of the rate of convergence are higher in period I than in the full sample period. The opposite happens in period II, in which the implicit λ is around 50% lower than in period I. The estimated λ is about significantly different from the one obtained in period I and as well as less significant.

Introducing time dummies in – columns (2) and (6) – improves very little the fit in period I and somewhat more in period II, changing the estimates of the relevant parameters only marginally. Again the estimated α, β and γ differ markedly across periods. The share of physical capital maintains its value, but the labour share declines sharply in the recession period, from 0.48 to 0.26, whereas the share of human capital increases. The estimates of these last two shares raise some doubts about their interpretation in periods with high unemployment, in which the model written in terms of per capita income may be seriously misspecified.

The introduction of macroeconomic variables, in cols. (3) and (7), improves the fit remarkably in both periods, although much more in period II. The estimated equation for period I bears many similarities to the one estimated for the whole sample, although it shows a higher rate of convergence and a higher labour share. The estimated equation for period II shows no convergence at all, and yields an implausibly low estimate for the share of labour. Macroeconomic indicators enter the equation in a similar way in both periods. However, when we add these variables, the increase in the adjusted R^2 is higher in period II. Export growth accounts for most of the explanatory power of macroeconomic variables. In period II this variable alone explains almost as much as all the steady state variables included in Eq. (1). This reinforces the previous impression that the Solow model does not fit the data properly during recession periods. The lack of convergence shown in col. (7) implies that the historical process of catching up among the OECD economies was interrupted by the recession. Column (8) reinforces somehow this impression. When the performance of the five poorest countries in the OECD is taken into account, by introducing a specific dummy variable, convergence is found to be strong again. [13] The recession hit poorer countries more than richer ones, and stopped the general convergence process. However, the low growth rate did not prevent convergence to continue among richer countries. This implies that the OECD as a whole still has too much heterogeneity to allow the Solow model to describe the convergence process in detail.

The estimates of the shares of physical capital, human capital and labour are very unstable in period II, as it is shown in cols. (5) to (8). Furthermore, these estimates are quite different from those obtained for period I and, unlike the results displayed in Tables 1 and 2, they depart also from the (1/3, 1/3, 1/3) distribution. The investment rate is no longer significant once macroeconomic indicators and the dummy for the five poorest countries are included in period II.

[13] Several authors (e.g. Cohen, 1993) have shown that the effect of some growth related variables in convergence equations vanishes once country specific effects are taken into account. We have not pursued this avenue enough to make our results comparable with the existing literature. Nevertheless the estimation of the equations in cols. (2) and (9) of Table 2, including country dummies, reinforces the results we have presented so far. In particular, the level of significance of the investment rate is lower but the signs and t-statistics of medium term macroeconomic indicators remain stable. Only the significance of the budget surplus falls to some extent; however, as we shall show later, this variable is non robust to other changes in the model specification.

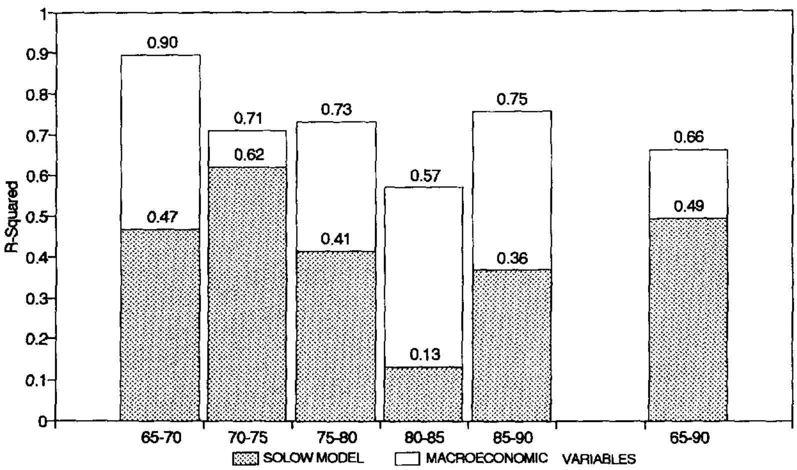

Fig. 1. Explanatory power of the Solow model and macroeconomic variables.

Note: The explanatory power attributed to macroeconomic variables is computed as the difference between the R^2 of the estimated equations.

This is at odds with Levine and Renelt's results about the robustness of this variable. There is also a large change in the coefficient of human capital from period I to period II. Furthermore, macroeconomic indicators have more stable coefficients than those of the accumulation rates. Fig. 1 also shows that, in some periods, macroeconomic indicators have more explanatory power than accumulation and initial income variables.

2.5. *Robustness of macroeconomic indicators*

The equations in Tables 1–3 are the outcome of a conventional process of specification search in which other variables such as imports growth, different indicators of external openness and the variance of inflation have been used. At first sight, the variance of money and the rate of growth of exports were robust in the sense of Levine and Renelt (1992). [14] Furthermore, inflation and money growth are almost always significant when they are included simultaneously. To explore these results in more detail, the robustness of macroeconomic indicators has been analysed using two alternative procedures. The first one consists of

[14] Although Levine and Renelt (1992) used another data set, we have estimated the same equation in Tables 1 and 2 using Penn World Tables (Mark 5.5). Comparisons between both sets of results show that our findings seem to be robust to the use of alternative data sets. However, probably due to the reasons presented in Section 2.1, in our data set the fit is better in all specifications and, in general, the coefficients of macroeconomic indicators are estimated with lower standard errors.

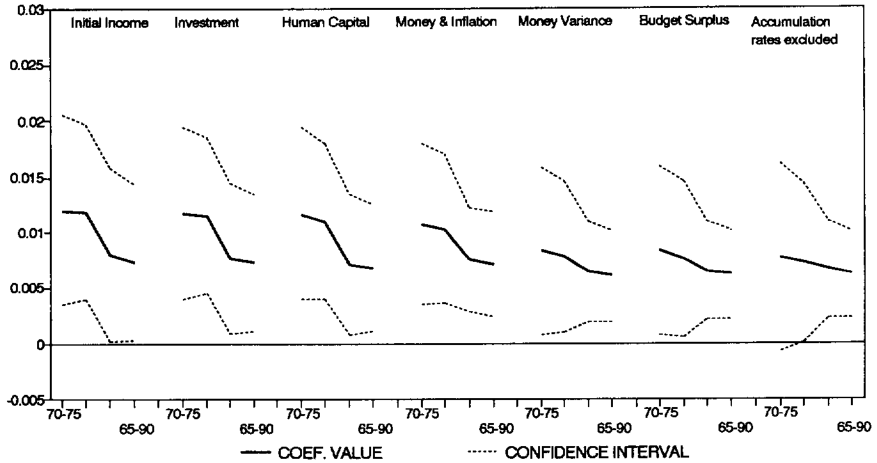

Fig. 2. Sensitivity analysis of exports growth recursive non-linear least squares.

Note: This figure shows the changes in coefficients estimates and in their confidence intervals when we add observations and variables in the basic regression. As an example, the first estimation in the first set inludes only the variable of interest and initial income, and refers to 1970–75. The following estimations expand the sample period until 1990. The second set of estimations adds investment as a regressor, the third, human capital and so on. The last set of regressions includes all macroeconomic variables.

running all possible regressions with different combinations of initial income and the other variables considered in Eq. (1). [15] This amounts to 255 regressions for each variable other than initial income. [16] The results of this exercise are summarized in Table 4. Investment and exports growth are outstandingly robust, being significant and positive in all equations. In contrast to Levine and Renelt's results, exports growth is significant in all regressions even if the investment share is included. On the other hand, human capital, public consumption and the budget surplus are only significant in less than 10% of the cases. Finally, nominal variables such as money growth and its variance are significant in almost two thirds of the cases, whereas inflation is significant in 47% of the possible combinations. However, when inflation and money growth are simultaneously included they are significant in 90% and 96% of the cases, respectively.

The second approach consists of extending the extreme-bound methodology used by Levine and Renelt (1992) to the time dimension. Figs. 2–4 represent the changes in coefficient estimates and in their confidence intervals (±2.5%) when we add observations and variables to the basic equation. Figs. 2 and 3 present two

[15] We thank Xavier Sala-i-Martín for this suggestion.

[16] It ought to be noticed that these regressions are linear and that the constant returns to scale constraints are not imposed.

Table 4

	Investment	Human capital	Population growth	Exports	Money growth	Inflation	Variance of money growth	Public consumption	Budget surplus
Coefficients									
Min	0.05642	−0.02291	−0.38566	0.00624	−0.00073	−0.01058	−0.00039	−0.09657	−0.00490
Mean	0.09295	0.02200	−0.04078	0.00800	0.00438	−0.00344	−0.00021	−0.02113	−0.00117
Max	0.11800	0.07240	−0.07996	0.00978	0.01182	0.00245	−0.00005	0.02994	0.00261
Std. dev.	0.01259	0.01997	0.05972	0.00089	0.00353	0.00384	0.00009	0.02748	0.00170
t-statistics									
Min	2.20	−0.76	−4.66	2.95	−1.09	−5.29	−4.68	−3.21	−2.32
Mean	3.47	0.70	−3.04	3.94	2.59	−1.72	−2.64	−0.72	−0.53
Max	4.54	2.18	−0.98	4.97	5.58	1.93	−0.85	1.12	1.06
Std. dev.	0.46	0.63	0.81	0.50	1.71	1.98	1.06	0.94	0.77
Percentages									
Significant (+)	100.0%	1.6%	0.0%	100.0%	62.4%	0.0%	0.0%	0.0%	0.0%
Non significant	0.0%	98.4%	10.2%	0.0%	37.6%	52.9%	32.2%	89.4%	95.3%
Significant (−)	0.0%	0.0%	89.8%	0.0%	0.0%	47.1%	67.8%	10.6%	4.7%
No. of regressions	255	255	255	255	255	255	255	255	255

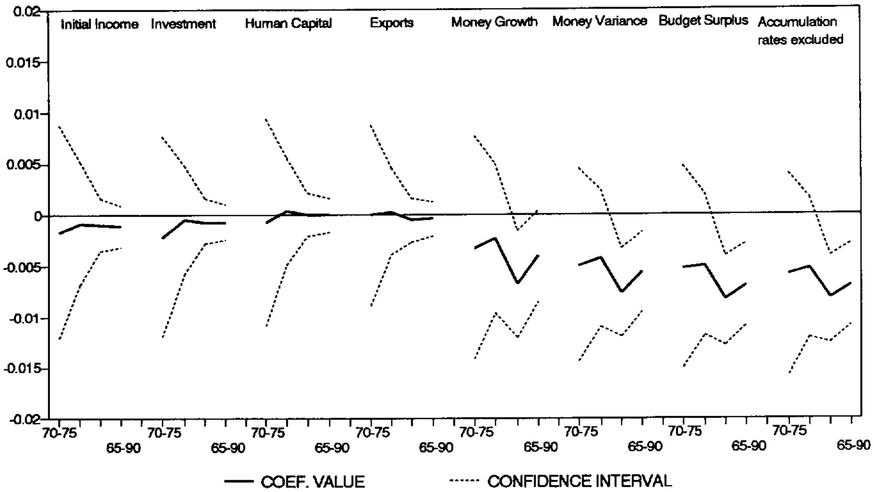

Fig. 3. Sensitivity analysis of inflation recursive non-linear least squares.

Note: See note of Fig. 2.

interesting cases. Exports growth, on its own, is robust with respect to the time periods and the specification of Eq. (1). Conversely, inflation is only robust when we include period II in the sample and money growth as regressor. Such finding

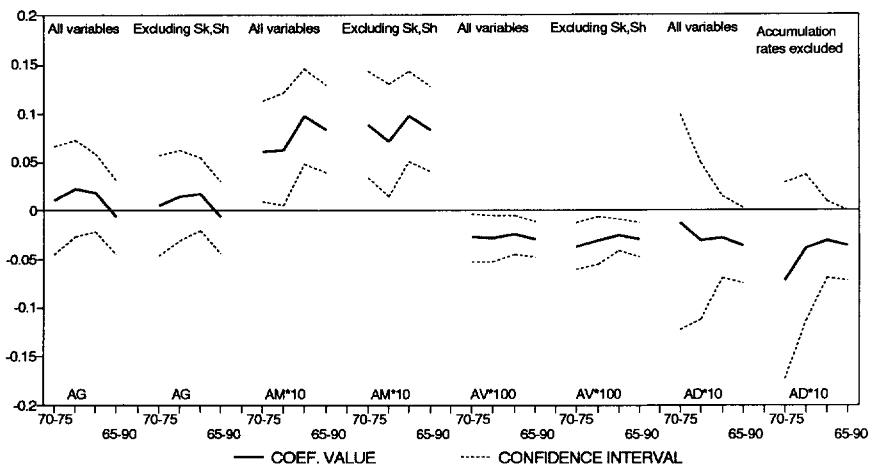

Fig. 4. Sensitivity analysis of other variables recursive non-linear least squares.

Note: This figure is a compact version of Figs. 2 and 3 for the rest of macroeconomic indicators. Only the plots when the whole set of variables are included and accumulation rates excluded are shown. Coefficients are AG (public consumption), AM (money growth), AV (variance of money growth) and AD (public budget surplus).

reinforces the idea that the examination of the effects of macroeconomic indicators one by one may lead to an omitted variables problem, which could severely bias the results. [17] Inflation has a significant negative influence in period II, where it seems to reflect the impact of supply shocks, while until 1975 it was positive although not significant, suggesting a demand-driven expansion.

Notice that, in Figs. 2 and 3, the results do not change very much when both kinds of capital accumulation, s_k and s_h, are excluded from the regression, while the rest of the macroeconomic indicators are included. Nevertheless, in that case, the coefficients of these indicators increase slightly in absolute value, suggesting that their effect upon growth operates through both the level and the marginal efficiency of investment, although this latter effect dominates. Fig. 4 shows, in a compact way, that this finding extends to all the macroeconomic indicators of Table 4. Macroeconomic performance, as represented by this set of variables, is quite robust with respect to the specification of the basic growth model represented by Eq. (1).

3. Conclusions

The first conclusion to be drawn from this paper is that macroeconomic performance indicators have considerable explanatory power in growth regressions for OECD countries. In four out of five subperiods, macroeconomic performance indicators add much more explanatory power to the Solow model than in the whole sample period. Such result shows that averaging over long periods somehow hides the effect of variables, such as macroeconomic indicators, which may be very important in explaining growth in the medium run.

The second conclusion is that the coefficients of the macroeconomic performance indicators, taken as a whole, are more robust than the coefficients of the basic variables of the Solow model. This finding holds across time and across countries. Furthermore, when macroeconomic indicators are taken one by one or in subgroups, the same fragility pointed out by Levine and Renelt (1992) is found, although with some remarkable exceptions. These findings indicate that although the search for stable relationships between growth and any particular macroeconomic indicator may be particularly hazardous, macroeconomic performance taken as a whole is important in explaining growth. Moreover, the coefficients of the set of macroeconomic indicators included in our equations are more robust than those of the basic variables of the Solow model. How can the differences with the findings by Levine and Renelt be accounted for? We surmise that the large heterogeneity in their sample diminishes the chances of finding robust correlations between growth and macroeconomic indicators.

[17] Sala-i-Martín (1994) makes a closely related point.

The third conclusion is that, as far as economic growth is concerned, our results give little support to the widespread belief that the increase in the size of the public sector has had a major effect on the long-run prospects of these economies. On the other hand, money and inflation variability could be threats to economic prosperity. Similarly, the rate of inflation in excess of money growth is negatively related to current and future growth. Exports have an important role in the explanation of growth. Contrary to other macroeconomic indicators, whose medium-term effects partially vanish in the long run, exports growth has a significant and positive effect on growth irrespective of the sample period, of the countries included, and of the specification of the convergence equation. Williamson (1995) has pointed out that the historical periods in which real convergence has taken place, coincide with periods of free trade and increased international trade. To some extent, the robustness of the exports variable found by us, and by other authors, corroborates this idea.

Finally, the inclusion of macroeconomic indicators does not solve the instability of the enlarged Solow model in a period of low growth and macroeconomic turbulence. Such finding suggests that a different analytical framework could be required to account for the long run performance of the OECD economies.

4. Data sources

Population	*National Accounts, 1960–1991* (OECD, 1992b)
GDP	Gross Domestic Product at 1990 international dollars. *National Accounts, 1960–1991* (OECD, 1992b)
Public consumption	Government final consumption expenditures at 1990 international dollars as percentage of GDP. *National Accounts, 1960–1991* (OECD, 1992b)
Investment rates	Gross Fixed Capital Formation at 1990 international dollars as percentage of GDP. *National Accounts, 1960–1991* (OECD, 1992b).
Exports growth	Rate of growth of exports at 1990 international dollars. *National Accounts, 1960–1991* (OECD, 1992b).
Inflation	Rate of growth of GDP deflator. *National Accounts, 1960–1991* (OECD, 1992b).
PPP	Benchmark year: 1990. *Purchasing Power Parities and Real Expenditures* (OECD, 1992a).
Budget Surplus	Deficit (−) or surplus of public administrations from line 80 as percentage of GDP, *International Financial Statistics* (IMF).
Money Supply	M1 from line 34, *International Financial Statistics* (IMF). We have avoided break points using information of different issues when available, or rates of growth of line 35.

Human capital Total years of schooling of the labour force. Kyriacou (1991).

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