Gundlach, Erich



# On the empirics of capital accumulation and economic growth

Kiel Working Paper, No. 577

**Provided in Cooperation with:**
Kiel Institute for the World Economy – Leibniz Center for Research on Global Economic Challenges

*Suggested Citation:* Gundlach, Erich (1993) : On the empirics of capital accumulation and economic growth, Kiel Working Paper, No. 577, Kiel Institute of World Economics (IfW), Kiel

This Version is available at:
https://hdl.handle.net/10419/643

# Kieler Arbeitspapiere
# Kiel Working Papers

Kiel Working Paper No. 577

**On the Empirics of Capital Accumulation and Economic Growth**

by

Erich Gundlach

May 1993

Institut für Weltwirtschaft an der Universität Kiel
The Kiel Institute of World Economics

ISSN 0342 - 0787

Kiel Institute of World Economics
Düsternbrooker Weg 120, D-24105 Kiel
Department IV

Kiel Working Paper No. 577

# On the Empirics of Capital Accumulation and Economic Growth

by

Erich Gundlach

May 1993

# On the Empirics of Capital Accumulation and Economic Growth

by Erich Gundlach

**Abstract**

Recent advances in the theory of economic growth have led to a large number of competing endogenous-growth models. The empirical evidence presented in this paper supports the Rebelo (1991) growth model with constant returns to scale and constant returns to aggregate capital. For reasonable parameterizations, this model predicts that a one percentage point increase in the rate of investment in physical capital increases the growth rate by about 0.1 percentage points. The results do not support models which postulate diminishing returns to aggregate physical and human capital, externalities in the accumulation of physical capital, or aggregate economies of scale

Author's adress: The Kiel Institute of World Economics
P.O. Box 4309
D-24100 Kiel
Germany

Phone: **49-431-8814-284
Facsimile: **49-431-8814-500

## 1. Introduction*

One of the most remarkable stylized facts of economic development over the past thirty years or so is the large variety in growth rates and levels of output per capita across countries. A small number of countries, notably in Southeast Asia, have increased their per capita GDP by a factor of 5 to 7 during this period; others, mainly in Africa, have experienced a decline in per capita GDP, sometimes in the range of 50 per cent. The majority of Latin American countries has faced stagnation, while the industrialized countries have roughly doubled their per capita GDP. Figure 1 shows this dispersion of economic growth for a sample of 94 countries: In one third of all countries, there was no growth at all, in another third, per capita output has grown with a factor of 2.5 or more.

The result of the variety in growth rates has been a rather uneven international distribution of output per capita (Figure 2). In 1990, more than 50 per cent of all countries revealed a per capita output below 20 per cent of that of the United States. At present, only the OECD countries and some advanced developing countries in Southeast Asia exhibit productivity levels that are comparable to those of the United States. Notwithstanding particular success stories such as the Asian Tigers, economic development seems to exhibit no natural tendency to a convergence of per capita incomes across a very broad sample of countries.

The major economic explanations for the variation in comparative economic growth include physical capital accumulation, technological catch-up and endogenous technological change, demographic change in combination with natural resource depletion, human capital accumulation, and government policy.[1] For the applied economist, the question is whether there are models of economic growth which provide a reasonable account of the stylized empirical facts. Recently, two developments have facilitated the search for an answer: The emerging literature on endogenous-growth theory[2] has provided a number of alternative explanations for the causes of economic growth as compared to the traditional Solow (1956) model; and the availability of large cross-country data sets[3] has made possible the empirical testing of alternative models. Up to now, the limiting factor has been the poor database on stocks and flows of human

* I thank seminar participates at the Kiel Institute of World Economics, the University of Konstanz, and the Bologna Center of Johns Hopkins University for useful comments on an earlier version of this paper.

1 For a recent review, see Brander (1992).

2 The seminal contributions are Romer (1986), Lucas (1988), and Grossman and Helpman (1991); for surveys of the literature, see Sala-i-Martin (1990), Romer (1991), and Shaw (1992).

3 The most recent database is the Penn World Table Mark 5 (Summers, Heston, 1991) , which is available through BITNET and on diskettes. An update is available from the NBER Publications Department.

capital accumulation which figure prominently in many models of economic growth. Happily, this bottleneck has also been widened, since Mankiw et al. (1992) provide data for proxies on the former, and Barro and Lee (1993) as well as Psacharopoulos and Arriagada (1992) provide data for proxies on the latter.

Mankiw et al. (1992) use an augmented Solow model to explain the cross country variation in output per worker. They maintain that their empirical evidence supports the assumption of decreasing returns to capital . This finding casts doubt on the recent trend among economists to dismiss the Solow growth model in favor of endogenous-growth models that assume constant or increasing returns to scale in capital. In this paper, I use the modelling framework of Mankiw et al. (1992) in order to check the stability of their findings. In contrast to their approach, however, I estimate an empirical model that uses the *stock* of human capital as an explanatory variable. Theoretically, this change from a flow to a stock variable involves predictable changes in the way the parameters of the empirical model can be estimated, but no change in the parameters themselves. Hence, the estimated returns to scale to capital derived from a model that uses the stock of human capital as an explanatory variable should not differ from those derived from a model that uses the flow of human capital.

The next section presents a general empirical model of economic growth which encompasses a number of sub-models, e. g., the traditional Solow model (Solow, 1956), the augmented Solow model (Mankiw et al., 1992), the Lucas model (1988), the Romer (1987) model, and the Rebelo model (1991). Section 3 discusses data and samples, and presents the results which favor the Rebelo model. Section 4 looks at the implications for the role of investment in economic growth.

## 2. The General Growth Model

Let the production function for the general model of economic growth at time $t$ be

$$Y_t = A_t K_t^{\alpha} H_t^{\gamma} L_t^{\beta} \qquad (1)$$

where the notation is standard: $Y$ is output, $K$ physical capital, $H$ human capital, $L$ labor, and $A$ the level of technology. $L$ and $A$ are assumed to grow exogenously at rates $n$ and $g$:

$$L_t = A_0 e^{nt}$$

$$A_t = A_0 e^{gt}.$$

This specification includes the following models:

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} \qquad (\alpha+\beta=1;\gamma=0) \tag{2}$$

$$Y_t = A_t K_t^{\alpha} H_t^{\gamma} L_t^{\beta} \qquad (\alpha+\gamma+\beta=1) \tag{3}$$

$$Y_t = A_t K_t^{\alpha} H_t^{\gamma} L_t^{\beta} \qquad (\alpha+\gamma+\beta>1) \tag{4}$$

$$Y_t = A_t K_t^{\alpha} L^{\beta} \qquad (\alpha+\beta>1;\gamma=0) \tag{5}$$

$$Y_t = A_t K_t^{\alpha} H_t^{\gamma} \qquad (\alpha+\gamma=1;\beta=0). \tag{6}$$

which stand for the traditional Solow (1956) model (2), the augmented Solow model (3) suggested by Mankiw et al. (1992), the Lucas (1988) model (4), the Romer (1987) model (5) and the Rebelo (1991) model (6).

The general model assumes that constant fractions of output are invested in physical ($s_k$) and human ($s_h$) capital. Define $k_t = Y_t / L_t$ as the stock of physical capital per unit of labor, and $h_t = H_t / L_t$ as the stock of human capital per unit of labor, and let $\delta$ be the rate of depreciation for physical and human capital. Using

$$\dot{K}_t = s_k Y_t - \delta K_t \qquad \text{and} \qquad \dot{H}_t = s_h Y_t - \delta H_t \quad \text{as well as}$$

$$\frac{\dot{k}_t}{k_t} = \frac{\dot{K}_t}{K_t} - \frac{\dot{L}_t}{L_t} \qquad \text{and} \qquad \dot{k}_t = \frac{\dot{K}_t}{L_t} - nk \ ,$$

where the dot denotes absolute changes of the variables over time, the evolution of $k$ and $h$ is given by

$$\dot{k}_t = A_t s_k k_t^{\alpha} h_t^{\gamma} L_t^{\alpha+\beta+\gamma-1} - (n+\delta) k_t \quad \text{and} \tag{7}$$

$$\dot{h}_t = A_t s_h k_t^{\alpha} h_t^{\gamma} L_t^{\alpha+\beta+\gamma-1} - (n+\delta) h_t \ . \tag{8}$$

From these equations, the steady state values $k^*$ and $h^*$ (for $\dot{k} = \dot{h} = 0$) can be derived as

$$k^* = A_t^{1/(1-\alpha-\gamma)} \left[ s_k^{1-\gamma} s_h^{\gamma} (n+\delta)^{-1} L_t^{\alpha+\beta+\gamma-1} \right]^{1/(1-\alpha-\gamma)} \quad \text{and} \tag{9}$$

$$h^* = A_t^{1/(1-\alpha-\gamma)} \left[ s_h^{1-\alpha} s_k^{\alpha} (n+\delta)^{-1} L_t^{\alpha+\beta+\gamma-1} \right]^{1/(1-\alpha-\gamma)} . \tag{10}$$

Rewriting (1) as

$$Y_t = A_t k_t^{\alpha} h_t^{\gamma} L_t^{\alpha+\beta+\gamma-1}, \tag{11}$$

inserting (9) and (10), and taking logs gives

$$\ln Y_t = \ln A_t + \frac{\alpha}{1-\alpha-\gamma}\ln s_k + \frac{\gamma}{1-\alpha-\gamma}\ln s_h - \frac{\alpha+\gamma}{1-\alpha-\gamma}(n+\delta) + \frac{\beta}{1-\alpha-\gamma}\ln L_t. \qquad (12)$$

For $\alpha+\beta+\gamma=1$ , $y_t = Y_t / L_t$, and apart from modelling the technology term differently, this is the basic equation used by Mankiw et al. (1992).[4] Solving (10) for $s_h$ gives

$$s_h = \left[\frac{h^{*(1-\alpha-\gamma)}(n+\delta)}{A_t\, s_k^{\alpha}\, L_t^{\alpha+\beta+\gamma-1}}\right]^{1/(1-\alpha)} \qquad (13)$$

With the identifying assumptions of constant growth rates of technology ($g$) and constant depreciation rates ($\delta$) across countries, and the term A(0) reflecting the level of technology in some base period as well as resource endowments, climate, institutions, and possibly other endowments which may differ across countries but are not related to the *rhs*-variables, (13) can be inserted into (12) to give the basic equation for the empirical analysis of the next section:

$$\ln Y_t = c + \frac{\alpha}{1-\alpha}\ln s_k + \frac{\gamma}{1-\alpha}\ln h^* - \frac{\alpha}{1-\alpha}\ln(n+\delta) + \frac{\beta+\gamma}{1-\alpha}\ln L_t + \varepsilon \qquad (14)$$

with $\ln A_t = \ln A_0 + gt + \varepsilon$, where $c$ is a regression constant and $\varepsilon$ represents country specific random shocks. Under the assumption that physical capital accumulation ($s_k$), the steady state level of human capital ($h^*$) and the growth rate of the labor force ($n$) are independent of such country specific shocks, this equation can be estimated with ordinary least squares (OLS).[5]

This specification predicts equal coefficients with opposite signs on the share of physical investment and growth of the labor force, and it also predicts the magnitude of these coefficients, because under the assumption that all factors are paid their marginal product $\alpha$ equals physical capital's share in income, which is expected to be about one third (Maddison, 1987). Hence, the model implies an elasticity of income with respect to physical capital in the range of 0.5. Given the estimate for $\alpha$ , the estimate for $\gamma$ can be inferred from the coefficient of the stock of human capital ($h^*$). For constant returns to scale $(\alpha+\beta+\gamma=1)$, the coefficient on $L_t$ should not be different from one; it should be larger than one for the Lucas (1988) and the Romer (1987) model.

---

4 Using these restrictions and the data published in the appendix of Mankiw et al. (1992), I was able to replicate all of their results.

5 As was noted by Mankiw et al. (1992), OLS produces inconsistent estimates if this assumption does not hold. Up to now, this issue has been largely neglected in the literature on cross-country growth equations. One attempt to identify country specific effects is the panel data approach employed by Knight et al. (1992). Their results point to a faster speed of convergence to the steady state than was estimated by Mankiw et al. (1992).

## 3. Empirical Results

*Data and Samples*

In order to check the robustness of the Mankiw et al. (1992) results with respect to an alternative measurement of the impact of human capital on economic growth, I use two new data sources which provide a proxy for the stock of human capital: both Barro, Lee (1993) and Psacharopoulos, Arriagada (1992) - BL and PA hereafter - provide cross country data for the average (mean) years of schooling. The BL and PA data are highly correlated, but not identical because there are slight methodological differences. Another difference is that BL use interpolation techniques to end up with a sample that covers 129 countries over five-year periods from 1960-85. PA solely rely on census data collected around 1980. Their sample covers almost 100 observations. Here, I take the 1985 observations from BL, and observations around 1985 (1980-88) from PA. These data are used as a proxy for $h^*$ in equation (14).

The other variables in equation (14) are measured as follows: $Y_t$ is real gross domestic product in 1985, $s_k$ is the average share of real investment in real GDP for the period 1960-85, $n$ is the annualized growth rate of the working age population, $\delta$ is assumed to be 0.03[6], and $L_t$ is working age population in 1985. $Y_t$ , $s_k$ , and $L_t$ are dereived from Summers, Heston (1991); $n$ is taken from Mankiw et al. (1992).

Further, I consider four alternative samples to check the stability of the results. Following the approach suggested by Mankiw et al. (1992), "All countries" refers to countries with populations of more than 1 million (in 1985) excluding countries with oil production as the dominant industry. "D countries excluded" refers to the resulting number of countries if those countries with the weakest quality of the data (labelled "D" by Summers and Heston) are excluded from the "All countries" sample. Both samples are matched with the BL and the PA data. See the Appendix for each of the samples and the data.

*Results for the General Model*

The results in Mankiw et al. (1992) point to distributional shares for the three factors of production in equation (1) in the range of one third $(\alpha = \beta = \gamma = 1/3)$ which are estimated with relatively low standard errors and an adjusted $\overline{R}^2$ in the range of 0.8. This finding can be questioned because their empirical model does not allow for increasing returns to scale; given the cross country context, the extremely high $\overline{R}^2$ might also be a point of concern. The results for the general empirical model of the previous section (equation 14) are presented in Table 1.

6 See Mankiw et al. (1992), footnote 6.

The upper part of Table 1 gives the results for the unrestricted model, which confirm the theoretically expected signs of the coefficients. Furthermore, the results are not sensitive with respect to the two different proxies for the stock of human capital and different sample sizes. The lower part of Table 1 gives the results for the restricted version of equation (14), amounting to equal coefficients with opposite signs on physical investment $(\ln s_k)$ and the growth rate of the working age population plus the depreciation rate $[\ln(n+\delta)]$. The p-value indicates that the theoretically justified restriction cannot be rejected at conventional levels of statistical significance.[7] Therefore, the following interpretations are based on the restricted version of equation (14).

The coefficient on $\ln L$ is not statistically different from 1. Hence the Lucas (1988) and Romer (1987) models which postulate overall increasing returns to scale due to an externality related to the accumulation of human or physical capital are rejected. This finding in favor of overall constant returns to scale confirms the underlying assumption of Mankiw et al. (1992) Although the implied estimate for the share of physical capital $(\alpha)$ also confirms the Mankiw et al. estimate of 0.3, this is not the case for $\beta$ and $\gamma$, the distributional shares of raw labor and human capital: here, $\beta$ is estimated to be zero, and $\gamma$ is estimated to be approximately 0.7. The implication is that only those factors of production that can be accumulated are important for an explanation of the observed cross-country distribution of output. Thus, the estimates for the general model favor a Rebelo model with constant returns to scale and constant returns to aggregate human and physical capital which can be written as

$$Y_t = A_t\, K^{0.3}\, H^{0.7} \tag{15}$$

*Results for Rebelo Model Specifications*

The major statistical problem with the specification of the general model is the presence of a dominant variable, $L_t$, which is responsible for the unreasonably high $\overline{R}^2$. To eliminate this effect, I estimate the Rebelo model directly. Starting from a formulation like equation (1) with $\alpha+\gamma=1$ and $\beta=0$ as restrictions imposed, it can be shown that

$$Y_t = A_t \left(K_t / H_t\right)^{\alpha} H_t \,. \tag{16}$$

The evolution of $K$ over time is governed by

$$\dot{K} = s_k\, A_t\, K_t^{\alpha}\, H_t^{\gamma} - \delta\, K_t \,. \tag{17}$$

---

[7] Maddala (1992, p. 177) suggests to use a level of statistical significance of 25 to 50 per cent because the F-test is a pre-test. Three of the four results even match this more demanding interpretations.

Deriving the equilibrium solution by setting this equation equal to zero gives

$$\frac{K^*}{H^*} = \left[\frac{A_t\, s_k}{\delta}\right]^{\frac{1}{1-\alpha}}. \tag{18}$$

Inserting (18) into (16), and taking logs, gives the unrestricted specification of the Rebelo model

$$\ln Y_t = c + \frac{\alpha}{1-\alpha}\ln s_k + \ln H^* \tag{19}$$

which can be estimated with the data at hand since $\ln H = \ln L + \ln h$. The restricted version of the Rebelo model can be estimated as

$$\ln\left(Y_t / H^*\right) = c + \frac{\alpha}{1-\alpha}\ln s_k. \tag{20}$$

The results are presented in Table 2. All coefficients have the theoretically expected sign, and the restriction is uniformly accepted, as is indicated by the p-value. Not surprisingly, the implied $\alpha$ does not differ significantly from the previous estimates. The $\overline{R}^2$, however, is substantially reduced. The implication is that the present Rebelo model explains much less of the observed cross-country variance in output (per capita) than the augmented Solow model estimated by Mankiw et al. (1992). That does not necessarily mean, however, that the Rebelo model is less plausible. Although a cross section $\overline{R}^2$ in the range of 0.15 is a clear indication that something important is missing, this is not a surprising result because in the Rebelo model, country characteristics determine long-run growth rates and the cross-country distribution of output. Therefore, a large fraction of the observed variance will remain unexplained or be attributed to random shocks as long as country specific characteristics are ignored by simple specifications like equation (19). Put differently, a cross section $\overline{R}^2$ in the range of 0.8 as in Mankiw et al. (1992), for a model of similar simplicity, is not necessarily a sign of success. In the end, the conflict between the two interpretations of the cross section data, either in favor of the augmented Solow model based on flow data for a proxy of human capital, or in favor of the Rebelo model based on stock data for a proxy of human capital, can not be solved on the basis of the highest $\overline{R}^2$. Yet some insight can be gained from formulating and testing alternative versions of the augmented Solow and the Rebelo model.

*Alternative Specifications*

Again starting from equation (1) with the restrictions $\alpha+\gamma=1$ and $\beta=0$, it can be shown that

$$\dot{H}_t = s_h\, A_t\, K_t^{\alpha}\, H_t^{\gamma} - \delta\, H_t \tag{21}$$

which can be used to derive log specifications similar to equations (19) and (20):

$$\ln Y_t = c + \frac{\gamma}{1-\gamma} \ln s_h + \ln K^* \quad \text{and} \tag{22}$$

$$\ln Y / K^* = c + \frac{\gamma}{1-\gamma} \ln s_h \,. \tag{23}$$

Similarly, for the augmented Solow model with constant returns to scale $(\alpha+\beta+\gamma=1)$ equation (9) reduces to

$$K^* = A_t^{1/(1-\alpha-\gamma)} \left[ s_k^{1-\gamma}\, s_h^{\gamma}\, (n+\delta)^{-1} \right]^{1/(1-\alpha-\gamma)}. \tag{9'}$$

Solving for $s_k$ , and inserting into equation (12), gives specifications which are alternatives to those used by Mankiw et al (1992):

$$\ln y = c + \frac{\gamma}{1-\gamma} \ln s_h - \frac{\gamma}{1-\gamma} \ln(n+\delta) + \frac{\alpha}{1-\gamma} \ln k^* \quad \text{and} \tag{24}$$

$$\ln y = c + \frac{\gamma}{1-\gamma} \left[ \ln s_h - \ln(n+\delta) \right] + \frac{\alpha}{1-\gamma} \ln k^* \tag{25}$$

as the restricted version.

As compared to the previous formulations, these specifications reverse the stock and flow variables on the right-hand-side: Here, the *flow* data provided by Mankiw et al. (1992) are used to proxy human capital, and *stock* data are used to proxy physical capital. From a theoretical point of view, it should be possible to replicate the estimates for $\alpha$ and $\gamma$, both for the augmented Solow and for the Rebelo model. If the results differ, however, it may be possible to speculate about the plausibility of the flow data- or the stock data-proxy for human capital, given that all other variables are correctly measured.

The data for the stock of physical capital $K^*$ (in 1985) are also taken from Summers, Heston (1991). These data are available for most OECD countries and a small number of developing countries. Therefore, estimation of equations (22) to (25) is only possible for relatively small sample sizes. To check the overall stability of the estimates with respect to the data on the stock of fixed capital, I consider a subsample "A and B countries only". This subsample consists of countries which were given the highest quality levels by Summers and Heston (1991). The estimation results for equations (22), (23), (24), and (25) are presented in Tables 3 and 4, respectively: as before, the upper part of the tables gives the results for the unrestricted models. The disturbing finding is the *negative* coefficient on $\ln s_h$ , the proxy for the investment in human capital that was used by Mankiw et al. (1992). Taken at face value, the implication for

the Rebelo model is that investment in human capital seems to *reduce* the productivity of physical capital; for the augmented Solow model, the estimated negative coefficient on $\ln s_h$ is statistically insignificant for all cases, implying no impact of human capital investments on the level of per capita output.

Yet one has to consider that the proxy for investment in human capital used by Mankiw et al. (1992) only relies on the fraction of the working age population that is in *secondary* school enrollment. With rising incomes, and a rising stock of physical capital, this fraction may indeed decline because the fraction of the working age population that is in *tertiary* school enrollment increases. Hence it can be argued that a more general proxy for investment in human capital would be positively correlated with the stock of physical capital. I.e., the Mankiw et al. (1992) results in favor of the augmented Solow model can be criticized for using a proxy for investment in human capital that is likely to be biased because it ignores possible substitution between second and third level schooling in the course of economic development. The proxies for the *stock* of human capital used in this paper include all levels of schooling and are, therefore, immune to this kind of bias. Following this argument, the Rebelo model seems to provide a better summary of cross-country data on output, the labor force, and physical and human capital than the augmented Solow model. This interpretation is at least partly confirmed by the results for the alternative augmented Solow model presented in Table 4: For the larger samples, the coefficient on $\ln k$ equals 0.8; using equation (24), and a profit share ($\alpha$) of 0.3, this gives a value for $\gamma$ in the range of 0.6. This is pretty close to the results presented in Table 1 and 2, and almost twice as high as estimated by Mankiw et al. (1992).

Further support for the usefulness of the Rebelo model comes from rather diverse strands of the recent empirical literature which establish a number of stylized facts consistent with the results presented in this paper. First, the finding of aggregate constant returns to scale is confirmed by Backus et al. (1991), who find no significant scale effects in the growth of output per capita; Helliwell, Chung (1992) report slight economies of scale among the industrial countries which are, however, only one seventh as large as suggested by the example calculations reported by Lucas (1988). Second, the finding of diminishing returns to human capital alone is confirmed by independent evidence for the returns to investment in education.[8] Third, the estimated distributional share of physical capital is about the size estimated by the traditional growth accounting framework.[9] Fourth, the empirically robust positive correlation

---

8 For a recent summary, see Psacharopoulos (1993).

9 For a summary, see Maddison (1987).

between the rate of investment in physical capital and the growth rate[10] is predicted by the Rebelo model. Other models of economic growth cannot easily account for this broad spectrum of empirical facts. E.g., Lucas (1988) and Romer (1986) postulate non-diminishing returns to human capital accumulation; Romer (1987) postulates a production elasticity for physical capital higher than its distributional share; and the augmented Solow model (Mankiw et al., 1992) is only compatible with a correlation between investment in physical capital and the growth rate for large and persistent deviations from the steady state.

## 4. Investment and Growth in the Rebelo Model

Many recently developed endogenous-growth models rely on the existence of aggregate economies of scale. While the empirical evidence presented in this paper does not support the existence of aggregate economies of scale, it does not reject endogenous-growth theory in general. The findings in favor of the Rebelo model highlight the dominant role of factors that can be accumulated for an explanation of economic growth, and point to the possible irrelevance of factors that cannot be accumulated. The difference with respect to the (augmented) Solow model is that in the Rebelo model, changes in the investment of physical and human capital have *permanent* effects on the growth rate. Hence the Rebelo model allows for persistent international differences in per capita incomes without taking regress to international difference in technologies and preferences. Such a setting implies that economic policy has a larger role to play: E.g., output losses due to an inappropriate economic policy or due to terms of trade shocks will not be balanced in the long run, as they are in the Solow model. Put differently, the Rebelo model does not exhibit a tendency to return to a previous "steady state" after an external shock, a tendency which is labelled conditional convergence in the (augmented) Solow model.

This conceptional difference between the two models is of minor practical relevance for economic policy if the speed of adjustment towards the steady state is rather low. E.g., with a halfway time of approximately 35 years for a return to the steady state after an exogenous shock,[11] the differences between the models with respect to the impact of changes in investment on the growth rate almost diminish, but become more pronounced with a high speed of adjustment. Recent evidence for the augmented Solow model based on the Mankiw et al. data for investment in human capital (Knight et al., 1992), but allowing for country specific effects by means of panel data estimation, indicates a speed of convergence which is as twice as high. The implication is that the

[10] For time series evidence, see De Long (1991); for cross-country evidence, see Kormendi, Meguire (1985), Levine, Renelt (1992), and Levine, Zervos (1993).

[11] For supporting empirical evidence, see Barro, Sala-i-Martin (1991, 1992) and Mankiw et al. (1992).

long-run impact of changes in investments on the growth rate is substantially reduced for this kind of model.

For the Rebelo model estimated in the previous section, the permanent impact of a change in physical investment on the growth rate can be derived as follows. With constant returns to scale and constant returns to aggregate capital $(\alpha+\gamma=1, \beta=0)$, equation (1) can be rewritten as

$$Y_t = AK_t^{\alpha} H_t^{1-\alpha} . \tag{26}$$

The evolution of $K$ and $H$ is given by equations (17) and (21). Dividing by $K$ and $H$, respectively, results in two expressions for the growth rates of $K$ and $H$, which can be equated to give

$$\frac{s_k}{s_h} = \frac{K}{H}. \tag{27}$$

Hence the Rebelo model of equation (26) converges to a "steady state" were the ratio of the *investments* in physical and human capital equals the ratio of the *stocks* in physical and human capital.

Using equations (27) and, e.g., (17), the common growth rate for output, physical and human capital can be calculated as

$$\frac{\dot{K}}{K} = s_k \left[\frac{s_k H_t}{s_h}\right]^{\alpha-1} H^{1-\alpha} - \delta. \tag{28}$$

Hence the growth rate $(\mu)$ of the Rebelo model (26) is given by

$$\mu = s_k^{\alpha} s_h^{1-\alpha}. \tag{29}$$

This growth rate is positive as long as net investments in aggregate capital are higher than the growth of the labor force.[12] The impact of an increase in investment in physical capital on the growth rate is given by

$$\frac{\partial \mu}{\partial s_k} = A\alpha\left(s_h / s_k\right)^{1-\alpha} = A\alpha\left(H/K\right)^{1-\alpha} = \alpha / \left(K/Y\right). \tag{30}$$

With a profit share of about 0.3, and an approximate physical capital output ratio of 3 (the approximate average for, e.g., the United States and Germany), the Rebelo model (26) predicts that an increase in the rate of physical investment by 1 percentage point permanently increases the growth rate by 0.1 percentage points.

---

[12] For a graphical exposition, see Sala-i-Martin (1990).

For the impact of human capital investment on the growth rate, a similar prediction cannot be made since at present only internationally comparable *proxies* for the stock of human capital exist. Following Davies and Whalley (1989), however, who review the empirical literature and suggest that the stock of human capital is about three times as large as the stock of physical capital, the Rebelo model (26) predicts that the impact of an increase in the investment rate of human capital on the growth rate is somewhat smaller, because

$$\frac{\partial \mu}{\partial s_h} = (1-\alpha)/(H/Y). \tag{31}$$

## 5. Conclusion

Recent developments in the theory of economic growth provide a large number of competing endogenous-growth models. Many of these new models postulate the existence of aggregate economies of scale, and many stress the importance of human capital accumulation for an explanation of economic growth. Contrary to the theoretical developments, Mankiw et al. (1992) demonstrate that a human capital augmented Solow model seems to explain a large fraction of the observed variance in cross-country per capita output.

This paper shows that the Mankiw et al. (1992) results are not robust with respect to the proxy for human capital. Using two recently developed cross-country data series for the average years of schooling as a proxy for the stock of human capital, and a general production function framework which allows for increasing returns to scale, the Rebelo model is found to be consistent with the data. The estimation of alternative specifications reveals that the human capital proxy used by Mankiw et al. (1992) may suffer from a systematic bias. Therefore, the Rebelo model cannot easily be dismissed despite the relatively small fraction of the observed variance in cross-country output that is explained, especially because it is consistent with a number of stylized empirical facts established by rather diverse strands of the literature.

The results in favor of the Rebelo model do not support the existence of aggregate economies of scale, neither to the accumulation of physical capital as suggested by Romer (1987), nor to the accumulation of human capital as suggested by Lucas (1988). But due to the property of constant returns to aggregate capital, the Rebelo model is an endogenous-growth model. The policy implication derived from endogenous-growth models is that changes in investment in physical and human capital have a permanent impact on the growth rate. For reasonable parameterizations, the Rebelo model predicts a 0.1 percentage point increase in the growth rate as a result of a one percentage point increase in the rate of investment in physical capital. Tentative back-of-the-envelope

calculations suggest somewhat larger effects on the growth rate for a change in the rate of investment in physical capital than for a change in the rate of investment in human capital.

Future research should be directed at incorporating the apparently large cross-country variance in e.g., tax policies, education policies, political stability, and population growth. In contrast to Mankiw et al. (1992), I expect that the Rebelo model will provide a good starting point for understanding how these determinants influence a country's level of per capita output.

**References**

Backus, David K., Patrick J. Kehoe, Timothy J. Kehoe, "In Search of Scale Effects in Trade and Growth". Journal of Economic Theory, Vol. 58, 1992, pp. 377-409.

Barro, Robert J., Xavier Sala-i-Martin, "Convergence across States and Regions". Brookings Papers on Economic Activity, No. 1, 1991, pp. 107-158.

--, --, "Convergence". Journal of Political Economy, Vol. 100, 1992, pp. 223-251.

--, Jong-Wha Lee, International Comparisons of Educational Attainment. World Bank conference paper. Washington, D.C., February 1993.

Brander, James A., "Comparative Economic Growth: Evidence and Interpretation". Canadian Journal of Economics, Vol. 25, 1992, pp. 792-818.

Davies, James, John Whalley, "Taxes and Capital Formation: How Important is Human Capital?" In: B. Douglas Bernheim, John B. Shoven, National Saving and Economic Performance. Chicago 1991, pp. 163-197.

De Long, J. Bradford, Machinery Accumulation and Productivity Growth in the Very Long Run: A Five Nation Look. Harvard Institute of Economic Research, Discussion Paper No. 1551, Cambridge, Mass., 1991.

Grossman, Gene, M., Elhanan Helpman, Innovation and Growth in the Global Economy. Cambridge, Mass., 1991.

Helliwell, John F., Alan Chung, Convergence and Growth Linkages between North and South. NBER Working Paper 3948. Cambridge, Mass., 1992.

Knight, Malcom, Norman Loayza, Delano Villanueva, Testing the Neoclassical Theory of Economic Growth: A Panel Data Approach. IMF Working Paper 106. Washington, D.C., 1992.

Kormendi, Roger C., Philip G. Meguire, "Macroeconomic Determinants of Growth. Cross-Country Evidence". Journal of Monetary Economics, Vol. 16, 1985, pp. 141-163.

Levine, Ross, David Renelt, "A Sensivity Analysis of Cross-Country Growth Regressions". The American Economic Review, Vol. 82, 1992, No. 4, pp. 942-963.

--, Sara Zervos, Looking at the Facts. What We Know about Policy and Growth from Cross-Country Analysis. Word Bank Policy Research Working Paper WPS 1115. Washington, D.C., 1993.

Lucas, Robert E., Jr., "On the Mechanics of Economic Development". Journal of Monetary Economics, Vol. 22, 1988, pp. 3-42.

Maddison, Angus, "Growth and Slowdown in Advanced Capitalist Economies. Techniques of Quantitative Assessment". Journal of Economic Literature, Vol. 25, 1987, pp. 649-698.

Mankiw, N. Gregory, David Romer, David N. Weil, "A Contribution to the Empirics of Economic Growth". The Quarterly Journal of Economics, Vol. 107, 1992, pp. 408-437.

Psacharopoulos, George, Returns to Investment in Education. A Global Update. World Bank Policy Research Working Paper WPS 1067. Washington, D.C., 1993.

--, Ana Maria Arriagada, "The Educational Composition of the Labour Force: An International Update". Journal of Educational Planning and Administration, Vol. 6, 1992, No. 2, pp. 141-159.

Rebelo, Sergio, "Long-Run Policy Analysis and Long-Run Growth". Journal of Political Economy, Vol. 99, 1991, pp. 500-521.

Romer, Paul M., "Increasing Returns and Long-Run Growth". Journal of Political Economy, Vol. 94, 1986, pp. 1002-1037.

--, "Crazy Explanations for the Productivity Slowdown". NBER Macroeconomics Annual, 1987, pp. 163-210.

--, "Increasing Returns and New Developments in the Theory of Growth". In: William Barnett et al., Equilibrium Theory and Applications. Cambridge 1991. pp. 83-100.

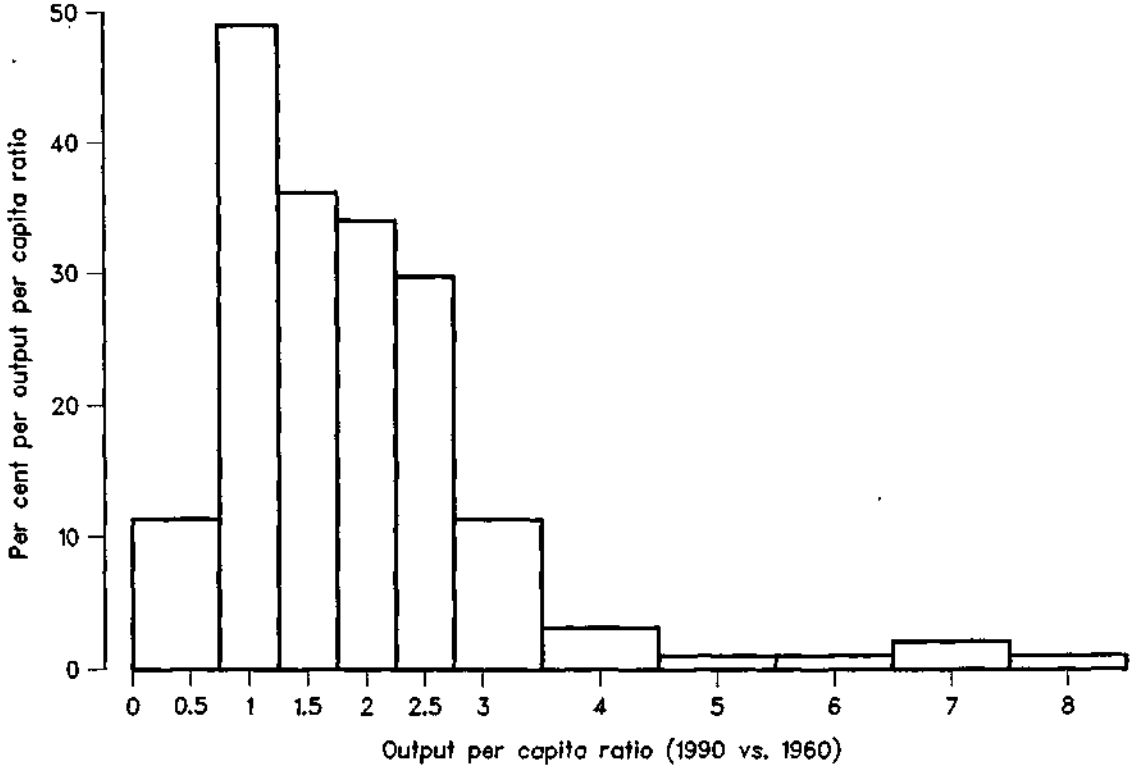
Sala-i-Martin, Xavier, Lecture Notes on Economic Growth. NBER Working Papers 5363 and 5364. Cambridge, Mass., 1990.

Shaw, Graham K., "Policy Implications of Endogenous Growth Theory". The Economic Journal, Vol. 102, 1992, pp. 611-621.

Solow, Robert M., "A Contribution to the Theory of Economic Growth". The Quarterly Journal of Economics, Vol. 70, 1956, pp. 65-94.

Summers, Robert, Alan Heston, "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-88". The Quarterly Journal of Economics, Vol. 106, 1991, pp. 327-368.

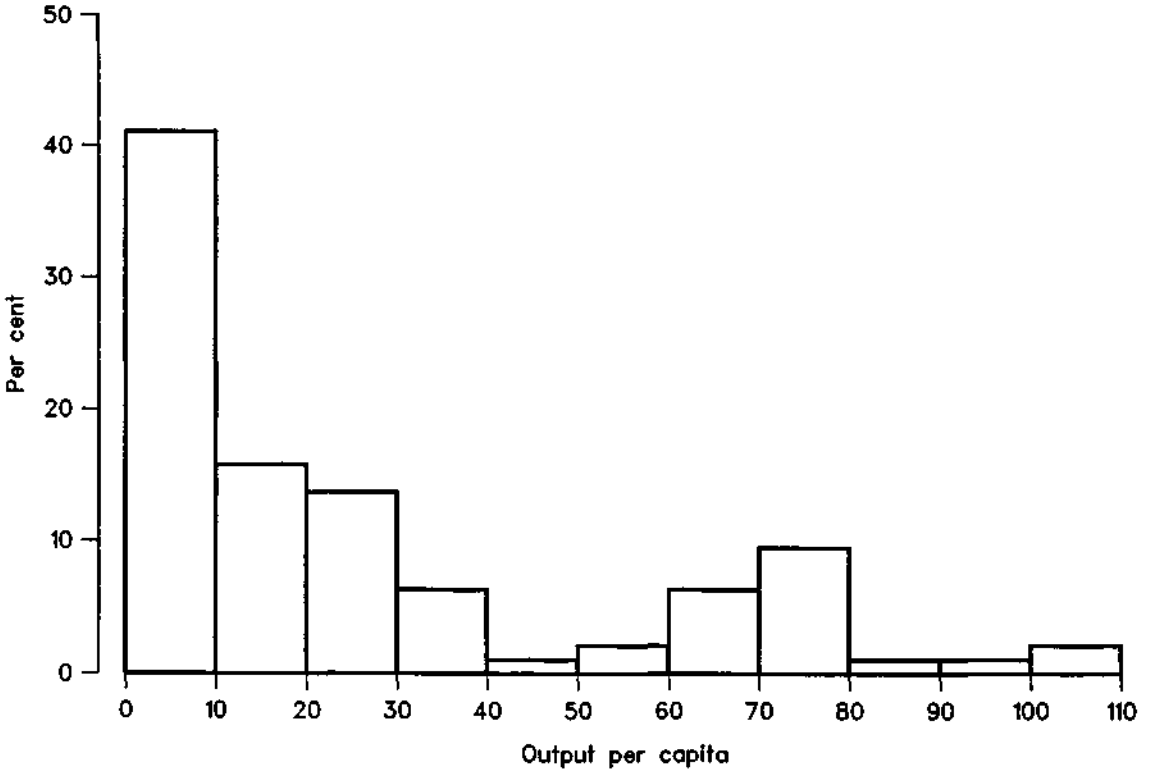
Figure 1 – The Cross-Country Dispersion of Economic Growth, 1960–1990[a]




[a] Countries with populations of more than 1 million (mid 1990), countries with oil production as the dominant industry excluded; total number of countries: 94.

Source: Summers, Heston (1991); World Bank (1992).

Figure 2 – The Cross–Country Dispersion of Output per Capita, 1990[a]




[a] Countries with populations of more than 1 million (mid 1990), countries with oil production as the dominant industry excluded; total number of countries: 95; USA = 100.

Source: World Bank (1992).

Table 1 - Estimation of the General Model

| Dependent variable: ln GDP in 1985 | | | | |
|---|---|---|---|---|
| Sample: PWT 5 | All countries | | "D" countries excluded | |
| Observations: | 89[a] | 45[b] | 62[a] | 38[b] |
| Constant | 6.09 | 6.55 | 7.07 | 5.75 |
| | (1.07) | (1.13) | (1.18) | (1.13) |
| $\ln s_k$ | 0.22 | 0.40 | 0.37 | 0.13 |
| | (0.13) | (0.18) | (0.21) | (0.23) |
| $\ln(n+\delta)$ | -0.70 | -0.69 | -0.52 | -0.64 |
| | (0.34) | (0.35) | (0.35) | (0.34) |
| $\ln h$ | 1.01 | 0.93 | 1.03 | 1.19 |
| | (0.11) | (0.15) | (0.17) | (0.18) |
| $\ln L$ | 0.97 | 0.94 | 0.95 | 0.95 |
| | (0.04) | (0.05) | (0.04) | (0.04) |
| $\bar{R}^2$ | 0.90 | 0.92 | 0.90 | 0.94 |
| s.e.e. | 0.55 | 0.42 | 0.48 | 0.37 |
| Restricted regression: | | | | |
| Constant | 7.40 | 7.38 | 7.44 | 6.93 |
| | (0.39) | (0.49) | (0.44) | (0.50) |
| $\ln s_k - \ln(n+\delta)$ | 0.29 | 0.47 | 0.42 | 0.30 |
| | (0.12) | (0.16) | (0.16) | (0.18) |
| $\ln h$ | 1.01 | 0.94 | 1.03 | 1.21 |
| | (0.11) | (0.15) | (0.17) | (0.18) |
| $\ln L$ | 0.98 | 0.95 | 0.95 | 0.96 |
| | (0.04) | (0.05) | (0.04) | (0.04) |
| $\bar{R}^2$ | 0.89 | 0.92 | 0.90 | 0.94 |
| s.e.e. | 0.55 | 0.42 | 0.48 | 0.37 |
| F-Test Statistic | 1.74 | 0.52 | 0.11 | 1.36 |
| p-value | 0.19 | 0.47 | 0.74 | 0.25 |
| implied $\alpha$ | 0.22 | 0.32 | 0.29 | 0.23 |
| | (0.08) | (0.07) | (0.08) | (0.10) |
| implied $\beta$ | -0.02 | 0.01 | -0.06 | -0.19 |
| | (0.10) | (0.11) | (0.13) | (0.16) |
| implied $\gamma$ | 0.78 | 0.64 | 0.73 | 0.93 |
| | (0.15) | (0.16) | (0.19) | (0.25) |
| deviation from constant returns to scale | -0.02 | -0.05 | -0.05 | -0.04 |
| | (0.04) | (0.05) | (0.04) | (0.04) |
| deviation from constant returns to capital | 0.006 | -0.04 | 0.02 | 0.16 |
| | (0.09) | (0.10) | (0.12) | (0.16) |

Note: Standard errors in parentheses. - [a]$h$ (average years of schooling) taken from Barro, Lee (1993). - [b]$h$ (average years of schooling) taken from Psacharopoulos, Arriagada (1992).

Table 2 - Estimation of the Rebelo Model

| Dependent variable: ln GDP in 1985 | | | | |
|---|---|---|---|---|
| Sample: PWT 5 | All countries | | "D" countries excluded | |
| Observations: | 89[a] | 45[b] | 62[a] | 38[b] |
| Constant | 8.14 | 8.67 | 8.87 | 8.84 |
| | (0.49) | (0.58) | (0.58) | (0.58) |
| $\ln s_k$ | 0.29 | 0.50 | 0.55 | 0.53 |
| | (0.10) | (0.14) | (0.17) | (0.18) |
| $\ln h + \ln L$ | 0.99 | 0.96 | 0.97 | 0.99 |
| | (0.04) | (0.05) | (0.04) | (0.05) |
| $\bar{R}^2$ | 0.89 | 0.91 | 0.90 | 0.93 |
| s.e.e. | 0.56 | 0.44 | 0.49 | 0.40 |
| Restricted regression: Dependent variable: ln GDP per human capital in 1985 | | | | |
| Constant | 8.05 | 8.23 | 8.49 | 8.29 |
| | (0.19) | (0.24) | (0.28) | (0.29) |
| $\ln s_k$ | 0.28 | 0.48 | 0.52 | 0.53 |
| | (0.10) | (0.14) | (0.16) | (0.18) |
| $\bar{R}^2$ | 0.07 | 0.20 | 0.13 | 0.17 |
| s.e.e. | 0.56 | 0.43 | 0.48 | 0.39 |
| F-Test Statistic | 0.03 | 0.70 | 0.57 | 0.08 |
| p-value | 0.85 | 0.41 | 0.45 | 0.78 |
| implied $\alpha$ | 0.22 | 0.33 | 0.34 | 0.35 |
| | (0.06) | (0.06) | (0.07) | (0.08) |

Note: Standard errors in parentheses. - [a]$h$ (average years of schooling) taken from Barro, Lee (1993). - [b]$h$ (average years of schooling) taken from Psacharopoulos, Arriagada (1992).

Table 3 - Estimation of an Alternative Rebelo Model

| Dependent variable: ln GDP in 1985 | | |
|---|---|---|
| Sample: PWT 5 | All countries | "A" and "B" countries only |
| Observations: | 29 | 19 |
| Constant | -0.16<br>(0.98) | -1.14<br>(1.34) |
| $\ln s_h$ | -0.54<br>(0.15) | -0.52<br>(0.41) |
| $\ln k + \ln L$ | 0.93<br>(0.04) | 0.98<br>(0.04) |
| $\bar{R}^2$ | 0.96 | 0.96 |
| s.e.e. | 0.28 | 0.26 |
| Restricted regression:<br>Dependent variable: ln GDP per physical capital in 1985 | | |
| Constant | -1.83<br>(0.34) | -1.53<br>(0.95) |
| $\ln s_h$ | -0.69<br>(0.13) | -0.53<br>(0.40) |
| $\bar{R}^2$ | 0.50 | 0.04 |
| s.e.e. | 0.29 | 0.26 |

Note: Standard errors in parentheses; $s_h$ (percentage of the labor force in secondary school) taken from Mankiw et al. (1992).

Table 4 - Estimation of an Alternative Augmented Solow Model

| Dependent variable: ln GDP per worker in 1985 | | |
|---|---|---|
| Sample: PWT 5 | All countries | "A" and "B" countries only |
| Observations: | 29 | 19 |
| Constant | 2.36 | 3.12 |
| | (0.99) | (2.04) |
| $\ln s_k$ | -0.19 | -0.42 |
| | (0.16) | (0.43) |
| $\ln(n+\delta)$ | 0.30 | 0.21 |
| | (0.29) | (0.38) |
| $\ln k$ | 0.80 | 0.57 |
| | (0.08) | (0.64) |
| $\bar{R}^2$ | 0.92 | 0.39 |
| s.e.e. | 0.23 | 0.23 |
| Restricted regression: | | |
| Constant | 2.09 | 3.71 |
| | (0.66) | (1.64) |
| $\ln s_k - \ln(n+\delta)$ | -0.21 | -0.29 |
| | (0.15) | (0.34) |
| $\ln k$ | 0.79 | 0.64 |
| | (0.08) | (0.17) |
| $\bar{R}^2$ | 0.93 | 0.42 |
| s.e.e. | 0.22 | 0.22 |

Note: Standard errors in parentheses; $s_k$ (percentage of the labor force in secondary school) taken from Mankiw et al. (1992).

Appendix

| Country | Quality rating | Real GDP per worker, 1985 (1985 international prices) | Working age population, 1985 (millions) | Growth rate of working age population, 1960-85 (per cent per year) | Average years of schooling BL, 1985 | PA | Year | Average real gross domestic investment, 1960-85 (% of real GDP) | Real capital stock per worker, 1985 (1985 international prices) |
|---|---|---|---|---|---|---|---|---|---|
| Algeria | D | 14,417 | 4.834 | 2.6 | 2.31 | 4.2 | 1985 | 25.7 | . |
| Benin | D+ | 2,271 | 1.964 | 2.4 | 0.98 | . | . | 5.6 | . |
| Botswana | C | 7,175 | 0.381 | 3.2 | 2.59 | 4.2 | 1984 | 23.9 | . |
| Cameroon | C- | 4,614 | 3.958 | 2.1 | 2.28 | . | . | 10.3 | . |
| Central Africa. Rep. | D | 1,408 | 1.262 | 1.7 | 1.28 | . | . | 8.5 | . |
| Congo | D+ | 7,024 | 0.710 | 2.4 | 3.14 | . | . | 14.5 | . |
| Egypt | D+ | 7,161 | 12.836 | 2.5 | 3.22 | 2.4 | 1986 | 6.2 | . |
| Ethiopia | D+ | 715 | 13.505 | 2.3 | . | 6.0 | 1984 | 4.7 | . |
| Ghana | D+ | 2,166 | 4.964 | 2.3 | 2.64 | . | . | 7.8 | . |
| Kenya | C | 2,050 | 8.389 | 3.4 | 2.60 | 3.5 | 1980 | 14.5 | 1,300 |
| Liberia | D | 2,542 | 0.808 | 3.0 | 1.58 | . | . | 29.5 | . |
| Malawi | D+ | 1,378 | 3.075 | 2.4 | 2.33 | . | . | 12.6 | . |
| Mali | D+ | 1,382 | 2.598 | 2.2 | 0.79 | . | . | 6.3 | . |
| Mauritius | D+ | 9,823 | 0.390 | 2.6 | 4.56 | . | . | 11.8 | . |
| Morocco | C- | 6,670 | 6.676 | 2.5 | . | 2.9 | 1986 | 8.5 | . |
| Mozambique | D | 1,494 | 7.671 | 2.7 | 0.99 | 1.2 | 1980 | 12.8 | . |
| Niger | D | 1,247 | 3.203 | 2.6 | 0.55 | . | . | 9.1 | . |
| Rwanda | D+ | 1,438 | 3.063 | 2.8 | 1.33 | . | . | 4.3 | . |
| Senegal | C- | 2,620 | 2.898 | 2.3 | 2.12 | . | . | 7.3 | . |
| Sierra Leone | D+ | 2,751 | 1.352 | 1.6 | 1.72 | . | . | 2.3 | . |
| South Africa | C- | 12,855 | 10 831 | 2.3 | 4.95 | . | . | 26.2 | . |
| Sudan | D | 2,952 | 69 869 | 2.6 | 0.91 | . | . | 1.8 | . |
| Tanzania | C- | 978 | 10.916 | 2.9 | 2.28 | . | . | 19.3 | . |
| Togo | D | 1,624 | 1 244 | 2.5 | 2.08 | . | . | 16.8 | . |
| Tunisia | C- | 10,134 | 2.224 | 2.4 | 2.50 | 4.8 | 1985 | 15.6 | . |
| Uganda | D | 895 | 7.053 | 3.1 | 1.58 | . | . | 4.0 | . |
| Zaire | D | 942 | 11.672 | 2.4 | 2.24 | . | . | 9.2 | . |
| Zambia | D+ | 2,279 | 2.242 | 2.7 | 3.91 | . | . | 30.2 | . |
| Zimbabwe | C- | 3,535 | 3.410 | 2.8 | 2.55 | . | . | 18.0 | 1,997 |
| Canada | A- | 29,947 | 12.723 | 2.0 | 10.37 | 12.4 | 1987 | 22.5 | 39,491 |
| Costa Rica | C | 9,342 | 0.904 | 3.5 | 5.35 | . | . | 13.6 | . |
| Dominican Rep. | C | 7,240 | 1.862 | 2.9 | 4.35 | . | . | 14.0 | 5,294 |
| El Salvador | C | 4,596 | 1.832 | 3.3 | 3.52 | . | . | 7.8 | . |
| Guatemala | C | 7,748 | 2.261 | 3.1 | 2.50 | . | . | 9.6 | 3,281 |
| Haiti | D | 1,939 | 2.822 | 1.3 | 1.64 | 1.6 | 1982 | 6.6 | . |
| Honduras | C | 4,171 | 1.303 | 3.1 | 3.56 | 4.5 | 1989 | 13.4 | . |
| Jamaica | C | 5.079 | 1.095 | 1.6 | 4.21 | . | . | 22.3 | . |
| Mexico | C | 16,054 | 26.080 | 3.3 | 4.09 | . | . | 20.1 | . |
| Nicaragua | D | 6,228 | 0 999 | 3.3 | 3.13 | . | . | 18.4 | . |
| Panama | C | 10,484 | 0.760 | 3.0 | 6.31 | . | . | 25.0 | . |
| Trinidad & Tobago | C | 19,592 | 0.450 | 1.9 | 6.50 | 6.6 | 1980 | 19.6 | . |
| USA | A | 34,374 | 116.801 | 1.5 | 11.78 | 13.0 | 1988 | 17.0 | 31,041 |
| Argentina | C | 11,097 | 10.884 | 1.5 | 6.61 | . | . | 12.2 | 10,141 |
| Bolivia | C | 5.021 | 1.987 | 2.4 | 4.28 | . | . | 17.7 | . |
| Brazil | C- | 10,910 | 49.641 | 2.9 | 3.48 | 6.4 | 1980 | 20.1 | . |
| Chile | C | 10,667 | 4.276 | 2.3 | 6.25 | 8.1 | 1981 | 13.4 | 7,768 |
| Colombia | C | 10.199 | 9 195 | 3.0 | 4.56 | . | . | 17.5 | 9,108 |
| Ecuador | C | 9.167 | 2.839 | 2.8 | 5.67 | 6.5 | 1982 | 25.3 | . |
| Paraguay | C | 7,081 | 1.220 | 2.7 | 4.80 | . | . | 11.1 | . |
| Peru | C | 8,529 | 6.204 | 2.9 | 5.74 | 7.0 | 1981 | 16.0 | . |
| Uruguay | C- | 13.351 | 1.171 | 0.6 | 6.56 | . | . | 15.9 | . |
| Venezuela | C | 16,695 | 5 871 | 3.8 | 5.37 | . | . | 16.7 | . |
| Afghanistan | D | 2,606 | 4.970 | 1.6 | 0.97 | . | . | 6.4 | . |
| Bangladesh | C- | 2,441 | 28.846 | 2.6 | 2.04 | 2.4 | 1981 | 5.9 | . |
| Burma(Myanmar) | D | 1.458 | 18.698 | 1.7 | 2.04 | 0.0 | . | 11.6 | . |
| Hong Kong | B- | 19,385 | 2.866 | 3.0 | 7.51 | 9.1 | 1988 | 21.2 | . |
| India | C | 1,816 | 293.250 | 2.4 | 3.36 | 1.9 | 1981 | 16.6 | 1,519 |
| Indonesia | C | 4,423 | 63.425 | 1.9 | 3.56 | 5.0 | 1988 | 17.5 | . |
| Israel | B | 24,433 | 1.610 | 2.8 | 9.30 | 11.3 | 1983 | 27.2 | 20,095 |
| Japan | A | 21,780 | 59.773 | 1.2 | 8.34 | . | . | 31.1 | 45,354 |
| Jordan | D | 11,984 | 0.799 | 2.7 | 4.04 | 5.9 | 1987 | 16.4 | . |
| Korea, Rep. of | B- | 9.434 | 16.790 | 2.7 | 7.85 | 8.0 | 1980 | 24.3 | 14,520 |
| Malaysia | C | 12,073 | 6.171 | 3.2 | 5.02 | 7.0 | 1986 | 28.4 | . |
| Nepal | D+ | 1.771 | 6.869 | 2.0 | 0.62 | . | . | 9.9 | . |
| Pakistan | C- | 4,686 | 29.802 | 3.0 | 1.92 | . | . | 16.4 | . |
| Philippines | C | 4,912 | 19.875 | 3.0 | 6.50 | 7.0 | 1980 | 19.7 | 2,942 |
| Singapore | C | 21,735 | 1.226 | 2.6 | 4.65 | . | . | 29.2 | . |
| Sri Lanka | C- | 5,249 | 5.920 | 2.4 | 5.46 | 4.5 | 1981 | 21.0 | . |
| Syria | C- | 20,207 | 2.596 | 3.0 | 3.96 | . | . | 16.9 | . |
| Taiwan | D- | 11,387 | 7.651 | 3.0 | 7.00 | 9.0 | 1988 | 22.9 | . |
| Thailand | C- | 4,878 | 26.657 | 3.1 | 4.87 | . | . | 15.0 | 2,792 |
| Austria | A- | 22,189 | 3 504 | 0.4 | 5.79 | 12.9 | 1987 | 27.2 | 27,320 |
| Belgium | A | 25.194 | 4.092 | 0.5 | 9.11 | 10.5 | 1986 | 23.2 | 41,964 |
| Denmark | A- | 22,006 | 2.784 | 0.6 | 10.38 | 8.6 | 1981 | 28.4 | 29,039 |
| Finland | A- | 22.143 | 2.488 | 0.7 | 9.54 | 8.5 | 1980 | 34.7 | 44,367 |
| France | A | 25,472 | 24.639 | 1.0 | 6.54 | 6.2 | 1982 | 26.1 | 37,040 |
| Germany, Fed. Rep. | A | 24,175 | 29,403 | 0.5 | 8.61 | 10.4 | 1982 | 27.2 | 36,600 |
| Greece | A- | 14,989 | 3.780 | 0.7 | 6.64 | 7.9 | 1981 | 26.3 | 15,305 |
| Ireland | A- | 15.475 | 1.367 | 1.1 | 7.84 | . | . | 26.9 | 23,484 |
| Italy | A | 26,569 | 22.763 | 0.6 | 5.78 | 10.2 | 1987 | 28.3 | 32,260 |
| Netherlands | A | 27,041 | 5.851 | 1.4 | 8.60 | 11.0 | 1987 | 24.5 | . |
| Norway | A- | 27,486 | 2.039 | 0.7 | 10.31 | 11.0 | 1987 | 33.0 | 48,175 |
| Portugal | A- | 10,095 | 4.563 | 0.6 | 3.70 | 9.5 | 1987 | 23.7 | . |
| Spain | A- | 16,056 | 13.725 | 1.0 | 5.58 | 10.4 | 1987 | 26.5 | 25,114 |
| Sweden | A- | 24,402 | 4.237 | 0.4 | 9.33 | 12.4 | 1987 | 22.9 | 24,498 |
| Switzerland | B+ | 29,351 | 3 173 | 0.8 | 7.99 | 12.7 | 1986 | 29.8 | . |
| Turkey | C | 7,538 | 21.394 | 2.5 | 3.18 | . | . | 20.8 | . |
| United Kingdom | A | 22.041 | 27.432 | 0.3 | 8.51 | 12.2 | 1987 | 18.0 | 21,633 |
| Australia | A- | 26,855 | 7.364 | 2.0 | 10.22 | 12.3 | 1987 | 28.5 | 29,436 |
| New Zealand | A- | 22,578 | 1.458 | 1.7 | 11.21 | 11.7 | 1981 | 21.8 | . |
| Papua New Guinea | D | 3,478 | 1.685 | 2.1 | 1.38 | . | . | 24.2 | . |

Source: Barro, Lee (1993); Mankiw et al. (1992); Psacharopoulos, Arriagada (1992); Summers, Heston (1991).