From Which Side to the Steady State of the Augmented Solow Model?

The Role of Country-Specific Total Factor Productivity Growth Rates

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Abstract

The human capital-augmented Solow model (Mankiw *et al.*, 1992) has been criticized by Cho and Graham (1996) by stating that half of all countries converge to their steady state from above, i.e. from income levels above those obtained in their steady state. This is clearly at odds with the general idea that countries approach their steady state from a backward position. In this paper we will argue that this result is primarily due to the assumption of an identical exogenous rate of technological progress for all countries. Once different rates of technological progress are introduced into the model, the number of countries approaching their steady state from above is reduced to a number more in line with what the augmented Solow model would predict. However, for a sample consisting of 98 non-oil countries, the assumption of constant returns to scale has to be rejected. For the non-oil sample our analysis thus both supports and challenges the human capital-augmented Solow model. For a more limited sample consisting of 22 OECD countries, the results clearly support the augmented Solow model by both reducing the number of countries converging from above their steady state to zero and by accepting the assumption of constant returns to scale.

1. Introduction

Mankiw, Romer and Weil (1992; from here on abbreviated as MRW) have augmented the Solow (1956) growth model by including human capital. They estimated the Solow model using a linear approximation of the transition process towards the steady state. Cho and Graham (1996; from here on abbreviated as CG) criticize MRW by pointing out that 49 of the 98 countries in MRW's non-oil sample approach the steady state from per capita income levels that are above those of the steady state; this result is somewhat at odds with the usual story that countries converge from being poor to their steady state.

In this paper we start out from the suspicion that this somewhat surprising result is due to the fact that CG have assumed a common rate of labor-augmenting technological progress of 2% for all 98 countries in the non-oil sample. However, the empirical research of Young (1994) yielded zero total factor productivity (TFP) growth for 52 out of the 118 countries of the Summers and Heston (1988) data set. In the light of these results one might guess that for about half of all countries the rate of technological progress is zero rather than 2%. In a Solow model a technological progress rate of 2% yields a lower steady-state value of the capital-labor ratio than a rate of zero. Therefore, the hypothesis of this paper is that getting the rates of technological progress right would bring many countries from values larger than the steady state to values lower than the steady state simply because the steady-state values for the capital-labor ratio are increased for many countries with rates of technological progress lower than 2%.

To see whether or not this hypothesis is correct we will recalculate the CG results by substituting country-specific rates of technological progress. First, in section 2, we use Young's TFP data to obtain rates of labor-augmenting technological progress. By replacing the value of 2% used by CG by these rates, and re-estimating the model and finally recalculating the steady state per capita income levels, we reduce the number of countries that approach the steady state from the 'wrong' side. However, the reduction is only a minor from 49 to 43 countries in the non-oil sample, which is still quite a few more countries than one might expect. For our second sample, including 22 OECD countries, this number even increases from 4 to 7.

In section 3 we will discuss a number of problems using Young's TFP growth rates. Taking these problems into account, we then calculate an alternative set of TFP growth rates using the Summers and Heston data set. In section 4 we use these new TFP growth rates to re-estimate the MRW model and to recalculate the results of CG, showing that 35 countries approach their steady state per capita income level from above. For the OECD sample, this number even decreases to only 2. Although particularly for the non-oil sample the result is far from perfect, this result is closer to what one would expect from a Solowian perspective.

In section 5 we will extend the analysis by including changes in human capital endowments in the calculation of TFP growth rates. We will consider two different proxies for human capital growth: changes in the enrollment ratio for secondary education and changes in the average years of secondary education. The latter is the bext proxy both theoretically and empirically. For the non-oil sample, the number of countries approaching their steady state from above will be reduced to only 25. For the OECD sample we see no improvement, as there are still 2 countries converging from above.

Although the augmented Solow model predicts a negative sign for the variable including labor growth and technological progress, our empirical results show the opposite, i.e. a positive sign. As this might be due to a model misspecification, we drop the assumption of constant returns to scale (abbreviated to CRS) in section 6. CRS can now only be obtained by introducing so-called '*B*-type technological change', which is composed of the standard concept of technological change and labor growth. Using human capital-adjusted TFP growth rates, the number of countries approaching their steady state from above is reduced to 22 in the non-oil sample. For the OECD sample we find a perfect result as all countries approach their steady state from below.

In section 7 we explicitly test for CRS by estimating a set of restricted regressions. Although the results improve for the non-oil sample because the number of countries approaching from above is reduced to 16, the regression results force us to reject the assumption of CRS for this sample. The assumption of CRS can be confirmed for the OECD sample.

In section 8 we will draw conclusions based on the analyses of the previous sections. For the non-oil sample, our results provide both support and a challenge for the augmented Solow model. The model is supported by the reduced number of countries approaching their steady state from above. However, one of the basic assumptions of the augmented Solow model, the assumption of CRS, has to be strongly rejected. For the OECD sample, the support is more convincing as both the assumption of CRS cannot be rejected, and the number of countries approaching their steady state from above is reduced to zero.

2. The Solow-MRW Model: Manipulations and Empirical Results by Cho and Graham

MRW have augmented the standard Solow model by adding human capital to the production function and by adding a human capital accumulation function. This augmented Solow-MRW model consists of the following three equations:

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta} \tag{1a}$$

$$\dot{k}_t = s_k y_t - (n+g+\delta) k_t \tag{1b}$$

$$\dot{h}_t = s_h y_t - (n+g+\delta) h_t \tag{1c}$$

where Y is output, K physical capital, H human capital, L labor, and A the level of technology. The production function assumes CRS in all production inputs. Both labor and technology are assumed to grow exogenously at rates n and g. Both physical and human capital are accumulated by investing a fraction s_k and s_h of output respectively, and both are assumed to depreciate at the rate δ. The accumulation functions are expressed in units of effective labor: $y = Y/AL$, $k = K/AL$ and $h = H/AL$. MRW solve this model in order to find the solution for the level of steady state per capita income at time t, $y_t^* = Y_t/L_t$:

$$\ln(y_t^*) = \ln(A_0) + gt - \left(\frac{\alpha+\beta}{1-\alpha-\beta} \right) \ln(n+g+\delta) + \left(\frac{\alpha}{1-\alpha-\beta} \right) \ln(s_k) + \left(\frac{\beta}{1-\alpha-\beta} \right) \ln(s_h) \tag{2}$$

CG manipulate the human capital-augmented Solow-MRW model to estimate steady state per capita income in the base year, i.e. y_0^*. Using MRW's equation (2), they approximate the model around the steady state[1]:

$$\frac{d\ln(y_t)}{dt} = g + \lambda\left(\ln(y_t^*) - \ln(y_t)\right) \tag{3}$$

where $\lambda = (n+g+\delta)/(1-\alpha-\beta)$ is the rate of convergence, in order to find the following relation for per capita income growth:

$$\ln(y_t) - \ln(y_0) = \alpha_0 + \alpha_1\ln(y_0) + \alpha_2\ln(n+g+\delta) + \alpha_3\ln(s_k) + \alpha_4\ln(s_h) \tag{4}$$

where the α parameters are defined as: $\alpha_0 = gt + (1-e^{-\lambda t})\ln(A_0)$, $\alpha_1 = -(1-e^{-\lambda t})$, $\alpha_2 = -(1-e^{-\lambda t})(\alpha+\beta)/(1-\alpha-\beta)$, $\alpha_3 = (1-e^{-\lambda t})\alpha/(1-\alpha-\beta)$, and $\alpha_4 = (1-e^{-\lambda t})\beta/(1-\alpha-\beta)$.

Equation (4) can now be used to estimate the parameters α_0, α_1, α_2, α_3 and α_4.[2] These are then substituted in equation (5)[3] to calculate steady state per capita income in the base year:

$$\ln(y_0^*) = -\frac{\alpha_0 - gt + \alpha_2\ln(n+g+\delta) + \alpha_3\ln(s_k) + \alpha_4\ln(s_h)}{\alpha_1} \tag{5}$$

Using the regression results from MRW's sample of 98 non-oil countries for the period 1960 - 1985[4], and assuming an exogenous growth rate of technological change *g* of 2%, CG calculate the steady-state levels of per capita income for these countries in 1960. It turns out that half of all countries approached their 1960 steady state from above, i.e. the estimated y_0^* was above real

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[1] Note that in the original MRW model, the *g* in equation (3) is not included.

[2] Note that the model predicts that $\alpha_0 > 0$, $\alpha_1 < 0$, $\alpha_2 < 0, \alpha_3 > 0$ and $\alpha_4 > 0$.

[3] The procedure to derive this equation is similar to that of deriving equation (3b') in Cho and Graham (1996).

[4] These regression results are given in Table 1.

per capita income for only 49 countries. Moreover, Cho and Graham conclude that there is a difference between rich and poor countries: "[o]n average, relatively poor countries converge to their steady-state position *from above*, while rich countries converge from below". Of the 22 OECD countries in this sample, there are indeed only 5 countries which were above their 1960 steady state: Canada, New Zealand, Switzerland, the UK, and the US.

Table 1 'Steady-state' regression results: Cho & Graham and Young's TFP data

		α_0	α_1	α_2	α_3	α_4	$\bar{R}^2$	#
	Non-oil							
(1)	MRW-CG	3.022 (3.651)	-0.288 (-4.683)	-0.506 (-1.752)	0.524 (6.029)	0.231 (3.887)	0.463	49 (98)
(2)	Young	3.991 (7.109)	-0.143 (-2.413)	0.419 (4.093)	0.474 (5.749)	0.139 (2.408)	0.530	43 (98)
	OECD							
(3)	MRW-CG	2.755 (2.294)	-0.398 (-5.668)	-0.863 (-2.557)	0.332 (1.914)	0.228 (1.570)	0.651	4 (22)
(4)	Young	5.064 (5.295)	-0.363 (-4.331)	0.157 (0.933)	0.327 (1.583)	0.126 (0.751)	0.541	7 (22)

Regression equation: $\ln(y_t) - \ln(y_0) = \alpha_0 + \alpha_1 \ln(y_0) + \alpha_2 \ln(n+g+\delta) + \alpha_3 \ln(s_k) + \alpha_4 \ln(s_h)$

t-values in parentheses; # = number of countries converging from above the steady state (total number of countries)

Table 1 also shows the regression results for our second sample, consisting of 22 OECD countries.[5] When the same procedure is repeated for these 22 countries, the estimated coefficients are close to those for the non-oil sample. However, both 'catching-up', as expressed by the parameter α_1, and the 'technology variable' $\ln(n+g+\delta)$ seem to be relatively more significant in explaining economic growth. Human capital seems to be less important in explaining OECD economic growth. Although, due to a smaller disparity in growth performance, one would expect that there would be fewer OECD countries converging from above their steady state, Table 1

[5] Only those 22 countries have been included that were an OECD member in 1985 (thereby excluding the Czech Republic, Hungary, the Republic of Korea, Mexico and Poland) and countries for which data were available (thereby excluding Iceland and Luxembourg).

shows that there are still 4 countries which convergence from above. With the exception of the UK, these are the same countries as those found in the non-oil sample.

The MRW-CG results for the non-oil sample contradict the 'stylised fact' that countries approach their steady state from a relatively backward position (i.e. from below). One explanation for this result could be the assumption of a 2% growth rate of labor-augmenting technological progress for all countries. As reported by, for example, Young (1994), technological progress is different between countries. For about half of the countries in his sample, Young finds that this growth rate is not 2% but zero. The introduction of different growth rates for technological change should improve the CG result by resulting in lower steady-state values. As the Solow model predicts that a higher rate of technological change results in lower steady-state values of the capital-labor ratio, allowing for technological growth rates smaller than the CG assumption of 2% will increase the steady-state capital-labor ratios and thus steady state per capita income.

3. Introducing Country-Specific TFP Growth Rates: Young's TFP Data

CG find that in 1960 50% of the 98 countries in the non-oil sample converge from above their steady state. As this result is conflicting with the general notion that countries approach their steady state from below, we will improve this result – i.e., reduce the number of countries 'approaching from above' – by allowing for different rates of technological progress among the sample countries. In this section we will use total factor productivity (TFP) data as constructed by Young (1994) to adjust the CG result.

Young (1994) uses the Summers and Heston (1988) data set to construct capital stock data necessary for estimating TFP growth rates. Assuming a depreciation rate of 6%, 1960-1969 investment flows are accumulated to estimate a benchmark capital stock for 1970. Capital stocks for the sample period 1970-1985 are then calculated by using this benchmark capital stock and the 1970-1985 investment flows. Finally, Young performs a cross-country regression of per capita income growth on the growth rate of the capital-labor ratio:

$$\hat{Y}_t - \hat{L}_t = \beta_0 + \beta_1(\hat{K}_t - \hat{L}_t) + E_t \tag{6}$$

where E is the residual term. The parameters were estimated to be $\beta_0 = -0.21$ and $\beta_1 = 0.45$. TFP growth rates are then calculated as the sum of the average TFP growth β_0 and the country-specific residual. For the non-oil countries, the TFP estimates of Young are given in Appendix A. For only 54 of these 98 countries TFP growth rates are non-negative.

We now use these TFP growth rates to introduce different rates of technological progress. Multiplying these TFP growth rates by 3 – roughly the inverse of labor's share of income – gives the rates of labor-augmenting technological progress. Substituting these for g in regression equation (4) gives the regression results as reported in Table 1. Most parameter estimates are close to those of MRW-CG. The estimate of the "technology parameter" $\ln(n+g+\delta)$, however, is of opposite sign. A possible explanation for this unexpected result, as the model predicts a negative sign, will be given in section 6.

Substitution of these parameter estimates in equation (5), enables us to calculate 1960 steady state per capita income for each country. For the non-oil sample, the natural logarithms of these are plotted in Figure 1 against those of real per capita income in 1960, where the bold line indicates the equality of both values. Figure 1 shows that 43 countries are below this bold line, i.e., these countries are converging from above their steady-state position. This result is only a small change compared to the '49 countries' of CG. For the OECD sample the results have even deteriorated: the number of countries approaching from above has increased from 4 to 7[6].

CG have shown that particularly the relatively poor countries converged from above their steady state per capita income levels. Figure 1, however, shows that both rich (i.e. OECD countries) and poor countries converge from above their steady state. Only 12 of the 22 OECD countries in the non-oil sample were approaching their steady state from below.[7]

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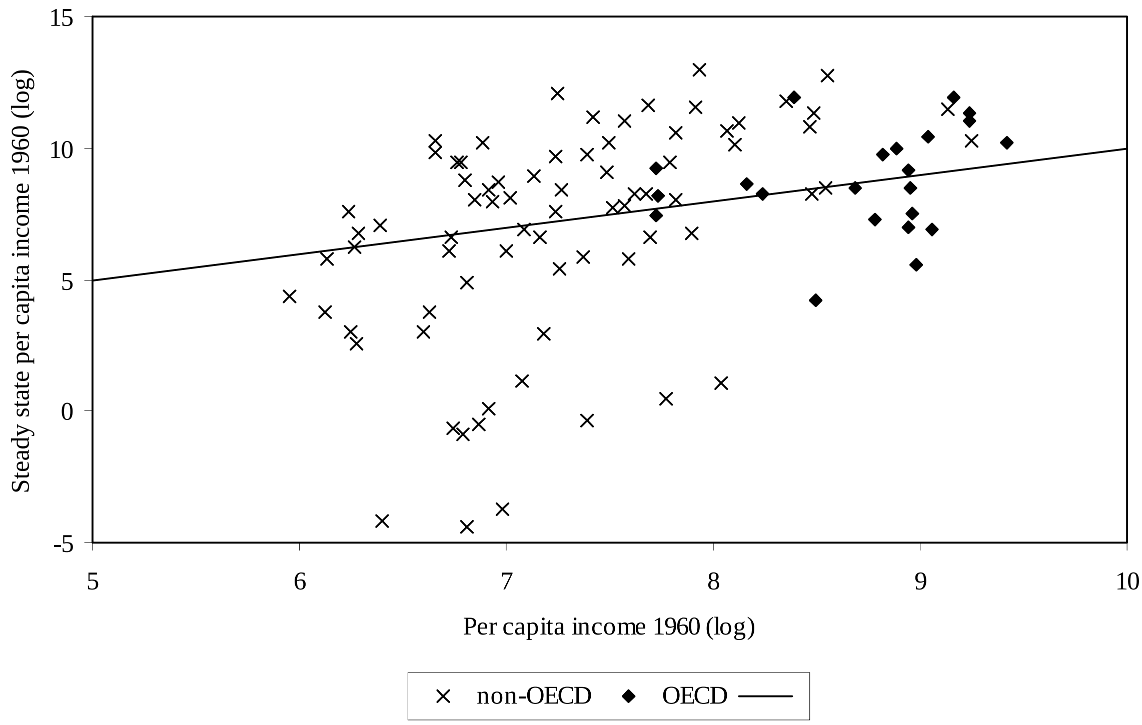
[6] I.e., Denmark, Finland, Germany, Italy, Norway, Spain and the UK.

[7] The 10 countries approaching from above are Austria, Denmark, Finland, Germany, Greece, Italy, Norway, Spain, Sweden, and the UK.

By using Young's TFP growth rates to replace the common 2% rate of technological change by country-specific rates, we have reduced the number of countries converging from above by less than one might have expected. In the next section we will discuss a number of problems with Young's TFP estimates. Solving these problems will lead to improved estimates of TFP growth rates estimates and will improve the results by reducing the number of countries converging from above.

Figure 1: Convergence from above or below (using Young's TFP data)



4. Re-estimating TFP Growth Rates

In the previous section we have shown that adjustment of the CG result for different rates of labor-augmenting technological progress by using Young's TFP estimates, only reduces the number of countries in the non-oil sample approaching their 1960 steady state per capita income from above from 49 to 43. For the OECD sample, this number even increases from 4 to 7. In our opinion, this is due both to the fact that Young used a broader set of countries than MRW to construct these TFP estimates, and the fact that Young's TFP estimates relate to a different period, i.e., 1970-1985, than MRW's sample period. Using these TFP estimates to estimate 1960 steady state per capita income may lead to serious under- or overestimations. In this section we will construct an alternative set of TFP estimates to overcome these problems.

Similar to Young, we will estimate TFP growth rates by performing a cross-country regression of per capita output growth on the growth rate of the capital-labor ratio. The estimated residuals can be interpreted as a country's deviation from the estimated average rate of TFP growth. One should keep in mind that these residuals also include a range of other 'growth factors', such as changes in human capital, energy, capacity utilization and economies of scale. However, it should be clear that this approach is to be preferred to just assuming a common 2% growth rate of labor-augmenting technological change as MRW and CG do, thereby ignoring the fact that countries experience different rates of technological progress (see e.g. Morrison, 1992).

To estimate equation (6) for the sample period 1960-1985, we need capital stock data for the same period. Ideally, we would like to make use of the perpetual inventory method (PIM) to construct the capital stock data. Because investment data are lacking for the 'early years' between 1950 and 1960 for a large number of countries in the Summers and Heston data set, we do not use the PIM method to calculate the 1960 benchmark capital stock. Following the procedure suggested in Griliches (1980), the benchmark capital stock is calculated by taking the investment flow of the following year, and dividing this by an assumed depreciation rate of 3% – identical to the one assumed by MRW – plus an assumed growth rate of 5%.[8] [9] Subsequent capital stock values are then calculated by using the perpetual inventory method:

$$K_t = (1-\delta)K_{t-1} + I_t \tag{7}$$

where K is the capital stock and I the investment flow. For those countries for which longer time series of investment data are available in the Summers and Heston data set[10], we have calculated the benchmark capital stock as far back as possible. These capital stock data are then used to perform the cross-country regression as given in equation (6). The parameter estimates for both the non-oil and OECD sample are reported in Table 2.

Table 2 TFP regression results

		β_0	β_1	$\bar{R}^2$
	Non-oil			
(1)	Young	-0.21 (n.a.)	0.45 (n.a.)	n.a.
(2)	TFP δ = 3%	0.068 (0.287)	0.521 (9.726)	0.496
(3)	TFP δ = 6%	0.289 (1.347)	0.471 (9.905)	0.506
	OECD			
(4)	TFP δ = 3%	0.292 (1.203)	0.601 (10.860)	0.848

Regression equation: $\hat{Y}_t - \hat{L}_t = \beta_0 + \beta_1(\hat{K}_t - \hat{L}_t) + E_t$
t-values in parentheses; n.a. = not available.

[8] Thus: $K_0 = I_1/(\delta + 0.05)$, where δ = 0.03.

[9] As a comparison, for the non-oil sample the regression results assuming a depreciation rate of 6% (cf. Young) are also given in Tables 2 and 3.

[10] Due to a lack of data, Sierra Leone and Sudan were excluded from the set of 98 countries used by MRW and CG.

For the non-oil sample, the TFP growth rates – for a depreciation rate of 3% – are shown in Appendix B. For 57 countries the growth rate of TFP is positive, and 39 countries have experienced a negative TFP growth.[11] We will use these TFP estimates to re-estimate the augmented Solow-MRW model. The regression results as reported in Table 3 show that all parameter estimates are significant and comparable to those obtained by MRW-CG (both in sign and value), with the exception of the parameter for the technology variable which has the 'wrong' sign. Assuming a 6% depreciation rate to calculate capital stock data does not change the parameter estimates, with the exception of the technology variable. Therefore, following MRW, we will from now on focus on the results using a depreciation rate of 3% only.

Table 3 'Steady-state' regression results: adjusted TFP estimates

		α_0	α_1	α_2	α_3	α_4	$\bar{R}^2$	#
	Non-oil							
(1)	TFP δ=3%	4.094 (6.914)	-0.178 (-2.838)	0.324 (2.565)	0.488 (5.607)	0.153 (2.504)	0.485	35 (96)
(2)	TFP δ=6%	4.304 (7.266)	-0.169 (-2.758)	0.538 (3.001)	0.467 (5.356)	0.140 (2.294)	0.498	35 (96)
	OECD							
(3)	TFP δ=3%	4.914 (5.079)	-0.402 (-4.718)	-0.115 (-0.675)	0.398 (1.977)	0.205 (1.148)	0.530	2 (22)

Regression equation: $\ln(y_t) - \ln(y_0) = \alpha_0 + \alpha_1 \ln(y_0) + \alpha_2 \ln(n+g+\delta) + \alpha_3 \ln(s_k) + \alpha_4 \ln(s_h)$
t-values in parentheses; # = number of countries converging from above the steady state (total number of countries)

Using these parameter estimates, we can estimate 1960 steady state per capita income levels for each of the 96 non-oil countries. These are plotted against real per capita income in Figure 2, which shows that 35 countries are still approaching their steady state from above. There is also no clear distinction between richer and poorer countries. Seven out of the 22 OECD countries are approaching their steady state from above[12].

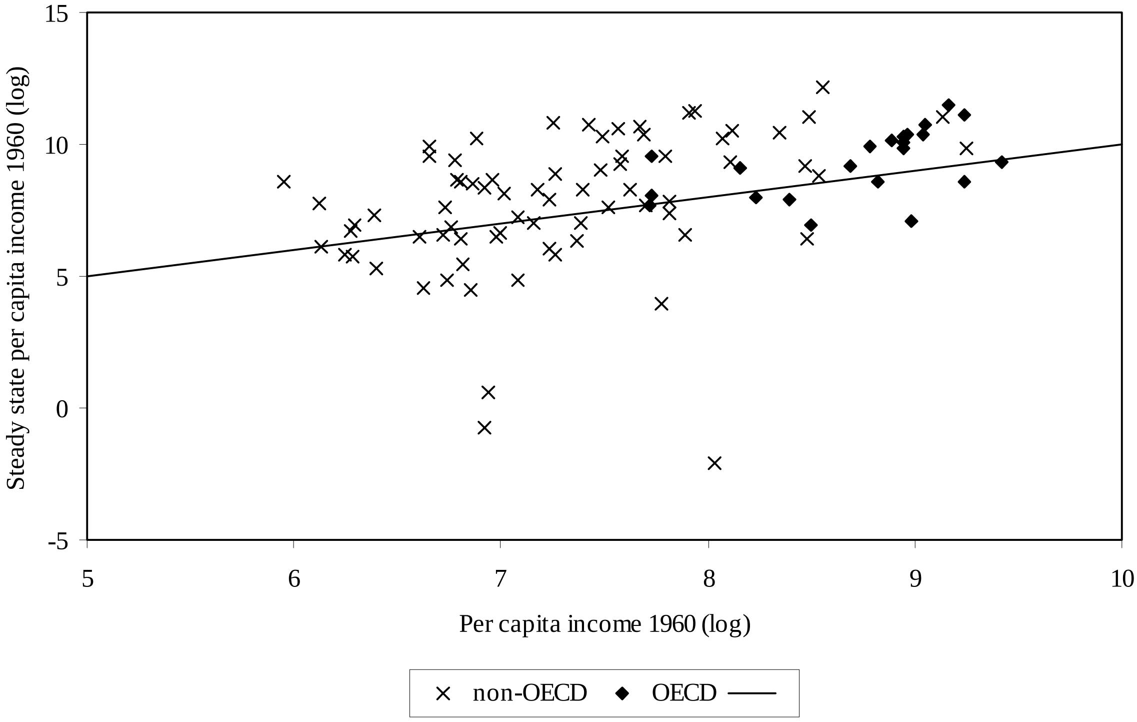
[11] These are set at zero when estimating equation (4) and calculating the level of steady state per capita income in equation (5).

[12] I.e., Belgium, Canada, Ireland, Italy, Norway, Spain and the US.

For the OECD sample the estimated coefficients for the catch-up and technology variable differ from those reported for the non-oil sample. The catch-up variable explains more of economic growth, being more than twice as large (in absolute terms). The technology variable, although statistically insignificant, shows the expected negative sign. The number of countries approaching their steady state from above has dropped to only 2: Canada and Norway.

Although these results are an improvement compared to those based on Young's TFP data[13], especially for the OECD sample, these results are not entirely convincing in supporting the augmented Solow model. As explained before, our TFP estimates include a wide range of other growth improving factors. In section 5, we will improve our TFP growth rates estimates by introducing changes in human capital endowments in equation (6).

Figure 2: Convergence from above, adjusted TFP data



[13] The regression results for a depreciation rate of 6% confirm this result for the non-oil sample.

5. Introducing Human Capital Growth: TFP Re-estimated

Improvements in educational or human capital endowments contribute to the growth performance of countries to an important extent. It thus seems straightforward to take these improvements into account when estimating TFP growth rates. We do this by adjusting our TFP growth equation as follows:

$$\hat{Y}_t - \hat{L}_t = \beta_0 + \beta_1(\hat{K}_t - \hat{L}_t) + \beta_2(\hat{H}_t - \hat{L}_t) + E_t \quad (8)$$

where *H* is human capital.

Total gross enrollment ratio for secondary education

As a first proxy for human capital we take the 1960-1985 growth rate of the total gross enrollment ratio for secondary education (ESS), which are taken from Barro and Lee (1994). The parameter estimates of the TFP regression are presented in table 4.

Table 4 Human capital-augmented TFP regression estimates

		β_0	β_1	β_2	$\bar{R}^2$
	Non-oil				
(1)	TFP-ESS	0.341 (1.117)	0.518 (9.710)	-0.047 (-1.411)	0.502
(2)	TFP-YSS	-0.113 (-0.403)	0.518 (9.675)	0.062 (1.210)	0.499
	OECD				
(3)	TFP-ESS	0.350 (1.342)	0.614 (10.345)	-0.041 (-0.667)	0.843
(4)	TFP-YSS	0.198 (0.726)	0.587 (9.993)	0.046 (0.767)	0.845

ESS = enrollment ratio for secondary education, YSS = average years of schooling; t-values in parentheses

For both samples, the parameter of the growth rate of the capital-labor ratio is not sensitive to the introduction of human capital growth in the TFP regression equation. For the non-oil sample it reduces from 0.521 for regression (2) in Table 2 to 0.518. It is somewhat surprising to see that human capital growth has a negative influence on TFP growth. Table 5 shows the regression results for the steady-state growth equation. The parameter estimates are close to those reported previously, but the number of countries approaching their steady state from above has now increased from 35 to 42 for the non-oil sample. For the OECD sample, only 2 countries are still approaching their steady state from above.

Average years of secondary schooling

As a second human capital proxy we use the growth rate of average years of secondary schooling (YSS), which are taken from Barro and Lee (1994). Table 4 shows that the coefficient of the human capital variable now has a positive sign but that it is statistically insignificant in the TFP regression. Table 5 shows that the steady-state regression results are almost identical to those for ESS, except that the number of countries converging from above has decreased significantly to 25 for the non-oil sample.

Table 5 'Steady-state' regression results: human capital adjusted TFP data

		α_0	α_1	α_2	α_3	α_4	$\bar{R}^2$	#
	Non-oil							
(1)	TFP-ESS	3.933 (6.658)	-0.168 (-2.631)	0.314 (2.618)	0.478 (5.440)	0.145 (2.344)	0.487	42 (96)
(2)	TFP-YSS	4.135 (6.894)	-0.188 (-2.981)	0.282 (2.175)	0.504 (5.781)	0.165 (2.694)	0.475	25 (96)
	OECD							
(3)	TFP-ESS	4.926 (5.102)	-0.403 (-4.705)	-0.111 (-0.683)	0.391 (1.952)	0.203 (1.146)	0.530	2 (22)
(4)	TFP-YSS	4.858 (5.028)	-0.402 (-4.828)	-0.144 (-0.847)	0.406 (2.023)	0.215 (1.216)	0.537	2 (22)

Regression equation: $\ln(y_t) - \ln(y_0) = \alpha_0 + \alpha_1 \ln(y_0) + \alpha_2 \ln(n + g + \delta) + \alpha_3 \ln(s_k) + \alpha_4 \ln(s_h)$

ESS = enrollment ratio for secondary education, YSS = average years of secondary schooling; t-values in parentheses; # = number of countries converging from above the steady state (total number of countries)

Based on these empirical results, one may conclude that YSS is a better proxy for human capital than ESS. A theoretical problem of the use of ESS growth rates as a proxy for human capital growth is that the level of ESS is limited to an upper bound of 100%, making it by definition more and more difficult to sustain high growth rates as the level of ESS increases. Although one could argue that the YSS proxy also faces this problem, although to a far more limited extent, we shall limit our analysis to YSS from now on.

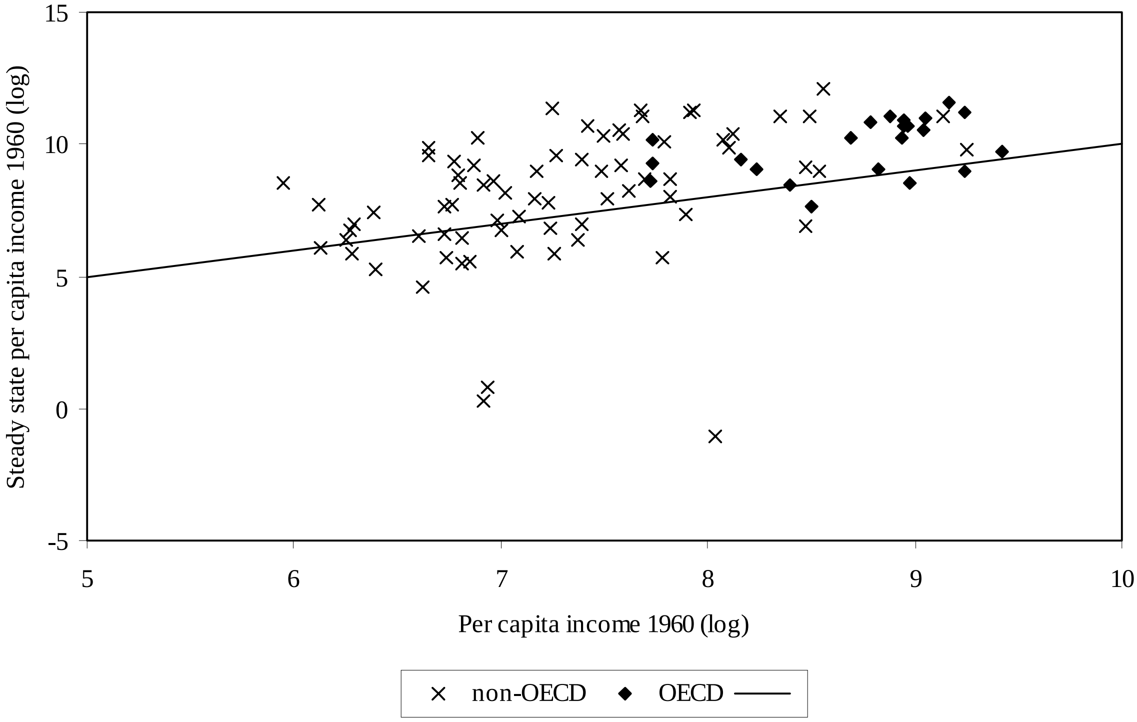
For the non-oil sample, Figure 3 shows the steady state and real per capita income levels using average years of secondary schooling. Only 3 of the 22 OECD countries are approaching their steady state from above.[14] It thus seems that especially the poorer countries approach their steady state from above if we adjust the TFP data for human capital growth.

For the OECD sample, the catch-up variable is once again relatively more important in explaining economic growth. It is exactly equal to the one reported in Table 3, where the TFP estimates were not adjusted for human capital changes. The technology variable has a negative sign but is statistically insignificant. Once again, Canada and Norway are the only 2 countries approaching their steady state from above.

Although we have been able to reduce the number of countries converging from above their steady state from 49 (CG) to 25 for the non-oil sample, so far we have failed to solve one major problem. The augmented Solow-MRW model predicts that the technology variable $\ln(n+g+\delta)$ should have a negative sign. However, all regression results for the non-oil sample turn out to have a positive sign for this variable. Hence, there seems to be a misspecification in the model and we will drop the assumption of CRS in the next section. We will show that this will further reduce the number of countries coming from above.

[14] I.e., Canada, Italy and Norway.

Figure 3: Convergence from above, YSS data



6. A-type vs. B-type Technological Change

The MRW model, which has been used as the basic model in the previous sections, assumes constant returns to scale in all production inputs. As a result, the model predicts that the technology variable $\ln(n+g+\delta)$ should have a negative sign. However, our empirical results for MRW's non-oil sample have shown that this variable turns out to be positive, a result clearly in conflict with the model. We will therefore drop the assumption of CRS in all production inputs. In this section we define so-called *B*-type technological change, and show that this will significantly reduce the number of countries approaching their steady state from above.

Instead of assuming the CRS production function as given in equation (1a), we will start from the following production function:

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{\gamma} \tag{9a}$$

where $\gamma \neq 1-\alpha-\beta$.[15] Equation (9a) can be rewritten to express CRS by introducing *B*-type technological change:

$$Y_t = K_t^{\alpha} H_t^{\beta} A_t^{\gamma} L_t^{\gamma} = K_t^{\alpha} H_t^{\beta} (B_t L_t)^{1-\alpha-\beta} \tag{9b}$$

Hence we find the following relation between *A* and *B*-type technological change:

$$B_t = A_t^{\frac{\gamma}{1-\alpha-\beta}} L_t^{\frac{-(1-\alpha-\beta-\gamma)}{1-\alpha-\beta}} \tag{10}$$

In MRW's CRS model, one might now use technological change *B* as expressed in equation (10), instead of directly using *A* as MRW, CG and we have done previously.[16]

[15] Note that we do not explicitly assume increasing or decreasing returns to scale.

[16] Rewriting equation (10) in growth rates yields *B*-type technological progress as a combination of population growth and an exogenous progress rate. Population growth appears as an argument in the TFP growth formulas derived by Arrow (1962), Phelps (1966) and Jones (1995).

The equation which has to be estimated to calculate TFP growth rates has been adjusted to:

$$\hat{Y}_t - \hat{L}_t = \varphi_0 + \varphi_1(\hat{K}_t - \hat{L}_t) + \varphi_2(\hat{H}_t - \hat{L}_t) + \varphi_3\hat{L} + E_t \tag{11}$$

where (cf. equation (9a)) $\varphi_0 = \gamma\hat{A}$, $\varphi_1 = \alpha$, $\varphi_2 = \beta$ and $\varphi_3 = -(1-\alpha-\beta-\gamma)$. The TFP regression results with and without human capital (i.e. $\varphi_2 = 0$ by assumption) are given in Table 6 for the non-oil and OECD sample.

Table 6 B-type TFP regression estimates

		φ_0	φ_1	φ_2	φ_3	$\bar{R}^2$
	Non-oil					
(1)	TFP	-0.328 (-0.829)	0.524 (9.798)		0.187 (1.249)	0.499
(2)	TFP-YSS	-0.504 (-1.197)	0.520 (9.747)	0.061 (1.203)	0.185 (1.242)	0.502
	OECD					
(3)	TFP	0.042 (0.109)	0.600 (9.527)		0.194 (1.194)	0.832
(4)	TFP-YSS	-0.089 (-0.194)	0.611 (9.148)	0.056 (0.903)	0.139 (0.781)	0.841

YSS = average years of schooling; t-values in parentheses.

Once again the parameter of the growth rate of the capital-labor ratio is not very sensitive, because it is almost the same as those reported in Tables 2 and 4. The coefficient for human capital growth increases from 0.046 in Table 4 to 0.056 for the OECD sample, but is identical for the non-oil sample in Tables 4 and 6. Human capital growth and the ‘additional’ labor term are statistically insignificant for all regressions reported in Table 6.

Using the estimates in Table 6, we calculate TFP growth rates (see appendix D). These growth rates are then substituted in equation (12) to calculate the growth rate of *B*-type technological change:

$$\hat{B}_t = \left(\frac{1}{1-\varphi_1-\varphi_2} \right) T\hat{F}P + \left(\frac{\varphi_3}{1-\varphi_1-\varphi_2} \right) \hat{L}_t \qquad (12)$$

Equation (12) shows that the growth rate of *B*-type technological change depends positively on TFP growth and labor growth. Substituting the estimated coefficients from Table 6 in equation (12) shows that the parameter for TFP growth is roughly about 5 times that of labor growth. The estimates for *B* are now first substituted for *g* in equation (4) to estimate the α parameters, and second for *g* in equation (5) to calculate the steady state per capita income levels in 1960.

Table 7 'Steady-state' regression results (B-type technological change)

		α_0	α_1	α_2	α_3	α_4	$\bar{R}^2$	#
	Non-oil							
(1)	TFP	4.164 (6.671)	-0.214 (-3.289)	0.184 (1.130)	0.530 (6.044)	0.186 (3.009)	0.456	28 (96)
(2)	TFP: YSS	4.100 (6.443)	-0.231 (-3.547)	0.091 (0.546)	0.539 (6.146)	0.197 (3.200)	0.450	22 (96)
	OECD							
(3)	TFP	4.367 (4.396)	-0.393 (-5.086)	-0.276 (-1.555)	0.387 (2.041)	0.220 (1.361)	0.577	2 (22)
(4)	TFP: YSS	4.182 (4.177)	-0.397 (-5.227)	-0.346 (-1.779)	0.374 (2.011)	0.233 (1.463)	0.593	0 (22)

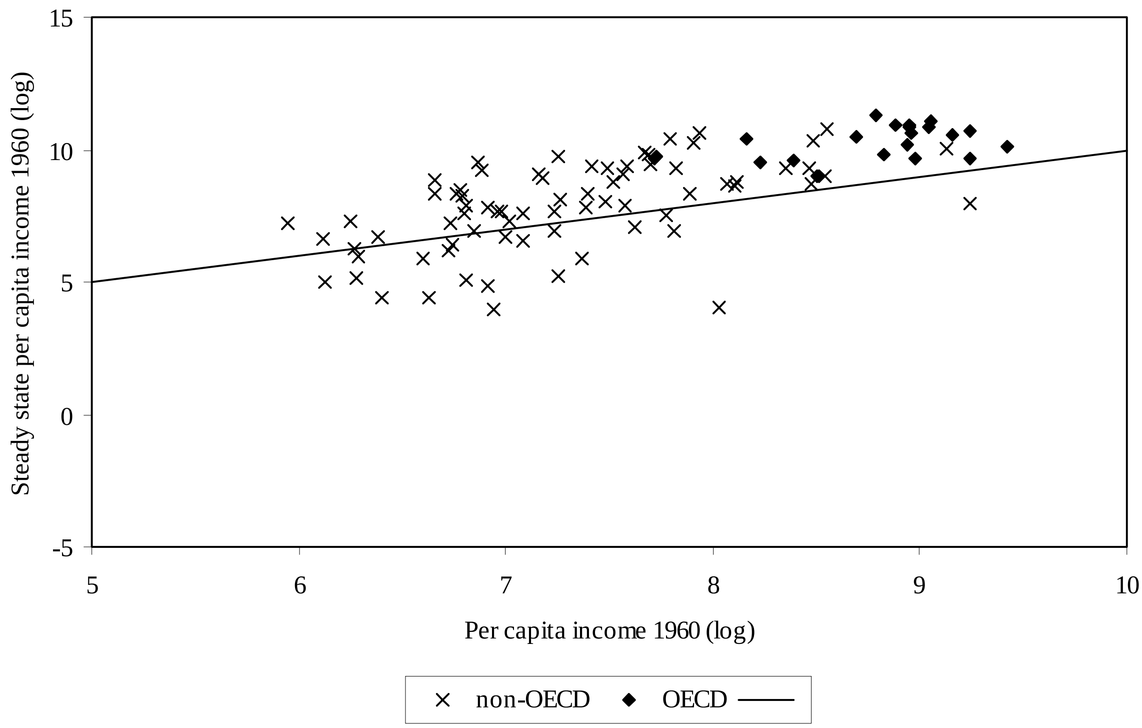
Regression equation: $\ln(y_t) - \ln(y_0) = \alpha_0 + \alpha_1 \ln(y_0) + \alpha_2 \ln(n+g+\delta) + \alpha_3 \ln(s_k) + \alpha_4 \ln(s_h)$

YSS = average years of secondary schooling; t-values in parentheses, # = number of countries converging from above the steady state (total number of countries)

The regression results are shown in Table 7. With the exception of the technology variable, all parameters have the expected sign and are almost identical to those reported previously. The technology variable is now statistically insignificant. The number of non-oil countries converging from above their steady state has decreased to 28 when the TFP data are not corrected for human capital growth, and to 22 when we include human capital growth in calculating TFP growth rates. This latter result is graphically shown in Figure 4. This figure shows that all OECD countries in the non-oil sample were approaching their steady state from below in 1960. This result is confirmed by the regression results for the OECD sample. For the OECD sample, the technology variable has a negative sign and is statistically significant at a 10% level.

Dropping the assumption of CRS, by introducing *B*-type technological change, has reduced the number of countries converging from above their steady state to 22 for the non-oil sample and even 0 for the OECD sample. However, the results in this section call for further testing of the CRS specification of the production function. In the next section we will test various restricted regressions to see whether this assumption should be rejected.

Figure 4: Convergence from above, YSS data, B-type technological change



7. Testing for Constant Returns to Scale: Restricted Regressions

In this section we will take a closer look at the restricted augmented Solow model by imposing the restriction that the coefficients of $\ln(s_k)$, $\ln(s_h)$ and $\ln(n+g+\delta)$ sum to zero:

$$\ln(y_t)-\ln(y_0)=\alpha_0+\alpha_1\ln(y_0)+\alpha_3\left(\ln(s_k)-\ln(n+g+\delta)\right)+\alpha_4\left(\ln(s_h)-\ln(n+g+\delta)\right) \qquad (13)$$

The regression results are summarized in Table 8. For the non-oil sample, the regression coefficients of the restricted and non-restricted MRW regression are almost the same. The number of countries approaching from above their steady state is exactly the same. For the Young-adjusted regression, all coefficients turn out to be insignificant and the adjusted R^2 is almost zero. There is no clear explanation for these results, and the fact that the number of countries approaching the steady state from above has decreased from 43 to 37 is thus an insignificant drop.

The coefficients for the *B*-type technological change regressions with and without human capital adjusted TFP data are now almost identical to those found by MRW. Compared to the unrestricted regressions (cf. Table 7) the coefficient for investment has decreased from, on average, 0.535 to 0.385. The human capital parameter shows an average increase from 0.192 to 0.217. The best results, based on the number of countries converging from above, are now obtained for *B*-type technological change when the TFP data are not adjusted for human capital growth. Figure 5 shows that there are now only 16 countries approaching their steady state from above, including 5 OECD countries.[17]

Table 8 also shows the implied values for λ, α and β. Once again, these results are almost identical to those reported by MRW. The implied coefficient for the capital stock in equation (9a) is equal to, on average, 0.452, only slightly below the value of 0.484 as reported in regression (1). The coefficient for the human capital stock is roughly equal to 0.255 as compared to the MRW

[17] I.e., Canada, Ireland, Italy, Norway and the US.

value of 0.228. As compared to MRW-CG, convergence to the steady state takes more time, from roughly 50 years for MRW-CG to 60 years for our *B*-type technological change[18].

Table 8 'Steady-state' restricted regression results

		α_0	α_1	α_3	α_4	implied λ	implied α	implied β	F-value[a]	$\bar{R}^2$	#
	Non-oil										
(1)	MRW-CG	2.457 (5.195)	-0.298 (-4.931)	0.501 (6.092)	0.235 (3.975)	0.014	0.484	0.228	0.700	0.465	49 (98)
(2)	'Young'-adjusted	0.797 (1.228)	-0.050 (-0.600)	0.113 (1.078)	0.120 (1.468)	0.002	0.399	0.424	97.355	0.054	37 (98)
(3)	TFP(B)	2.048 (3.540)	-0.240 (-3.193)	0.376 (3.897)	0.214 (3.008)	0.011	0.453	0.258	32.442	0.272	16 (96)
(4)	TFP(B)-YSS	2.157 (3.863)	-0.259 (-3.569)	0.393 (4.257)	0.220 (3.197)	0.012	0.450	0.252	24.477	0.311	22 (96)
	OECD										
(5)	MRW-CG	3.554 (5.608)	-0.402 (-5.814)	0.395 (2.605)	0.241 (1.694)	0.021	0.381	0.232	0.654	0.659	4 (22)
(6)	'Young'-adjusted	3.538 (4.192)	-0.327 (-3.476)	0.030 (0.157)	-0.059 (0.172)	0.016	0.102	-0.198	6.740	0.404	7 (22)
(7)	TFP(B)	3.473 (4.836)	-0.373 (-4.844)	0.241 (1.564)	0.153 (0.984)	0.019	0.314	0.200	1.733	0.562	2 (22)
(8)	TFP(B)-YSS	3.477 (5.028)	-0.384 (-5.143)	0.267 (1.782)	0.191 (1.248)	0.019	0.317	0.227	1.006	0.594	0 (22)

Regression equation:

$$\ln(y_t) - \ln(y_0) = \alpha_0 + \alpha_1 \ln(y_0) + \alpha_3((\ln(s_k) - \ln(n+g+\delta)) + \alpha_4((\ln(s_h) - \ln(n+g+\delta))$$

implied $\lambda = -\ln(1+\alpha_1)/25$, implied $\alpha = -\alpha_3/(\alpha_1 - \alpha_3 - \alpha_4)$ and implied $\beta = -\alpha_4/(\alpha_1 - \alpha_3 - \alpha_4)$;

YSS = average years of secondary schooling; t-values in parentheses, # = number of countries converging from above the steady state (total number of countries)

[a] The *F* value is defined as $F = \dfrac{(\Sigma e_R^2 - \Sigma e_{UR}^2)/m}{\Sigma e_{UR}^2/(N-k)}$, where Σe_R^2 resp. Σe_{UR}^2 is the residual sum of squares of the restricted and unrestricted regression respectively, *m* is the number of linear restrictions, *k* is the number of parameters in the unrestricted regression and *N* is the number of observations. The *F* statistic follows the *F* distribution with *m*, (*N*-*k*) degrees of freedom. The decision rule (see Gujarati, 1988) to test the null hypothesis of CRS is: if the computed *F* exceeds $F_\alpha(m, N-k)$, where $F_\alpha(m, N-k)$ is the critical *F* at the α level of significance, we may reject the null hypothesis of CRS, otherwise we may accept it.

[18] The time to move halfway to steady state is given by $t = -\ln(0.5)/\lambda$.

An explicit testing for this CRS restriction is by *F* statistics as reported in Table 8. For the non-oil sample, only for the MRW-CG regression the observed *F* value is significant (at the 1% level)[19], and we may thus accept the null hypothesis of CRS. For the *B*-type regressions in Table 8, CRS is strongly rejected, as the observed *F* values are not even significant at a 25% level of significance.

For the OECD sample, the restricted regressions give results close to those found by MRW-CG. The number of countries approaching from above decreases to 0 for the human capital adjusted TFP growth rates regression, a result identical to that of the non-restricted regression. For the OECD sample it is this regression which gives the best results, as opposed to the non-oil sample, where it is best not to include human capital to estimate TFP growth rates. The implied λ, α and β are identical to those reported by MRW-CG. Only if we assume a 25% level of significance, we may reject the null hypothesis of CRS for regression (7). For the MRW-CG regression and for the regression with human capital adjusted TFP growth rates, the hypothesis of CRS cannot be rejected.

Although the restricted regressions perform best in reducing the number of countries approaching their steady state from above, we cannot accept these results for the non-oil sample based on the rejection of the null hypothesis of CRS. Therefore, the *B*-type technological change results as reported in section 6 are theoretically and empirically the best we have found for the non-oil sample. Regression (2) in Table 7, where TFP growth rates are adjusted for changes in human capital endowments, turns out to be our benchmark regression in comparison to the MRW-CG result. The number of countries approaching their steady state from above has been reduced from 49 to 22, a result which is clearly in support of the augmented Solow model. However, the wrong

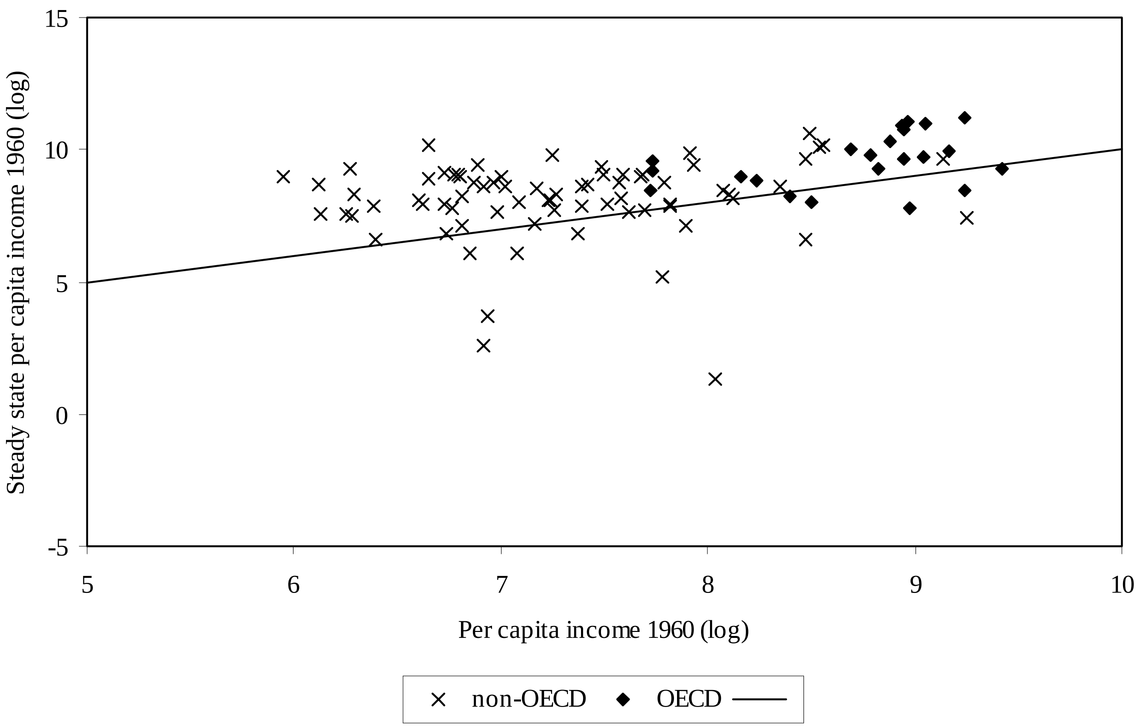
[19] Gujarati (1988) gives the following critical *F* values:

	$\alpha = 0.25$	$\alpha = 0.10$	$\alpha = 0.05$	$\alpha = 0.01$
$m = 1, N - k = 18$	1.41	3.01	4.41	8.29
$m = 1, N - k = 60$	1.35	2.79	4.00	7.08
$m = 1, N - k = 120$	1.34	2.75	3.92	6.85

sign for the technology variable and the rejection of CRS for *B*-type technological change, is not supporting the augmented Solow model.

For the OECD sample, the best results are found for the restricted regression with TFP data adjusted for human capital growth: regression (8) in Table 8. Whereas for the non-oil sample the support for the Solow model has been both weakened and strengthened, the results for the OECD sample are clearly in favor of the augmented Solow model. This seems to suggest that economic growth in non-OECD countries differs from that in the more developed OECD economies.

Figure 5: Convergence from above, adjusted TFP data, restricted regression



8. Conclusions

Our work restores the expected Solowian result that countries are expected to approach their steady state from an initial situation of being poorer than at the steady state. This is done firstly by giving up the assumption of technology being a pure public good and countries therefore having identical rates of technological progress. This assumption is replaced by the assumption that countries have different exogenous rates of technological progress. As the assumption of country-specific rates of technological progress yields more plausible results than that of a pure public good property of technology, our work provides some justification for the work of those economists who have tried to endogenize TFP growth by taking into account country-specific arguments.

Secondly, we have included changes in human capital endowments to estimate TFP growth rates. By reducing the 'residual factor', these improved TFP growth rates further reduced the number of countries approaching their steady state from above.

Finally, we have dropped the assumption of constant returns to scale by introducing *B*-type technological change. Although the results improved, the regression results did not provide sufficient support in favor of either increasing or decreasing returns to scale. Hence we have tested for CRS by performing restricted regressions. Although the results have improved significantly, the assumption of CRS had to be rejected for the non-oil sample.

The number of non-oil countries approaching their steady state from per capita income levels above those in the steady state has been reduced from 49 as reported by CG to 22 for the *B*-type technological change regression with TFP growth rates adjusted for changes in human capital endowments (cf. regression (2) in Table 7). As the number of countries approaching their steady state from above has decreased from 50% to only 23%, our analysis is in support of the augmented Solow model. However, the rejection of CRS for the non-oil sample sharply collides with the assumptions of this model.

Only when the analysis is limited to the sample of OECD countries, is the Solow model strongly supported by both a strong reduction in the number of countries approaching their steady state from above, and by the acception of the CRS assumption. All countries now approach their steady state from above, and the technology variable shows the expected negative sign.

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Appendix A. Relative percentage annual growth of Total Factor Productivity, 1970-1985 (Young)

Egypt	3.500	Turkey	0.800	Morocco	0.000
Pakistan	3.000	Netherlands	0.800	Nigeria	0.000
Botswana	2.900	Ethiopia	0.700	Haiti	0.000
Congo Peop. Rep.	2.800	Austria	0.700	Benin	0.000
Syrian Arab Rep.	2.500	Australia	0.700	Madagascar	0.000
Hong Kong	2.500	Kenya	0.600	Sudan	0.000
Cameroon	2.400	Spain	0.600	Ivory Coast	0.000
Zimbabwe	2.400	France	0.500	Senegal	0.000
Tunisia	2.400	Liberia	0.400	Zambia	0.000
Uganda	2.100	Honduras	0.400	Mozambique	0.000
Bangladesh	1.900	Paraguay	0.400	Angola	0.000
Thailand	1.900	Portugal	0.400	Bolivia	0.000
Italy	1.800	Belgium	0.400	Philippines	0.000
Norway	1.700	United States	0.400	Papua New Guinea	0.000
Finland	1.500	Algeria	0.300	Dominican Rep.	0.000
Burma	1.400	Canada	0.300	El Salvador	0.000
Korea Rep. of	1.400	Central Afr. Rep	0.200	Jordan	0.000
Ecuador	1.400	India	0.100	Guatemala	0.000
Mauritius	1.300	Sri Lanka	0.100	Jamaica	0.000
Denmark	1.300	Singapore	0.100	Nicaragua	0.000
Greece	1.200	Rwanda	0.000	Peru	0.000
Japan	1.200	Sierra Leone	0.000	Costa Rica	0.000
Israel	1.200	Burkina Faso	0.000	Mexico	0.000
Tanzania	1.100	Niger	0.000	Ireland	0.000
Colombia	1.100	Zaire	0.000	S. Africa	0.000
Malawi	1.000	Burundi	0.000	Argentina	0.000
Brazil	1.000	Mauritania	0.000	Uruguay	0.000
Malaysia	1.000	Togo	0.000	Chile	0.000
Sweden	1.000	Nepal	0.000	Trinidad Tobago	0.000
Panama	0.900	Indonesia	0.000	New Zealand	0.000
United Kingdom	0.900	Somalia	0.000	Switzerland	0.000
Germany Fed Rep	0.900	Chad	0.000	Venezuela	0.000
Mali	0.800	Ghana	0.000		

Source: Young (1994), Table 3.

Appendix B. Relative percentage annual growth of Total Factor Productivity, 1960-1985 (δ=3%)

Hong Kong	3.590	Netherlands	0.588	Chile	0.000
Congo Peop. Rep.	3.345	Austria	0.533	Costa Rica	0.000
Morocco	2.103	Senegal	0.518	El Salvador	0.000
Syrian Arab Rep.	1.895	France	0.408	Ethiopia	0.000
Zimbabwe	1.708	Singapore	0.403	Haiti	0.000
Israel	1.685	Tunisia	0.395	India	0.000
Kenya	1.539	S. Africa	0.391	Jamaica	0.000
Norway	1.405	Turkey	0.390	Madagascar	0.000
Korea Rep. of	1.349	Ivory Coast	0.384	Malawi	0.000
Italy	1.244	Germany Fed Rep	0.375	Mali	0.000
Colombia	1.203	Mauritius	0.337	Mauritania	0.000
Greece	1.177	Malaysia	0.309	Mozambique	0.000
Egypt	1.174	Denmark	0.239	Nepal	0.000
Ecuador	1.164	Honduras	0.235	Nicaragua	0.000
Ireland	1.143	Jordan	0.232	Niger	0.000
Algeria	1.098	Mexico	0.210	Nigeria	0.000
Japan	1.057	Zambia	0.186	Papua New Guinea	0.000
Brazil	1.049	Sweden	0.175	Paraguay	0.000
Liberia	1.043	Peru	0.173	Philippines	0.000
Canada	0.919	Cameroon	0.122	Rwanda	0.000
Burma	0.851	Guatemala	0.071	Somalia	0.000
Botswana	0.844	Ghana	0.036	Sri Lanka	0.000
Finland	0.810	New Zealand	0.015	Switzerland	0.000
Panama	0.808	Dominican Rep.	0.003	Tanzania	0.000
Pakistan	0.767	United Kingdom	0.000	Togo	0.000
Portugal	0.767	Indonesia	0.000	Trinidad Tobago	0.000
Bolivia	0.766	Angola	0.000	Uganda	0.000
Belgium	0.755	Argentina	0.000	Uruguay	0.000
Bangladesh	0.748	Benin	0.000	Venezuela	0.000
Spain	0.724	Burkina Faso	0.000	Zaire	0.000
Thailand	0.651	Burundi	0.000	Sierra Leone	n.a.
Australia	0.608	Central Afr. Rep	0.000	Sudan	n.a.
United States	0.601	Chad	0.000		

n.a. = not available

Appendix C. Relative percentage annual growth of Total Factor Productivity, adjusted for human capital growth (average years of secondary schooling), 1960-1985 (δ=3%)

Hong Kong	3.441	S. Africa	0.402	Indonesia	0.000
Congo Peop. Rep.	3.185	Ivory Coast	0.401	Jamaica	0.000
Morocco	2.111	Singapore	0.374	Jordan	0.000
Israel	1.584	Senegal	0.289	Madagascar	0.000
Syrian Arab Rep.	1.470	Germany Fed Rep	0.275	Malawi	0.000
Zimbabwe	1.440	Netherlands	0.268	Mali	0.000
Kenya	1.278	Austria	0.209	Mauritania	0.000
Egypt	1.191	Turkey	0.192	Mozambique	0.000
Korea Rep. of	1.114	Denmark	0.172	Nepal	0.000
Italy	1.073	France	0.148	New Zealand	0.000
Norway	1.034	Malaysia	0.110	Nicaragua	0.000
Ireland	1.022	Mauritius	0.090	Niger	0.000
Colombia	0.999	Sweden	0.081	Nigeria	0.000
Japan	0.979	Cameroon	0.081	Papua New Guinea	0.000
Brazil	0.963	Tunisia	0.050	Paraguay	0.000
Greece	0.941	Mexico	0.005	Peru	0.000
Ecuador	0.885	Angola	0.000	Philippines	0.000
Canada	0.824	Argentina	0.000	Rwanda	0.000
Liberia	0.814	Benin	0.000	Somalia	0.000
Bolivia	0.783	Burkina Faso	0.000	Sri Lanka	0.000
Algeria	0.733	Burundi	0.000	Switzerland	0.000
Burma	0.702	Central Afr. Rep	0.000	Tanzania	0.000
Belgium	0.651	Chad	0.000	Togo	0.000
Panama	0.651	Chile	0.000	Trinidad Tobago	0.000
Botswana	0.627	Costa Rica	0.000	Uganda	0.000
Pakistan	0.589	Dominican Rep.	0.000	United Kingdom	0.000
Australia	0.561	El Salvador	0.000	Uruguay	0.000
Finland	0.546	Ethiopia	0.000	Venezuela	0.000
Bangladesh	0.527	Ghana	0.000	Zaire	0.000
United States	0.500	Guatemala	0.000	Zambia	0.000
Thailand	0.443	Haiti	0.000	Sierra Leone	n.a.
Portugal	0.422	Honduras	0.000	Sudan	n.a.
Spain	0.411	India	0.000		

n.a. = not available

Appendix D. Relative percentage annual growth of Total Factor Productivity, adjusted for human capital growth (average years of secondary schooling), no constant returns to scale, 1960-1985 (δ=3%)

Hong Kong	2.861	Pakistan	0.072	Mozambique	0.000
Congo Peop. Rep.	2.754	S. Africa	0.001	Nepal	0.000
Morocco	1.598	Angola	0.000	Netherlands	0.000
Israel	1.019	Argentina	0.000	New Zealand	0.000
Italy	0.996	Benin	0.000	Nicaragua	0.000
Zimbabwe	0.949	Burkina Faso	0.000	Niger	0.000
Syrian Arab Rep.	0.934	Burundi	0.000	Nigeria	0.000
Ireland	0.865	Cameroon	0.000	Papua New Guinea	0.000
Greece	0.830	Central Afr. Rep	0.000	Paraguay	0.000
Egypt	0.777	Chad	0.000	Peru	0.000
Norway	0.748	Chile	0.000	Philippines	0.000
Japan	0.713	Costa Rica	0.000	Rwanda	0.000
Kenya	0.691	Denmark	0.000	Senegal	0.000
Korea Rep. of	0.549	Dominican Rep.	0.000	Singapore	0.000
Belgium	0.526	El Salvador	0.000	Somalia	0.000
Colombia	0.495	Ethiopia	0.000	Sri Lanka	0.000
Ecuador	0.406	France	0.000	Sweden	0.000
Bolivia	0.385	Ghana	0.000	Switzerland	0.000
Finland	0.384	Guatemala	0.000	Tanzania	0.000
Brazil	0.381	Haiti	0.000	Thailand	0.000
Liberia	0.369	Honduras	0.000	Togo	0.000
Canada	0.342	India	0.000	Trinidad Tobago	0.000
Algeria	0.320	Indonesia	0.000	Tunisia	0.000
Burma	0.313	Ivory Coast	0.000	Turkey	0.000
Spain	0.267	Jamaica	0.000	Uganda	0.000
Bangladesh	0.218	Jordan	0.000	United Kingdom	0.000
Portugal	0.202	Madagascar	0.000	Uruguay	0.000
Germany Fed Rep	0.179	Malawi	0.000	Venezuela	0.000
Austria	0.163	Malaysia	0.000	Zaire	0.000
Botswana	0.154	Mali	0.000	Zambia	0.000
United States	0.143	Mauritania	0.000	Sierra Leone	n.a.
Australia	0.123	Mauritius	0.000	Sudan	n.a.
Panama	0.112	Mexico	0.000		

n.a. = not available