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Controversy *OVER CONVERGENCE NOTION IN THE AUGMENTED SOLOW MODEL OF GROWTH:* *Survey of Selected Literature*

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Abstrak

Salah satu analisis pertumbuhan ekonomi yang cukup mempengaruhi dalam teori pertumbuhan ekonomi adalah model pengembangan dari Solow yang dikenal dengan MRW (Mankiw, Romus, Weil). Dalam tulisan ini disimpulkan bahwa memasukkan akumulasi sumberdaya insani (human capital) bisa menekan magnitude dari pengaruh pertumbuhan penduduk & tabungan atas pendapatan. Tulisan ini memaparkan adanya pro dan kontra adanya pertumbuhan Magnitude dengan pemasukan sumberdaya insani dalam modal.

1. Introduction

This present paper reviews an augmented Solow[1] model of economic growth using cross-section data. Among the influential analyses of the augmented Solow model is the MRW model. The MRW (or interchangeably in this paper with Solow-MRW) model of growth, named after Mankiw, Romer and Weil,[2] is basically Solow's growth model revised by

[1] Robert M. Solow, "A Contribution to the Theory of Economic Growth," Quarterly Journal of Economics, vol. 70, February 1956, 65-94.

[2] N Gregory Mankiw, david Romer, and David N. Weil, "A Contribution to the Empirics of Economic Growth," Quarterly Journal of Economics, vol. 107, 1992, pp. 407-437.

[3] John B. Crihfield, J. Fred Giertz and Shekhar Mehta, "Economic Growth in the American States: The End of Convergence?" The Quarterly Review of Economics and Finance, vol. 35, Special Issue 1995, pp. 551-557.

[4] Maurizo Pugno, "Structural Stability in a Cross-Country Neoclassical Growth Model," Applied Economics, vol. 28, 1996, pp. 1555-1566.

[5] Jonathan R.W. Temple, "Robustness Tests of the Augmented Solow Model," Journal of Applied Econometrics, vol. 13, 1998, pp. 361-375.

them with the inclusion of human capital variable therein. The MRW model, as it is argued, suggests that the extreme magnitude of saving and population growth effects on income in Solow, which calls for controversy, is the result of the exclusion of human capital. Therefore, inclusion of this type of capital is necessary to reduce the magnitude.

In addition, this paper also reviews reexamination of this MRW model as has been discussed by Crihfield, Giertz and Mehta (denoted by CGM),[3] Pugno,[4] and Temple,[5] with differences in the findings and conclusions. These four articles are chosen, it is argued, partly because they relatively represent latest discussions of the theme. On the other hand, they also stand in two "opposite" groups having two articles for each group. MRW strongly advocates the extended Solow's model representing cross-country data convergence in the living standard in international setting. While this finding is supported using cross-region data for the U.S. by CGM, on the other hand, Pugno and Temple challenge the MRW linear model in favor of a multiple or different regime alternative(s).

2. The Origin of the MRW Growth Model

The MRW model of economic growth is of neoclassical in origin as that of Solow. The model assumes a standard neoclassical (Cobb-Douglas) production function, with decreasing returns to capital. It also assumes that the rates of saving and of population growth are exogenous, determining the steady-state level of income per capita. The convergence of the two groups of countries –i.e. poor and rich, is the main feature of the model, using the sample size of about 121 countries. The evidence says that the higher the rates of saving, the richer the country; and in contrast, the higher the rates of population, the poorer the country. In this Solow-MRW model, convergence is defined as a tendency for per capita income differences of the economies due to initial conditions to disappear over time;[6] or, in general, for poorer countries (regions) to grow faster than richer countries (regions),[7] describing differential growth rates across nations or regions. While poorer nations can show their "social capability" to absorb the

[6] Durlauf and Johnson, *ibid.* pp.365.

[7] CGM, *ibid*, p. 552-553.

[8] See also Moses Abramovitz, "Catching Up, Forging Ahead, and Falling Behind," *Journal of Economic History,* vol. 46, 1988, pp. 385-406.

[9] Grihfield, et al., *ibid*, p. 553.

transformation of technology as one of the preconditions for the "catching-up" position,[8] the richer countries (regions) may also assume their growth increases but in the smaller rates. Again, growth rates of a poor country will enhance if the mobility of resources are free across the political divisions.[9] This model with a linear form, also applied to the cross-region data for the U.S. All these findings also enforce the powerful of the Solow-MRW model implemented to cross-country (-region) data.

There are criticisms of such extrapolation arguing that cross-country data that have various characteristic differences may not possess the linear model, but multiple according to specific conditions of each country. Even so, it is also possible for each different group of economies to obey different linear model. Nevertheless, occupying a linear model for the entire economies may lead to error specification, as studied, among others, by Durlauf and Johnson,[10] and Pugno. The robustness (econometric) test of the MRW is specifically examined by Temple. To specify the model of growth, one requires to clearly identify the behavior of the different country. The convergence growth theory may also be facing difficulty, at the moment, due to economic woes in many developing economies, especially in ASEAN countries. Unfortunately, limitations of the paper do not warrant inclusion of this.

3. The Formal Model and Its Results

3.1. The Initial Model

The model initially starts from, as usual, Cobb-Douglas production function (Y), in terms of capital (K) and labour (L), which are paid their marginal products:

$$Y = F(K, L, t) = A(t)\, K^a\, L^b \quad (1)$$

Where a and b are the share of income distributed respectively to capital and labour. One of C-D production function properties is a unique feature of homogeneity of degree 1, so that $(a + b = 1)$, or $b = (1 - a)$. $A(t)$ is said to be time-related shift factor that then is conceivable as total factor productivity (TFP) or some times as technological change. It measures disembodied technical change expressed in an exponential function of time, of which the rate being reflected by the shift parameter, $\ddot{e}$, so that $A(t) = e^{\ddot{e}t}$.

The above equation (1) exhibits Hicks-neutral disembodied technical change, where technical

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[10] Steven N. Durlauf and Paul A. Johnson, "Multiple Regime and Cross-Country Growth Behaviour," *Journal of Applied Econometrics*, vol. 10, 1995, pp. 365-384.

[11] See Albert N. Link, *Technological Change and Productivity Growth*, harwood academic publishers, Chur, Switzerland, 1992, p. 17.

change is equally capital- and labor-augmenting.[11] The augmented Solow model, with replacing b by $(1 - a)$ can be expressed as:

$$Y(t) = K(t)^a (A(t)L(t))^{1-a} \quad 0<a<1 \qquad (2)$$

The assumption of first degree homogeneity as the main property of C-D production function is taken less stiff in the MRW model, implying that $(a + b < 1)$, or decreasing returns to scale to all capital. It is hence assumed that A exogenously grows at the rate g, does so L at the rate n, and the number of effective units of labor, $A(t)L(t)$, grows at the rate $n + g$, so:

$$A(t) = A(0)\, e^{gt} \qquad (3)$$

$$L(t) = L(0)\, e^{nt} \qquad (4)$$

There is a fraction of output, s, to be saved and then invested. Defining k and y as stock of capital per effective unit of labor and output per effective unit of labor respectively, so that $k = K/AL$ and $y = Y/AL$, and incorporating the rate of depreciation as $ä$, yields the growth of k, defined by:

$$\dot{k}(t) = sy(t) - (n + g + ä)\, k(t)$$

$$= sk(t)^a - (n + g + ä)\, k(t)^{12} \qquad (5)$$

In a steady state value, equation (5) is set to be zero, so that:

$$sk^{*a} = (n+g+ä)k^*$$

$$k^{*1-a} = s/(n+g+ä)$$

$$k^* = [s/(n + g + ä)]^{1/(1-a)} \qquad (6)$$

This equation (6) explains that the steady state capital labor ratio is positively related to the rate of saving, and negatively to the rate of population growth.

Since $k = K/AL$, so that $k^* = K(t)/A(0)\, L(t)$

$$K(t) = A(0)\, L(t)\, k^*$$

$$K(t) = A(0)\, L(t)\, [s/(n + g + ä)]^{1/(1-a)} \qquad (7)$$

Substituting equation (7) into (2), and taking the natural logarithm we get equation:[13]

$$\text{Ln}[Y(t)/L(t)] = \ln A_0 + gt + a/(1 - a)\ \ln(s) - a/(1 - a)\ \ln(n + g + ä) \qquad (8)$$

3.2. Human Capital Consideration

Considering human capital, as measured by education only collected from the UNESCO yearbook,[14] to be incorporated in the model, equation (2) can be modified to obtain:

$$Y(t) = K(t)^a H(t)^â (A(t)L(t))^{1-a-â} \quad 0<(a+â)<1 \qquad (9)$$

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[12] Since from equation (2),

$$Y(t) = K(t)^a (A(t)L(t))^{1-a}$$
$$y(t)\,(A(t)L(t)) = k(t)^a (A(t)L(t))\,(A(t)L(t))^{1-a}$$
$$y(t) = k(t)^a (A(t)L(t))\,(A(t)L(t))^{-1}$$
$$y(t) = k(t)^a \quad (1)$$

[13] to prove:

$$Y(t) = A(0)^a L(t)^a [s/(n + g + ä)]^{a/(1-a)} (A(t)L(t))^{(1-a)}$$
$$= A(0)^a L(t)^a [s/(n + g + ä)]^{a/(1-a)} A(t)^{(1-a)} L(t)^{(1-a)}$$
$$= A(0)\, e^{gt} L(t)\, [s/(n + g + ä)]^{a/(1-a)}$$
$$Y(t)/L(t) = A(0)\, e^{gt} [s/(n + g + ä)]^{a/(1-a)}$$

[14] See MRW, *ibid*, pp. 418-419.

An assumption is held that $a + \hat{a} < 1$, implying decreasing returns to scale (to all capital). This is required to ensure the presence of steady state in this model.

In this context, the fraction of saving is also divided into two, to be invested in physical, s_k, as well human capital, s_h. hence, similar procedure can also be derived to obtain the specified model. So, similar notations as in the above are consequently used here, including human capital per effective unit of labor, denoted by $h = H/AL$, assumed to behave similarly with the physical capital in the production function. This provides:

$$\dot{k}(t) = s_k\, y(t) - (n + g + \ddot{a})\, k(t) \quad (10)$$

$$\dot{h}(t) = s_h\, y(t) - (n + g + \ddot{a})\, h(t) \quad (11)$$

in the steady state values, as equation (5) provides equation (6), likewise, equations (10) and (11) also yield further equations. However, there are two ways of expressing the model that incorporate human capital, depending upon the available data. *First*, to determine the rate of human capital accumulation (s_h); and *second*, to determine the level of human capital (h). The first expression results equations (12) and (13) respectively, by equating them to zero:

$$k^* = [s_k^{1-\hat{a}}\, s_h^{\hat{a}}/(n + g + \ddot{a})]^{1/(1-a-\hat{a})} \quad (12)$$

$$h^* = [s_k^{a}\, s_h^{1-a}/(n + g + \ddot{a})]^{1/(1-a-\hat{a})} \quad (13)$$

Finally, these equations to substituted into equation (9), resulting the key equation of the MRW model:

$$\ln[Y(t)/L(t)] = \ln A(0) + gt + a/(1-a-\hat{a})\ln(s_k) + \hat{a}/(1-a-\hat{a})\ln(s_h) - (a+\hat{a})/(1-a-\hat{a})\ln(n+g+\ddot{a}) \quad (14)$$

Likewise, using such a procedure, the second expression is obtained as:

$$\ln[Y(t)/L(t)] = \ln A(0) + gt + a/(1-a)\ln(s_k) + \hat{a}/(1-a)\ln(h^*) - a/(1-a)\ln(n+g+\ddot{a}) \quad (15)$$

Using the first approximation (the rate of accumulation of human capital), MRW examined the data on the fraction of the population, beginning from aged 12-17, for the secondary school. This enrollment rate was thus multiplied by the fraction of working aged population (aged 15-19). Ignoring the difficulty, which was also confessed by the authors, of its exclusion of teachers, primary school children, and the higher level students, the MRW model can relatively successfully enforce the prediction of the Solow model. It predicts in principle that all the coefficients on $\ln(s_k)$ and $\ln(s_h)$, represented by ln(I/GDP) and ln(SCHOOL) respectively, and on $\ln(n+g+\ddot{a})$, sum to zero.

4. The CGM Vindication on The U.S. Data

Instead of using cross-country data for examining the convergence of the Solow model, as done by MRW, CGM developed a similar way using cross-region data of the U.S., consisting of 50 American states. However, they did not only include human capital in their model, instead they extended the analysis with the augmented public capital, which has also a share in saving/investment, s_z. They also assumed some sort of endogenous factors – i.e. rates of population and labor growth, saving and investment – which can move freely within a single country like the U.S. so as to formalize the model similar as equations (2) and (9), but in a different way:

$$Y(t) = A(t)\ K(t)^{a}\ H(t)^{\hat{a}}\ Z(t)^{\tilde{a}}\ L(t)^{1-a-\hat{a}-\tilde{a}} \qquad a+\hat{a}+\tilde{a}<1 \qquad (16)$$

Therefore, while in the previous notations MRW model uses AL as denominator, CGM model occupies only L, per capita for all numerators. Thus, with $k = K/L$ and $y = Y/L$, z = public capital per capita can be defined as $z = Z/L$. Since these factors are endogenously determined, the CGM model thus characterizes, too, homogeneous of degree 1, implying that:

$$Y(t) = A(t)L(t)\ k(t)^{a}\ h(t)^{\hat{a}}\ z(t)^{\tilde{a}} \qquad (17)$$

Using the same prior procedure we get:[15]

$$\dot{k}(t) = s_k\ y(t) - (n + \ddot{a})\ k(t) \qquad (18)$$

$$\dot{h}(t) = s_h\ y(t) - (n + \ddot{a})\ h(t) \qquad (19)$$

$$\dot{z}(t) = s_z\ y(t) - (n + \ddot{a})\ z(t) \qquad (20)$$

Given the same way as the above, these three equations respectively provide:

$$k^{*} = [A(t)\ s_k^{1-\hat{a}-\tilde{a}}\ s_h^{\hat{a}}\ s_z^{\tilde{a}}\ /(n+\ddot{a})]^{1/(1-a-\hat{a}-\tilde{a})} \qquad (20)$$

$$h^{*} = [A(t)\ s_k^{a}\ s_h^{1-a-\tilde{a}}\ s_z^{\tilde{a}}/(n+\ddot{a})]^{1/(1-a-\hat{a}-\tilde{a})} \qquad (21)$$

$$z^{*} = [A(t)\ s_z^{a}\ s_h^{\hat{a}}\ s_z^{1-a-\hat{a}}\ /(n+\ddot{a})]^{1/(1-a-\hat{a}-\tilde{a})} \qquad (22)$$

which are substituted into equation (17) resulting:

$$y^{*}(t) = A(0)\ e^{gt}\ k^{*a}\ h^{*\hat{a}}\ z^{*\tilde{a}} \qquad (17)$$

and taking the logarithm to eventually yield per capita income at the steady state level:

$$\ln[Y^{*}(t)/L(t)] = \ln A(0) + gt/(1-a-\hat{a}-\tilde{a}) + a/(1-a-\hat{a}-\tilde{a})\ \ln(s_k) + \hat{a}/(1-a-\hat{a}-\tilde{a})\ \ln(s_h) + \tilde{a}\ /(1-a-\hat{a}-\tilde{a})\ \ln(s_z) - (a+\hat{a}+\tilde{a})/(1-a-\hat{a}-\tilde{a})\ \ln(n+\ddot{a}) \qquad (23)$$

Comparatively seeing, equation (23) is differed substantially from the MRW equation either (14) or (15) in technological change (or TFP) as appears in the second term of the right hand of all these three equations, which is interdependent from other factors here (within one country). However, this endogenous factor assuming constant returns to scale should not lead to dismissal of the Solow model, the

[15] The CGM model uses g, instead of n, to represent the growth rate of population, and $\tilde{a}$, instead of g for technological change over time. However, these notations are adjusted to confirm with the MRW notations.

one that MRW *cast doubt* through their findings. Despite little difference in this analysis, the CGM model remains supported that of MRW in predicting the convergence of cross-country (-region) growth. Now the paper comes to discuss the convergence question by taking variables as endogenous, one of the main aspects of the MRW model it is going to address.

5. Model Specification

5.1. The MRW Specification and the CGM Support

Casting doubt to Solow model that treats the relevant variables as exogenous should not necessarily imply its dismissal, MRW argued, as it may still be a useful (or even right) explanation of worldwide technological change, depending on many factors influencing the determination and specification of the model. On the other hand, treating them as endogenous to some extent can also provide more powerful explanation, as MRW described. The paper views that this is merely a matter of convenience in the choice relevant to each model.

The extent to which the MRW model calls for controversy is its convergence notion. Taking the Solow model as the point of departure, of which convergence prediction gives only income per capita in a given country with its steady state value, MRW say to predict their model convergence among countries using endogenous-growth analysis.

He Lets y^* be the steady-state level of income per capita as given in equation (14), and $y(t)$ be the actual value at time t, the convergence speed can thus be determined by:

$$d \ln (y(t))/dt = \ddot{e}[\ln (y^*) - \ln (y(t))] \qquad (24)$$

where ë in a general form equals $(1-a-\hat{a})(n+g+\ddot{a})$, for a matter of adjustment. It constitutes a country specific convergence rate towards the steady state. Equation (24) implies:

$$\ln (y(t)) = (1-e^{-\ddot{e}t}) \ln (y^*) + e^{-\ddot{e}t} \ln (y(0)), \qquad (25)$$

where $y(0)$ is income per capita at the initial period. Subtracting $\ln(y(0))$ from both sides, we get:

$$\ln (y(t)) - \ln (y(0)) = (1-e^{-\ddot{e}t}) \ln (y^*) + e^{-\ddot{e}t} \ln (y(0)) - \ln (y(0))$$
$$= (1-e^{-\ddot{e}t}) \ln (y^*) - (1-e^{-\ddot{e}t}) \ln (y(0)) \qquad (26)$$

and then:

$$\ln (y(t)) - \ln (y(0)) = b\, a/(1-a-\hat{a})\ln(s_k) + b\hat{a}/(1-a-\hat{a})\ln(s_h) - b\,(a+\hat{a})/(1-a-\hat{a}) \ln (n+g+\ddot{a}) - b \ln (y(0)) \qquad (27)$$

where $b = (1-e^{-\ddot{e}t})$.

Meanwhile, the augmented CGM model also provides similar equation, based on the same procedure. Defining $\delta = e^{-\ddot{e}t}$, the convergence speed can be determined using equation (23)

$$\ln (y(t)) - \ln (y(0)) = b/(1-a-\hat{a}-\bar{a}) \ln A(0) + bgt/(1-a-\hat{a}-\bar{a}) + ba/(1-a-\hat{a}-\bar{a}) \ln(s_k) + b\hat{a}/(1-a-\hat{a}-\bar{a}) \ln(s_h) + b\bar{a}/(1-a-\hat{a}-\bar{a}) \ln(s_t) - b(a+\hat{a}+\bar{a})/(1-a-\hat{a}-\bar{a}) \ln(n+\ddot{a}) - b \ln (y(0)) \quad (28)$$

5.2. The "Opponent" Group

Now the discussion turns to the specification made by the group of the opponents. At least we have DJ, Pugno, and Temple. Pugno did not make any specification except taking exactly into account the equation (27) of the MRW. He emphasized to differentiate the steady state of individual country, using notation *i* as also mentioned in MRW. He refered to:

$$\ln y(t)_i - \ln y(0)_i = -b_0 \ln y(0)_i + b_1 \ln s_{k,i} + b_2 \ln s_{h,i} - b_3 \ln (n_i+g+\ddot{a}) + b_4 + \hat{\imath}_i \quad (29)$$

the *b* coefficients of his notation can transformed into in the paper's notation becoming:

$b_0 = -b$

$b_1 = ba/(1-a-\hat{a})$

$b_2 = b\hat{a}/(1-a-\hat{a})$

$b_3 = -b(a+\hat{a})/(1-a-\hat{a})$

Equation (29) is for regression purposes. Therefore, substituting these coefficients in it and considering that $\ln A(0) = b + \hat{\imath}$, this equation becomes (27).

Temple on the other hand argued that the role of the initial efficiency, $A(0)$, should clearly be displayed. The difficulty is that this variable is unobserved, and thus, according to him, to be eliminated from the regression specification. Therefore, he used the same specification as the CGM had done, where his *è* is replaced by *b* in used here. The model is specified in terms of per capita output:

$$\ln[Y(t)/L(t)] - \ln[Y(0)/L(0)] = b \ln A(0) + gt + ba/(1-a-\hat{a}) \ln(s_k) + b\hat{a}/(1-a-\hat{a}) \ln(s_h) - b(a+\hat{a})/(1-a-\hat{a}) \ln(n+g+\ddot{a}) - \ln[Y(0)/L(0)] \quad (30)$$

The Temple model is specified similarly as that of the CGM in the sense that per capita output is used, with the same variable as the MRW.

6. About the Data Choice

These four models originated from that of Solow take in general two different, if not opposite, positions. In the first group, as mentioned earlier, the MRW model is vindicated by CGM with the different type of sample. The nature of their evidence is different. While cross-region data for a certain country characteristically might be homogeneous, countries behavior more characterize heterogeneity. It is therefore reasonable that objections have been raised concerning the convergence of countries behavior, rather than that of regions, partly due to this factor. Therefore, the analysis would be more focus on comparison among similar observations that is cross-country data as taken by Pugno and Temple, while the significance of CGM is the vindication they commit to the MRW model.

Concerning the data, MRW considered 121 countries of the world from which classification was made into three groups: non-oil producing countries consisting of 98 countries to be treated in the poor group; OECD countries as otherwise including 22 countries whose population is greater than one million; and between them the intermediate group containing 75 big countries, the countries with more than one million population. On the basis of this observation, Pugno and Temple [illegible] suggested their own examinations.

Pugno concentrated on reclassification of the 98 non-oil-country data according to the level of variables in order to examine the structural stability of the Solow-MRW model, see Table 1. Further classification is also made by Temple using re-weighted least squares (RWLS) technique to estimate the robustness of the MRW model. For this purpose, he considered to drop a number of observations as said unrepresentative, since they are some distance away from robustly fitted regression line.

On the other hand, CGM took a different way to consider 50 states of the U.S. for being their sample. These states were then classified using two ways: relative income and region grouping. There are three level of income (high, middle and low income groups); and nine regional groups such as: New England (NE), Middle Atlantic (MA), East North Central (ENC), West North Central (WNC), South Atlantic (SA), East South Central (ESC), West South Central (WSC), Mountain (M), and Pacific regions (P). Table I provides a relatively complete summary of the figures all of their analyses.

Table I

Data Collected for the Augmented Solow Model

	MRW Model	Pugno's Study	Temple's Study	CGM Model
Assumption about r and n variables.	Exogenous	Exogenous	Exogenous	Endogenous
Classification of data and observations	Cross-countries: Non-oil: 98 Intermediate: 75 OECD: 22	Cross-country data of 98 (MRW non-oil), further split according to MRW's order: a. 1-[illegible]; 1-68; 1-30; 1-50; 1-98. b. 47-98; 69-98 31-98; 51-98	Cross country MRW data, further split: a. Non-oil:* 92 In'diate: 69 OECD: 21 NOOECD: 71 INOECD: 50 b. Poorest: 21 Second: 22 Third : 21 Richest : 21	Cross-regions/ US 50 states: Low-income 17 Middle 17 High-income 16 NE, MA, ENC, WNC, SA, ESC, WSC, M, and P
Periods of observation	1960 – 1985	1960 – 1988	1960 – 1985	1955 – 1987: -1955 – 1980 -1980 – 1987

Notes: NOOECD = Non-oil, non OECD countries
INOECD = Intermediate, non-OECD countries

It is seen from Table I that the basis of observation is relatively similar in terms of time, though little variations are made to enlarge the size. The sample being observed is also similar except for CGM. so is the main assumption on the treatment of variables of saving rates and population growth.

7. Addressing the Convergence Theory

For the purpose of the analysis of the convergence theory of growth, persisting in cross-section data, which reflect the economic performance of both countries and states comparisons, we provide Table 2. The Table is given to show the comparative results of the examinations of whole studies reevaluated in this paper. However, limitations of the paper can only permit inclusion of one of the significant findings of each of the studies in question. This table, it is fair to say, does not necessarily represent the entire performance of the models under investigation, since it only incorporates one finding of each, which has the same sample, except for that of CGM, taken for the non-oil producing countries. It is in this case that Temple considered to drops 6 observations due to their distance from the fitted line. Tough there is no much to say about the CGM model, incorporation in this table is required to provide, more or less, information about its support to that of MRW.

Table 2
Comparative Results for the Analyses

	MRW Model		Pugno's Test for Structural Stability (Table I)	Temple's Test for Conditional Convergence (Table II)	CGM's
	Estimation of the Augmented Solow Model (Table II)	Test for Conditional Convergence (Table V)			
Sample/ observation	98	98	98	92	50
Regression method	OLS	OLS	OLS	RWLS	2SLS
constant	6.89 (1.17)	3.04 (0.83)	0.26 (3.65)	3.82 (0.79)	4.308 (5.691)
ln $y(0)$	-	-0.289 (0.062)	-0.011 (4.63)	-0.30 (0.06)	-0.378 (-5.041)
ln(I/GDP)	0.69 (0.13)	0.524 (0.087)	0.010 (3.57)	0.59 (0.09)	-
a. Private	-	-	-	-	0.061 (1.218)
b.public	-	-	-	-	0.104 (1.638)
Ln: $(n+g+\delta)$	-1.73 (0.41)	-0.505 (0.288)	-0.017 (1.78)	-0.04 (0.24)	-
$(n+\delta)$	-	-	-	-	-0.150 (-0.876)
ln(SCHOOL)	0.66 (0.07)	0.233 (0.060)	0.011 (4.66)	-0.01 (0.06)	0.039 (2.023)
Adj. R^2	0.78	0.46	0.345	0.697	0.517
The implied:					
α	0.31	-	0.31	-	-
β	0.28	-	0.35	-	-
λ (conv. rate)	-	0.014	-	0.092	-

Notes: *1. Standard errors are in parentheses*
2. Adjusted R^2 *for Temple's is calculated by the author, based on* R^2 *found thereof.*
3. All regression results in CGM's model are produced using log, instead of ln.

We begin the discussion of the examination by MRW. The augmented Solow model, according to them, has proven that inclusion of human capital accumulation into the model, in addition to physical capital, provides an excellent description of the international cross-country analysis. It accounts for about 80 percent, of the international variation in per capita income, using three variables: the investment ration, population growth, and a proxy for investment human capital, as shown by adjusted R^2 in the table, it is higher than any evidence from many others. The lowest adjusted R^2 is given by Pugno, only about 35% of cross-country variation can be explained. It is also asserted that the values of the explanatory powers of the model, a and $\hat{a}$, about one-third. In such a case, if $(n+g+\ddot{a}) = 0.06$, since $\ln(n+g+\ddot{a}) = -0.505$, as suggested by MRW, the rate of convergence (ë) would be 0.02. As previously discussed, $\ddot{e} = (n + g + \ddot{a})(1 - a - \hat{a})$. This means that the economies move halfway to steady state at about 2%. The greater rate of convergence was also given by Pugno, from ln –0.017 and combination of a and $\hat{a}$, we get about 3%. While the augmented Solow model (the first column) provides evidence of 2% convergence rate, MRW gives the evidence of conditional convergence with the rate as appears in the second column at about 0.014, or 1.4%. This means that the rate is lower in the augmented Solow model. So that according to the second column, in order for the economies to converge, they need longer time.

On the other hand, there is an interesting evidence from Temple that dropping the observations and adding the dummy variables of Africa, Latin America, East Asia and industrial countries (not appear here) leads to insignificance of the schooling variable, only about 0.01. This conclusion questions the important of the MRW's inclusion of human capital, in relation to geographical and technological influence in the model. Therefore, as Pugno did, Temple believed that there might be specification error in the model. The insistence on the objection of both has also been enforced with some other evidences, which is excluded in this paper due to its limitations, in their respective analysis.

8. Conclusion

The extreme magnitude of the influence of saving and population growth on income in Solow model is analysed by MRW, suggesting that inclusion of human capital accumulation may reduce such magnitude. This implies that the convergence rate as advocated using Solow model (about 4%) can be reduced to about 2% by considering human capital, or even 1.4% using conditional convergence. A support is given by CGM, though the rate of convergence is not clearly given. On the other hand, there have been objections about the significance of human capital accumulation in influencing the convergence of the economic growth of the countries, coming from Pugno and Temple. The former analyses the structural stability of the model used by MRW, while the latter examines its robustness. Both cast some doubt on the convergence of the economies of nations by advocating that specification error may persist in such a model. Temple rather argues that the doubt may also happen in regional convergence as suggested by CGM.

However, this paper is not meant at judging the "truth" of either of both sides. It only gives the opposite view, by which further possible analyses may still happen. The paper concludes that any different model as well as specification may give different results and conclusion.

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