Growth Convergence Reconsidered

By

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I. Introduction

During the 1980s, the field of growth economics has split into endogenous and exogenous models, differentiated by the assumption regarding the returns to scale of the accumulating factor. The model classes differ sharply in their implications. The neoclassical growth model with decreasing returns predicts that productivity growth rates across countries will converge over time. In sharp contrast, endogenous growth models with constant, or inreasing returns typically generate persistent or even widening growth rate differences. Government policy is largely ineffective in affecting long-run growth in the exogenous models but potentially highly effective in the newer endogenous growth models.[1]

The convergence properties of actual growth rates provide a natural test of the empirical support for the two approaches. While a substantial body of evidence has been accumulated, no firm conclusions on the relative merits of endogenous and exogenous growth models have emerged from this literature. In particular, results seem to be sensitive to the choice of the dependent variable. We show that this sensitivity can be at least partly resolved by taking account of a measurement error introduced into many studies by using per capita income rather than the variable indicated by the theoretical model, labor productivity.

Specifically, we show that a dependence between the development level, labor force participation rates and labor quality generates a coefficient bias towards rejection of the convergence hypothesis. We then re-estimate the standard convergence equation using labor pro-

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[1] For reviews of the literature, see Sala-i-Martin [1990], Wolf [1994] and the Winter 1994 issue of *The Journal of Economic Perspectives.*

ductivity both for total output and for sectoral output. While the results suggest convergence for aggregate output, agriculture and services, no significant convergence trend is found for manufactures, suggesting that endogenous growth models might play some role in that sector.

The remainder of the paper is set out in three parts. We begin with a brief review of the convergence hypothesis and the existing empirical literature. The second section suggests a resolution to the puzzle of conflicting empirical findings and Section III reports the empirical results.

II. The Convergence Hypothesis

The convergence hypothesis follows from suitably restricted variants of the neoclassical growth model developed by Ramsey [1928], Solow [1956] and Cass [1965]. In the simplest case without productivity growth and with a constant labor force, the evolution of per worker consumption is given by:

$$\frac{dc_t/dt}{c_t} = \sigma(c_t)\left[\frac{df(k_t)}{dk_t} - \delta\right], \tag{1}$$

where σ denotes the negative inverse of the elasticity of marginal utility, δ denotes the discount rate and c and k are expressed per worker. The crucial assumption of decreasing returns to the accumulating factor k implies an end to per capita growth at a critical capital level k^* defined by $df(k_t^*)/dk^* = \delta$. With some additional restrictions on the production and utility function the model generates a uniform negative relationship between the productivity level and economic growth, and hence predicts asymptotic convergence of growth rates (but not levels) towards zero across any set of economies. The results are robust to the introduction of exogenous productivity growth, with convergence taking place towards the shared growth rate of productivity.

The convergence hypothesis of the exogenous growth model depends critically on the assumption of decreasing returns to the accumulating factor. An important subclass of endogenous growth models abandons this assumption. With constant (increasing) returns to scale, growth rates become independent of the capital stock thus negating the convergence prediction of the exogenous growth model [Lucas, 1988; Romer, 1986, 1990].

The starkly different implication for convergence provides a natural test for the empirical relevance of the two competing paradigms.

During the last decade, a sizable literature on this topic has emerged. A review of this literature suggests two empirical regularities:

First, studies examining economies on different levels of economic development tend to reject convergence more frequently if no allowance for different steady states is made. Studies examining economies on similar development levels tend to find in favor of convergence regardless of whether steady state controls are included.

Second, overall studies using per capita income tend to reject convergence relative to studies using labor productivity. However, in studies examining economies at similar development levels the choice of dependent variable appears to be of little importance.

In the following section, we propose a potential explanation of these results based on a misspecification bias. We then turn to a re-examination of the data to determine whether the correction of the misspecification suffices to resolve the ambiguity.

III. Labor Force Participation, Learning and Growth

Theoretical growth models generate predictions on the convergence properties of labor productivity growth rates. A sizable fraction of empirical studies has instead employed the growth rate of per capita income as dependent variable. The two measures are related via two multiplicative factors, the labor force participation rate and the human capital endowment of the average worker. If *either* of these indices is systematically related to initial income per capita, the estimated convergence coefficient β_1 is biased.

Under the null of convergence, the true model is given by a variant of (2):[2] where Y, L and H denote real output, labor quantity and a labor quality index and the variable subscripts 0 and 1 denote the starting and end points of the sample.

$$\ln\left(\frac{Y_1}{L_1 H_1}\right) - \ln\left(\frac{Y_0}{L_0 H_0}\right) = \beta_0 + \beta_1 \ln\left(\frac{Y_0}{L_0 H_0}\right) + \varepsilon. \tag{2}$$

Rearranging (2) in terms of per capita income yields:

$$\ln\left(\frac{Y_1}{N_1}\right) - \ln\left(\frac{Y_0}{N_0}\right) = \beta_0 + \beta_1 \ln\left(\frac{Y_0}{N_0}\right) - \left[\ln\left(\frac{N_1}{L_1 H_1}\right) - (1+\beta_1)\ln\left(\frac{N_0}{L_0 H_0}\right)\right] + \varepsilon, \tag{3}$$

[2] We exclude controls for different steady states from this exposition.

where N denotes population. Studies examining the convergence of per capita income growth instead estimate (4):

$$\ln\left(\frac{Y_1}{N_1}\right) - \ln\left(\frac{Y_0}{N_0}\right) = b_0 + b_1 \ln\left(\frac{Y_0}{N_0}\right) + v. \tag{4}$$

Comparing (3) and (4) reveals that the estimate of b_1 in (4) suffers from omitted variable bias if the term in square brackets is correlated with initial income per capita. Specifically, we obtain (5) where δ, γ, η and ψ are the OLS coefficients corresponding to regressions of $\ln(N_0/L_0)$, $\ln(N_1/L_1)$, $\ln(H_0)$ and $\ln(H_1)$ separately on $\ln(Y_0/N_0)$, and ζ is residual noise.

$$b_1 = \beta_1 + (1+\beta_1)\,\delta - \gamma - (1+\beta_1)\,\eta + \psi + \zeta. \tag{5}$$

If fertility, labor force participation and education choices are uncorrelated with initial income per capita in a given sample, the replacement of productivity by income per capita would introduce additional noise into the equation, but would not affect the unbiasedness property of the estimated coefficients.

This special case is of some relevance for the group of developed countries having completed their demographic transition and may thus explain why studies employing income per capita but restricting attention to developed countries [Dowrick and Nguyen, 1989; Baumol, 1986] have generally found in favor of convergence.

However, if either labor quality or labor force participation rates are systematically related to initial per capita income, the convergence parameter β_1 obtained from estimating (4) rather than (2) will be biased, potentially leading to erroneous conclusions regarding convergence properties. We now consider the potential sources of bias in more detail.

1. Fertility

The first potential bias arises from the link between fertility and per capita income. An extensive body of literature documents the existence of a demographic transition from high to low fertility rates associated with the industrialization process.[3] A regression of fertility on per capita income and per capita years of primary and secondary

[3] Barro and Becker [1988, 1989] and Azariades and Drazen [1990] inter alia discuss the link between fertility, income and human capital accumulation.

education yields a strong negative relationship (t-statistics in parentheses):[4]

$$\underset{}{\text{Fertility}} = \underset{(19.91)}{6.60} - \underset{(3.06)}{0.69}\ \underset{}{\text{Income}} - \underset{(3.53)}{0.0002}\ \underset{}{\text{Education}} \qquad R^2 = 0.65.$$

In consequence, the ratio of the (economically inactive) population aged less than 14 years to the total population decreases with GDP per capita. For identical participation rates out of the working age population the initial values of per capita income measured relative to the entire population thus systematically understate the relative output per worker levels of poorer economies.

The measurement problem is furthermore not limited to the initial level of output per worker: the negative correlation between fertility and per capita income also implies a mismeasurement of productivity growth rates. Developed countries had predominantly completed their demographic transition by 1960. With a fairly constant labor force participation rate out of the adult population, the growth rate of per capita income thus approximately equalled the rate of output per worker growth, rendering the substitution innocuous in growth rates as well as in levels. In contrast, initially poor countries passed through their demographic transition during the sample period, implying a declining labor force participation rate measured relative to the total population.[5] Per capita growth rates thus systematically understate the productivity growth rates of initially poorer countries.

2. Labor Force Participation Choice

The second potential bias arises from a dependence of the labor force participation rate (measured correctly relative to the working age population) on income per capita. A regression of the participation rate on initial income reveals a strong and fairly time-invariant quadratic pattern. The data reveal participation rates in the poorest countries to be highest, followed by the richest countries and, at the lowest level, middle-income economies. The income per capita variable thus underestimates the level of output per worker of medium-income countries relative to both poor and rich economies. The income-fertility link, taken in conjunction with the income per capita-labor force participation nexus, implies that the ranking of initial income

[4] All regressions are based on an extended version of the Barro-Wolf [1989] dataset.
[5] A regression of the ratio of the final to the initial participation rate on initial per capita income yields a significant coefficient estimate of 0.06 ($t = 3.62$).

per capita levels does not replicate the ranking of the theoretically correct output per worker measure.

$$\underset{}{\text{Part. Ratio 1960}} = \underset{(44.4)}{0.643} - \underset{(8.84)}{0.115}\ \text{GDP} + \underset{(3.30)}{0.040}\ \text{GDP}^2 \qquad R^2 = 0.42$$

$$\underset{}{\text{Part. Ratio 1985}} = \underset{(49.5)}{0.646} - \underset{(9.01)}{0.118}\ \text{GDP} + \underset{(5.15)}{0.041}\ \text{GDP}^2 \qquad R^2 = 0.45$$

The substitution of income per capita for production per capita thus turns out to be a far from innocuous "approximation": both the relative underestimation of the initial output per worker levels of poorer and medium countries and the relative overestimation of the productivity growth rates of initially rich countries bias the estimated (absolute) convergence parameter downwards, raising the possibility of a spurious rejection of convergence.

3. Human Capital

A third potential measurement problem arises from the failure to take labor quality into account. The theoretical model provides a prediction about the time series behavior of labor productivity, i.e. the value of output per unit of labor input of comparable quality. In practice, the variable most commonly used even in the few convergence studies focusing on labor productivity has been output per worker. The shortcut of equating raw labor with labor input is only appropriate if human capital per worker is identical across countries as well as constant over time. Again, the assumption may provide a reasonable approximation for homogeneous samples but is unlikely to provide an acceptable description of the heterogeneous worldwide datasets used in many convergence studies.

A regression of the average years of primary and secondary education per member of the labor force on initial productivity suggests a strong positive link. The positive association of educational achievement with income implies that regressions based on output per worker systematically underestimate the initial productivity level and systematically overestimate the growth rate of initially poorer countries.

The first effect introduces a bias against convergence, the second a bias in favor of convergence, with ambiguous net result. In the convergence regressions, we control for the potential bias deriving from differential growth rates of human capital by including the initial level and growth rate of the two human capital proxies as additional explanatory variables.

Table 1 – *Human Capital Stock Determinants*

Variable	Primary		Secondary	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Constant	5259.4	6.13	1214.8	3.35
Output per worker	1022.0	3.21	446.5	3.96
Revolutions + coups	−1099.1	1.66	18.6	0.09
Political rights	−361.0	2.84	−163.9	2.62
Africa	−1198	1.95	−240.0	1.29
Latin America	150.9	0.31	−560.6	2.43
R^2	0.69		0.64	

IV. Empirical Results

Our empirical results are based on equation (6).

$$\ln\left(\frac{Y_1}{L_1}\right) - \ln\left(\frac{Y_0}{L_0}\right) = \beta_0 + \beta_1 \ln\left(\frac{Y_0}{L_0}\right) + \pi_0 \ln(H_0) + \pi_1 \ln\left(\frac{H_1}{H_0}\right) + \pi_2 + \xi_i D_i + \varepsilon \tag{6}$$

$$\pi_2 = \lambda_1 SAV + \lambda_2 LFG + \lambda_3 MORT + \lambda_4 COUP. \tag{7}$$

The dependent variable is the growth rate of output per worker. The level and growth rate of human capital are entered as additional explanatory variables, as indicated by (2). In addition, a set of variables π_2 proxying for different steady states are included to avoid bias.[6] The controls include the savings rate (*SAV*), the labor force growth rate (*LFG*), the mortality rate (*MORT*) as proxy of the discount rate, the number of coups and revolutions (*COUP*) as proxy of the security of property rights and continent dummies for Africa and Latin America. The controls are the same as used in many other growth regressions, see Barro [1991], inter alia. Under the null hy-

[6] Without controls for different steady states, a comparison between an initially poorer country with a low steady-state productivity and an initially richer economy with a higher steady-state productivity level will lead to a spurious rejection of the convergence hypothesis since the richer country enjoys transitional growth at productivity levels exceeding the poorer country's steady state.

pothesis, based on simulation studies [King et al., 1988; Sala-i-Martin, 1990] the following testable implications emerge:

1. $\beta_0 \in [0.015, 0.03]$
2. $-0.05 \leq \beta_1 \leq -0.01$
3. $\pi_0 > 0$
4. $\pi_1 = 1$
5. $\lambda_1 > 0$
6. $\lambda_2, \lambda_3, \lambda_4 < 0$.

1. Data

An estimate of labor productivity in sector i is obtained by dividing the constant price value added in the sector by the sectoral labor force. Data on real value added are taken from the World Bank World Tables, the labor force statistics are taken from the ILO, the FAO and the World Bank. The estimate of economy-wide labor productivity is obtained by dividing the Summers and Heston [1988] GDP per capita figures by the labor force participation rate. The human capital variables are obtained by integrating the flow of enrollment, taking account of mortality. The steady-state controls are taken from Barro and Wolf [1989].

2. Economic-wide Convergence

The regression results for the aggregate convergence equation are reported in Table 2.[7] Column 1 contains the "naive" convergence regression in terms of income per capita without steady-state controls. The explanatory power of the regression is virtually zero, although the estimated parameter is significantly positive. Column 2 reports the corresponding regression for output per worker. The convergence parameter declines by 62 percent and becomes insignificant. The replacement of income per capita by output per worker thus has the expected sign-effect on the estimated convergence parameter but does not reverse the divergence finding. Column 3 adds the steady-state determinants, improving the fit of the equation significantly and reducing the convergence coefficient into the significant negative range. All steady-state controls are correctly signed, although, reflecting the high degree of multicollinearity in the dataset [Levine and Renelt, 1992], not individually significant.

Finally, column 4 includes the human capital variables. The estimated convergence parameter now further declines and is well within the range of -0.05 to -0.01 suggested by simulations with realistic parameters. The constant likewise falls within the expected range.

[7] All regressions have been corrected for heteroscedasticity.

Table 2 – *Economy-wide β Convergence*

	[1]	[2]	[3]	[4]
Constant	0.019 (10.45)	0.017 (5.68)	0.019 (1.71)	0.02 (1.16)
Output per worker 1960		0.002 (1.33)	−0.009 (3.50)	−0.012 (3.04)
Income per capita 1960	0.0058 (3.89)			
Savings rate			0.001 (4.31)	0.002 (5.70)
Labor force growth			−0.217 (1.33)	−0.27 (1.51)
Mortality			−0.023 (0.37)	0.017 (0.23)
Revolutions + coups			−0.011 (1.58)	−0.20 (2.00)
Africa dummy			−0.014 (2.59)	−0.019 (2.65)
Latin America dummy			−0.001 (0.16)	0.001 (0.47)
Primary educ. 1960				0.027 (0.06)
Secondary educ. 1960				−0.03 (0.20)
Growth of prim. educ.				−0.00 (0.13)
Growth of seco. educ.				0.00 (0.21)
Growth of aggr. educ.				
R^2	0.08	0.03	0.50	0.62

Table 3 – *Economy-wide β Convergence: Continents*

	Africa	Latin Am.	Europe
Constant	−0.28 (5.36)	−0.01 (0.98)	0.04 (2.01)
Output per worker 1960	−0.05 (12.59)	−0.03 (14.8)	−0.02 (4.08)
Savings rate	−0.00 (0.51)	0.0003 (0.90)	0.0006 (1.11)
Labor force growth	0.53 (1.12)	0.13 (0.99)	−0.72 (1.89)
Mortality	0.44 (3.52)	−0.12 (2.15)	−0.10 (1.24)
Revolutions + coups	−0.11 (11.71)	0.007 (1.46)	−0.01 (0.50)
Primary educ. 1960	0.00 (3.01)	0.00 (4.19)	0.00 (0.53)
Secondary educ. 1960	0.0003 (11.19)	0.00 (2.15)	0.00 (0.58)
Growth of prim. educ.	2.40 (9.87)	2.20 (5.21)	0.44 (0.51)
Growth of seco. educ.	1.58 (8.61)	0.20 (1.55)	0.28 (1.22)
R^2	0.96	0.96	0.89

With the exception of the insignificant mortality rate proxying the discount rate, the steady-state variables have the predicted sign. As familiar from other convergence studies, the human capital variables are individually insignificant while jointly significant.

Table 3 reports the convergence regression by continent. The coefficient on the initial productivity level again enters highly significantly and within the predicted numerical range, while the importance of

Table 4 – *Economy-wide β Convergence: Sectors*

	Agriculture	Manufacturing	Services
Constant	1.00 (7.83)	0.015 (0.46)	0.92 (5.53)
Output per worker 1960	−0.05 (9.56)	−0.0001 (0.11)	−0.05 (7.15)
Savings rate	−0.002 (2.00)	−0.002 (5.24)	0.001 (0.82)
Labor force growth	2.17 (3.30)	−1.09 (3.20)	1.34 (1.48)
Mortality	−1.05 (2.91)	−0.04 (0.56)	−0.44 (1.35)
Revolutions + coups	−0.13 (2.26)	−0.009 (0.69)	−0.15 (2.63)
Primary educ. 1960	−0.00 (2.47)	0.00 (1.01)	−0.00 (0.64)
Secondary educ. 1960	0.00 (2.44)	0.00 (1.93)	0.00 (2.25)
Growth of prim. educ.	−1.22 (0.43)	−0.49 (0.63)	1.41 (0.49)
Growth of seco. educ.	−1.02 (1.64)	0.10 (0.52)	−0.55 (1.20)
R^2	0.92	0.78	0.93

controls for differential human capital is seen to decline with average productivity, again suggesting that the potential error from substituting income for productivity is lower for developed country studies.

Finally, Table 4 reports convergence results separately for agriculture, manufacturing and services. The results reveal very pronounced convergence in both services and agriculture, with β coefficients towards the upper end of the supported range. The very marked convergence in the agricultural sector may have been enhanced by the interplay of productivity growth stunting protection in developed economies and the vanishing of the Ranis-Fei "surplus labor pool" in the less developed economies.

In contrast, the data show little tendency towards convergence for the manufacturing sector. As most of the externality mechanisms underlying the endogenous growth literature seem most applicable to the manufacturing sector, the near absence of convergence in this sector provides some support for models with persistent growth rate differences.

V. Conclusion

Convergence properties of real world data provide a natural test of the relative empirical support for endogenous and exogenous growth models. Over the last decade, a substantial literature has emerged on the subject, alas, no firm conclusions have emerged. We showed in this paper that at least some of the ambiguities can be resolved by taking into account the measurement bias introduced by

the frequent but far from innocuous substitution of income per capita for the theoretically correct variable, labor productivity.

Re-estimation of the convergence equations using economy-wide labor productivity yielded results generally supportive of convergence. Estimation of sectoral convergence equations, however, suggested that the global convergence may predominantly reflect strong convergence in the primary and tertiary sector. In contrast, manufacturing, arguably the source of most of the externalities underlying the endogenous growth literature, showed little tendency towards convergence.

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Abstract: Growth Rate Convergence Reconsidered. – While convergence properties lie at the heart of the endogenous–exogenous growth debate, the empirical literature on convergence to date remains ambiguous. Results appear to be particularly sensitive to the choice of income per capita or labor productivity as dependent variable. The paper shows that the dependence reflects a measurement error arising from the interdependence of human capital accumulation, labor force participation rates and development levels. Estimation of a corrected convergence equation yields results generally supporting convergence except in the manufacturing sector. JEL No. N10, O47

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Zusammenfassung: Nochmals zur Konvergenz der Wachstumsraten. – Während die theoretischen Eigenschaften der Konvergenz im Mittelpunkt der Debatte um

endogenes und exogenes Wachstum stehen, bleibt die empirische Literatur zur Konvergenz bisher unklar. Die Ergebnisse scheinen besonders davon abzuhängen, ob das Pro-Kopf-Einkommen oder die Arbeitsproduktivität in der Beziehung als abhängige Variable gewählt wird. Der Verfasser zeigt, daß die Beziehung einen Meßfehler wiedergibt, der aus der Interdependenz von Humankapitalakkumulation, Erwerbsquote und Entwicklungsniveau resultiert. Die Schätzung einer korrigierten Konvergenzgleichung bringt Ergebnisse, die die Konvergenz generell bestätigen – allerdings nicht im gewerblichen Sektor.