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Per Capita Income, Human Capital, and Inequality Convergence: A Latent-Variable Approach

Sri Devi Deepak, James L. Seale, Jr., and Charles B. Moss

The purpose of this paper is to empirically analyze determinants of income-level convergence. Specifically, the effect of human capital on per capita income is estimated for 22 countries of the Organization for Economic Cooperation and Development (OECD). Additionally, the effects of openness in international trade and investment and government expenditures on per capita income are estimated and evaluated. Human capital is modeled as a latent variable, and results indicate that it is a significant factor in explaining the variation of per capita income levels among the OECD countries. Further, the entire time path of human capital is utilized to explain deviations in per capita income.

Key Words: convergence, human capital, inequality, latent variable, OECD

Whether or not countries are converging in terms of per capita income levels is an important question.[1] A direct way to answer this question for a group of countries is to measure income inequality among countries over time. Much of the recent work directly measuring convergence or divergence of per capita income levels has been done by Theil and associates at the University of Florida (Theil 1989; Theil and Deepak 1994, 2002a,b; Seale, Theil, and Deepak; Moss, Theil, and Deepak; and Theil and Seale). Of these, Theil (1996) and Theil and Seale are the most comprehensive, and Theil and Seale document that, over the period 1950–1990, the relatively rich northern countries are converging, South-East Asian countries are diverging, and tropical Africa has tended to converge during periods of income growth and to diverge during periods of negative growth.

Although answering the convergence question directly, the above studies do not analyze the determinants of convergence.[2] Several recent papers have looked at what factors determine income growth using regression analysis (e.g., Barro; Barro and Sala-i-Martin; and Mankiw, Romer, and Weil). Others including Lucas (1988, 1993) have developed theoretical models of endogenous growth to study the determinants of income growth. (See also Rebelo; Tamura; and Romer 1994.)

Barro analyzes convergence in 98 countries

Sri Devi Deepak is an assistant professor, Tippie College of Business, University of Iowa; James L. Seale, Jr., and Charles B. Moss are professors, Food and Resource Economics Department, University of Florida.

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Corresponding author: James L. Seale, Jr., P.O. Box 110245, Department of Food and Resource Economics, University of Florida, Gainesville, FL 32611-0240 (e-mail: jlseale@mail.ifas.ufl.edu).

[1] The phenomenon of convergence refers to the accelerated growth of relatively poor countries compared to that of relatively rich countries; the divergence-convergence hypotheses originated in neoclassical economics with Kuznets' inverted-U theory.

[2] The cointegration study of Weatherspoon, Seale, and Moss is unique in that they directly relate government expenditure inequality, investment inequality, and industrial employment inequality to income inequality for the G-7 and selected European countries.

during 1960–1985 by studying the relationship among growth rates in per capita income to levels of per capita income and initial levels of human capital. He uses school enrollment rates during 1960 as a proxy for the level of human capital and finds that, holding levels of human capital constant, the growth rate in per capita income is inversely related to the level of per capita income. Further, holding the initial level of per capita income constant, results indicate there is a positive relationship between the growth rate of income and the level of human capital. Therefore, convergence is evident only in countries with high levels of initial human capital.

This paper departs from Barro's work in several important ways. While Barro's study was based on cross-sectional data, this study utilizes pooled data (1955–1990) for 22 OECD countries.[3] Second, unlike Barro, we hypothesize that income convergence is conditional on convergence of its determinants and not just on initial starting values. Third, we construct a multiple-indicator index of human capital utilizing a latent-variable approach (Bollen) and estimate per capita income over time as a function of human capital, international openness, investment expenditures, and government expenditures. Finally, we answer the convergence question directly for the 22 OECD countries over the years 1955–1990 by utilizing Theil's inequality measure.

In the following sections, we describe the data, discuss the latent-variable model, and present the latent-variable-estimation results. We also present evidence on income convergence, discuss inequality measures over time for the hypothesized determinants of real per capita income levels, and draw conclusions based on the evidence.

Data

The three sources of data for this study are the Supplement to Mark 5 or Penn World Tables (PWT5.5) compiled by Summers and Heston; *Basic Facts and Figures* compiled by the United Nations Educational, Scientific and Cultural Organization (UNESCO 1952–1962); and the *Statistical Yearbook* compiled by UNESCO (1963–1993). The data on income, population, international openness, government expenditure, and investment expenditure are extracted from the Summers and Heston data. All the expenditures are in real terms (1985 international prices) and span the years 1955–1990. The unique feature of these data is that the expenditure entries are denominated in a common currency so that real international quantity comparisons can be made both among countries and for a particular country over time.

Real per capita income (Y) is taken directly from the Supplement, as is population (POP). Real per capita government expenditure (G) and real per capita investment (I) are computed from the Supplement. Data for openness (O), which is represented by the real per capita sum of exports and imports, is also computed from the Supplement.

The data on four indicators of human capital—per capita public expenditure on education as a percentage of per capita income (PE), per capita consumption of newsprint (CN), and the percentage of the population completing secondary school (ES) and university levels (ET)—are compiled from the two UNESCO series and span 36 years, 1955 to 1990. Though there are 24 countries in the OECD group, the data for Iceland and Luxembourg are insufficient for them to be included in the study. In total, the data set used in estimation of the latent-variable model has 36 observations for each of the 22 OECD countries (792 total observations) for each of the eight variables: Y, O, G, I, PE, CN, ES, and ET. The model estimates human capital (H) as a latent variable.

The Latent-Variable Model

The basic premises of the empirical model are derived from the national-income identity for an open economy and from recent developments in endogenous-growth models. The na-

[3] These countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Ireland, Italy, Japan, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the U.K., and the United States; Iceland, and Luxembourg were not included due to lack of data.

tional-income identity states that national income is a function of consumption, investment expenditures, government expenditures, and the volume of exports and imports. International trade is one of the key determinants of economic interaction among countries, and countries gain from trading goods and services by taking advantage of the differences in their factor endowments and by achieving economies of scale in production. These gains are reflected in the growth of national income. Further, growth theorists (e.g., Barro; Lucas 1988, 1993; Mankiw, Romer, and Weil; Romer 1989, 1994; Tallman) have shown that accumulation of human capital is beneficial to the economy in terms of income growth.

Based on the above, real income is specified as a function of human capital, international openness, government expenditure, and investment expenditure. Human capital is an unobservable or latent variable, which makes it appropriate to estimate the model as a latent-variable model (Bollen). Although an unobservable variable, human capital has observable indicators from which one can construct an index of human capital. We postulate that the human-capital index can be measured from the common movements of per capita public expenditure on education as a percentage of per capita income (PE), per capita consumption of newsprint (CN), and the percentage of the population completing secondary school (ES) and university levels (ET).

The latent-variable framework as described by Bollen is written as

$$\eta = \Gamma\xi + \zeta \tag{1}$$

where η is the latent variable measuring income (and in our case represents real per capita income [Y]), Γ is a vector of estimated coefficients, $[\gamma_1, \gamma_2, \gamma_3, \gamma_4]$, ξ is a vector of exogenous variables (which may or may not be latent), and ζ is the error term. In the current formulation,

$$\xi = \begin{bmatrix} H \\ O \\ I \\ G \end{bmatrix}.$$

Openness, government expenditures, and investment expenditures are observable exogenous variables while human capital is a latent variable. The indicators or the elements of the ξ vector are then quantified in the indicator equation,

$$x = \Lambda_x\xi + \delta, \tag{2}$$

where

$$x = \begin{bmatrix} \text{PE} \\ \text{CN} \\ \text{ES} \\ \text{ET} \\ O \\ I \\ G \end{bmatrix}, \qquad \Lambda_x = \begin{bmatrix} \lambda_1 & 0 & 0 & 0 \\ \lambda_2 & 0 & 0 & 0 \\ \lambda_3 & 0 & 0 & 0 \\ \lambda_4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \tag{2.a}$$

$$\delta = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \\ \delta_7 \end{bmatrix},$$

and δ_i is a random variable relating the observable variable to the unobservable latent variable. In the current case, $\delta_5 = \delta_6 = \delta_7 = 0$.

Assuming that the residuals across equations (1) and (2) are uncorrelated, the implied covariance matrix can be derived as

$$\Sigma(\beta) = \begin{bmatrix} \Sigma_{yy} & \Sigma_{yx} \\ \Sigma_{xy} & \Sigma_{xx} \end{bmatrix} \tag{3}$$

where β denotes the vector of unknown parameters,

$$\Sigma_{yy} = \Gamma\Phi\Gamma' + \psi, \qquad \Sigma_{yx} = \Gamma\Phi\Lambda_x', \tag{4}$$
$$\Sigma_{xy} = \Lambda_x\Phi\Gamma', \qquad \Sigma_{xx} = \Lambda_x\Phi\Lambda_x' + \Theta_\delta,$$
$$\Phi \text{ is } E[\xi\xi'], \qquad \psi \text{ is } E[\zeta\zeta'], \text{ and}$$
$$\Theta_\delta \text{ is } E[\delta\delta'].$$

This (unrestricted) specification yields 23 parameters to be estimated before normalization: the structural coefficients (λ_1, λ_2, λ_3, λ_4, γ_1, γ_2, γ_3, and γ_4); the variance parameter in the income equation (ψ); the noncommunal

portion of the indicator variances (θ_{11}, θ_{22}, θ_{33}, and θ_{44}); and the elements of the Φ matrix (ϕ_{11}, ϕ_{12}, ϕ_{13}, ϕ_{14}, ϕ_{22}, ϕ_{23}, ϕ_{24}, ϕ_{33}, ϕ_{34}, and ϕ_{44}). However, for estimation purposes, one must normalize either one of the λs or the variance of the latent variable, ϕ_{11}. We chose to set ϕ_{11} to one making the latent variable an $N(0, 1)$ variable and therefore making its statistical significance easily interpretable.

The parameters are estimated by maximum likelihood by searching over the parameter space to maximize:

$$(5) \quad \max_{\beta} F_{ML} = \text{Log}[\Sigma(\beta)] + \text{tr}[S\Sigma(\beta)^{-1}]$$

where tr[ ] is the matrix trace operator, and S the sample variance matrix. Given the structure of the current problem, this search can be further simplified. Note that

$$\Phi = \begin{bmatrix} \phi_{11} & \phi_{12} & \phi_{13} & \phi_{14} \\ \phi_{21} & \phi_{22} & \phi_{23} & \phi_{24} \\ \phi_{31} & \phi_{32} & \phi_{33} & \phi_{34} \\ \phi_{41} & \phi_{42} & \phi_{43} & \phi_{44} \end{bmatrix}$$

can be partitioned into

$$\Phi = \begin{bmatrix} \Phi_{11} & \Phi_{12}' \\ \Phi_{21} & \Phi_{22} \end{bmatrix}$$

where $\Phi_{11} = 1$ by normalization,

$$\Phi_{12} = \begin{bmatrix} \phi_{12} \\ \phi_{13} \\ \phi_{14} \end{bmatrix}, \quad \Phi_{21} = \begin{bmatrix} \phi_{21} \\ \phi_{31} \\ \phi_{41} \end{bmatrix}, \quad \text{and}$$

$$\Phi_{22} = \begin{bmatrix} \phi_{22} & \phi_{23} & \phi_{24} \\ \phi_{23} & \phi_{33} & \phi_{34} \\ \phi_{24} & \phi_{34} & \phi_{44} \end{bmatrix}.$$

By setting $\Phi_{22} = S_{22}$ from the sample variance matrix, the estimation can be considerably simplified. The intuition is that openness, government spending, and investment expenditures are exogenous to the model so their variance parameters are fixed in the same way the $x'x$ matrix in a regression analysis is fixed.

After estimating the parameters in the model, we estimate the latent variable, human capital, by minimizing the weighted squared errors as proposed by Bartlett,

Table 1. Estimated Parameters for the Measurement Model, 22 OECD Countries, 1955–1990

Variable	Parameter	Estimate	Standard Error
PE	λ_1	2.66	0.08
CN	λ_2	1.05	0.04
ES	λ_3	1.43	0.08
ET	λ_4	0.97	0.03
$E[\delta_1\delta_1']$	θ_{11}	1.22	0.06
$E[\delta_2\delta_2']$	θ_{22}	0.73	0.02
$E[\delta_3\delta_3']$	θ_{33}	1.89	0.05
$E[\delta_4\delta_4']$	θ_{44}	0.54	0.02

Notes: PE is per capita expenditure on education, CN is per capita consumption of newsprint, ES is education at the secondary level, and ET is education higher than secondary level; $E[\delta_i\delta_i']$ represent the diagonal elements of Θ_δ.

$$(6) \quad \hat{\xi} = (\hat{\Lambda}_x'\hat{\Theta}_\delta^{-1}\hat{\Lambda}_x)^{-1}\hat{\Lambda}_x'\hat{\Theta}_\delta^{-1}x.$$

We further compute the predicted estimated per capita income as

$$(7) \quad \hat{y} = \hat{\Gamma}\hat{\xi}.$$

Results

The data of the 22 OECD countries are pooled over the 1955–1990 period for a total of 22 countries × 36 years = 792 observations. Equations (1) and (2) are estimated simultaneously by the maximum-likelihood estimator (MLE) with and without the restriction that $\Phi_{12} = \Phi_{21} = 0$. The likelihood-ratio test failed to reject this hypothesis at the .05 level-of-significance, so only the results of the restricted model are reported (Tables 1 and 2). All the estimated coefficients are statistically significant at any conventional level of significance.

The results from the latent-variable model (Table 1) show that the four indicators—public expenditure, secondary and higher levels of education, and consumption of newsprint—all load positively on human capital. Public expenditure on education (PE) has the largest effect on human-capital accumulation, probably because this investment results in higher levels of schooling for the population and in the im-

Table 2. Estimated Parameters for Latent-Variable Model, 22 OECD Countries, 1955–1990

Variable	Parameter	Estimate	Standard Error	Elasticity
Human Capital (H)	γ_1	12.37	0.76	0.68
Openness (O)	γ_2	0.08	0.01	0.04
Investment (I)	γ_3	1.62	0.05	0.42
Government Expenditure (G)	γ_4	1.37	0.09	0.19
$E[\zeta\zeta']$*	Ψ	7.50	0.26	

* This gives the variance for the latent-variable model.

provement of skill levels and the level of technology. The factor with the next largest effect on human-capital accumulation is the percentage of the population with a secondary education (ES). The effects of the percentage of population with a university or equivalent degree (ET) and of the per capita consumption of newsprint (CN) are significantly positive and approximately the same. That the population percentage with a secondary education has a greater effect on human-capital accumulation than the percentage with a university education may be because secondary education is an input into university education, but it may also have implications for the industrial composition of the economy. In summary, increases in these four indicators increase the level of human capital for the 22 OECD countries.

Furthermore, the results reported in Table 2 indicate that an increase in human capital leads to an increase in per capita income. Increased international openness, investment expenditures, and government expenditures also lead to increased per capita income. These results correspond with basic macroeconomic and growth theories (i.e., that growth in real per capita income is positively correlated with the accumulation of physical capital, human capital, and with growth in international trade). Human capital has the greatest positive effect on income implying its key role in the growth of income for the 22 OECD countries. This result corresponds with the predictions and results of Barro, Tallman, and Wang and Lucas (1988, 1993). The positive effect of international openness is as predicted by Romer (1990).

Elasticity estimates are also calculated based on the estimated structural coefficients and are reported in column (5) of Table 2. The income elasticity with respect to human capital is most sensitive (0.68) followed by the elasticity with respect to investment expenditure (0.42). The income elasticities with respect to government expenditure (0.19) and international openness (0.04) are much lower. These results reiterate the dominance of human capital in determining growth in income.

Using Bartlett's method (Equation [6]) and the estimated parameters reported in Table 1, the per capita value of human capital is computed for each of the 22 OECD countries. Aggregate population-weighted (average) levels of observed per capita income (Y), human-capital index (H), international openness (O), investment and government expenditures (I and G, respectively) are calculated for the 22 OECD countries as a group and are reported in Table 3.

Aggregate human capital (Table 3, column 3) shows an increasing trend. Human-capital indices are also computed for each of the 22 countries and compared to the average (aggregate) human-capital index. From these comparisons, it is apparent that Canada, Denmark, The Netherlands, Norway, Sweden, and the United States have human-capital indices above the aggregate population-weighted human-capital index over the 1955–1990 period (Table 4). Austria, France, Germany, Greece, Ireland, Italy, Japan, Portugal, Spain, Turkey, and the U.K. have human-capital levels below the average, while Australia, Belgium, Finland, New Zealand, and Switzerland have levels of human capital comparable to the average level.

Comparing the individual countries' per capita income to the aggregate population-weighted per capita income level, Australia,

Table 3. Variables at Aggregate Level for 22 OECD Countries, 1955–1990

Year	Observed Income (Y)	Human Capital (H)	International Openness (O)	Investment Expenditure (I)	Government Expenditure (G)
1	2	3	4	5	6
1955	4,856.41	353.55	2,157.70	1,164.29	701.19
1956	4,981.50	356.04	2,258.89	1,205.18	710.36
1957	5,088.14	363.00	2,331.71	1,235.35	719.98
1958	5,088.95	365.93	2,176.01	1,181.26	726.71
1959	5,301.73	374.90	2,297.96	1,289.14	743.22
1960	5,592.00	385.29	2,534.22	1,438.33	765.48
1961	5,817.45	396.65	2,613.29	1,516.96	799.23
1962	6,025.18	411.59	2,653.05	1,574.16	835.98
1963	6,244.45	418.55	2,780.55	1,611.32	870.03
1964	6,580.23	431.71	2,963.95	1,816.69	893.46
1965	6,811.45	441.25	3,060.68	1,901.03	924.62
1966	7,020.50	448.00	3,153.81	1,955.31	963.15
1967	7,195.55	433.30	3,176.04	1,960.08	1,002.12
1968	7,494.64	437.58	3,406.02	2,041.00	1,032.08
1969	7,882.82	450.67	3,731.04	2,203.99	1,059.03
1970	8,201.82	458.16	4,035.93	2,363.61	1,102.05
1971	8,431.73	467.40	4,072.33	2,383.48	1,137.17
1972	8,773.59	475.14	4,191.35	2,431.35	1,173.57
1973	9,207.86	489.24	4,694.97	2,683.62	1,210.18
1974	9,348.23	497.12	5,480.03	2,722.33	1,254.94
1975	9,234.18	504.67	4,950.24	2,397.84	1,306.11
1976	9,547.45	511.74	5,310.18	2,528.27	1,343.81
1977	9,704.09	513.79	5,438.55	2,509.33	1,376.41
1978	9,931.27	516.18	5,416.12	2,473.30	1,425.61
1979	10,235.73	520.26	6,007.81	2,643.42	1,463.06
1980	10,386.86	528.43	6,412.30	2,672.14	1,498.23
1981	10,415.05	532.39	6,546.11	2,544.81	1,525.94
1982	10,390.77	531.96	6,436.97	2,454.46	1,547.66
1983	10,574.41	530.27	6,538.12	2,451.92	1,573.79
1984	10,912.41	533.77	7,143.68	2,617.43	1,594.88
1985	11,198.09	535.67	7,336.42	2,666.83	1,631.40
1986	11,464.18	544.86	6,750.47	2,781.84	1,664.05
1987	11,743.05	548.80	6,792.68	2,862.67	1,689.27
1988	12,121.86	547.42	7,137.16	3,044.30	1,709.62
1989	12,488.14	557.64	7,693.80	3,261.58	1,730.06
1990	12,713.18	566.87	7,738.67	3,233.76	1,781.16

Canada, Sweden, Switzerland, and the United States have per capita income levels above the average population-weighted level (Table 4, column 2). Austria, Greece, Ireland, Italy, Japan, Portugal, Spain, and Turkey (Table 4, column 3) have per capita income levels below the aggregate population-weighted level, while the per capita incomes levels of Belgium, Denmark, Finland, France, Germany, The Netherlands, New Zealand, Norway, and the U.K. (Table 4, column 4) are close to that of the aggregate population-weighted income level.

It is remarkable that all countries with per capita income levels greater than the aggregate population-weighted income level also have human-capital indices greater than the aggregate population-weighted human-capital index (Canada, Sweden, and the United States) or one that tracks closely the aggregate human-

Table 4. Summary of Cross-Country Analyses for Income Levels in 22 OECD Countries, 1955–1990

	Y_i Above Y_{OECD}	Y_i Below Y_{OECD}	Tracks Y_{OECD}
H_i above H_{OECD}	Canada, Sweden, United States		Denmark, The Netherlands, Norway
H_i below H_{OECD}		Austria, Greece, Ireland, Italy, Japan, Portugal, Spain, Turkey	France, Germany, U.K.
Tracks H_{OECD}	Australia, Switzerland		Belgium, Finland, New Zealand

Notes: H_i is level of human capital for country i, H_{OECD} is the average level of human capital for the 22 OECD countries, Y_i is observed income for country i, and Y_{OECD} is the average level of observed income for the 22 OECD countries.

capital index (Australia and Switzerland). Furthermore, all countries with per capita income levels below the aggregate population-weighted income level (Austria, Greece, Ireland, Italy, Japan, Portugal, Spain, and Turkey) have human-capital indices also less than the aggregate population-weighted human-capital index. Of the nine countries that have per capita income levels that closely track that of the aggregate population-weighted level, three (The Netherlands, Denmark, and Norway) have human-capital indices greater than the aggregate population-weighted human-capital index, three (Belgium, Finland, and New Zealand) have human-capital indices that closely track that of the aggregate level, and three (France, Germany, and the U.K.) have human-capital indices below that of the aggregate population-weighted index.

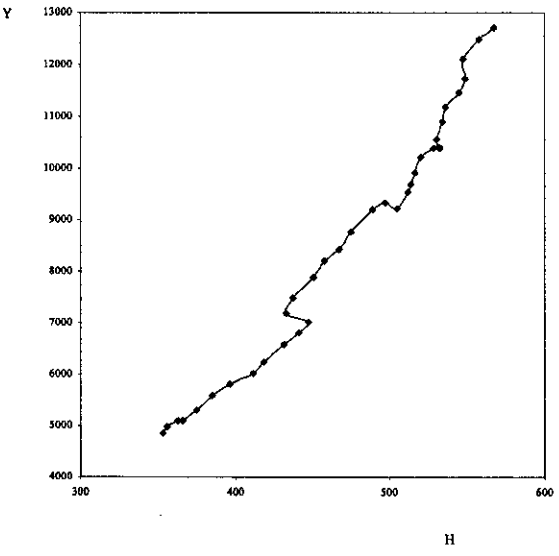

Figure 1. Relationship between Human Capital (H) and Observed Per Capita Income (Y) for 22 OECD Countries, 1955–1990.

The predicted per capita income level is calculated using Equation (7) for each of the 22 countries, as well as an average population-weighted predicted level. For the 22 countries, the model underestimates the income for three countries (United States, Canada, Switzerland), overestimates the income for five countries (Greece, Ireland, Norway, Portugal, and Turkey), and fits well for the remaining 14 countries (Australia, Austria, Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, New Zealand, Spain, Sweden, and the U.K.).

Lastly, Figure 1 graphs the aggregate observed per capita income against the human-capital index, and the relationship is strongly positive. A comparison at the individual-country level reveals that the relationship is positive in every case.

Convergence

To answer the question of per capita income convergence, we apply Theil's inequality index to per capita levels of observed income. Theil's income inequality applied to the 22 countries is written as

$$J = \sum_i p_i \operatorname{Log}\left[\frac{p_i}{y_i}\right],$$

Table 5. Average Inequality in Observed Income, Human Capital, International Openness, Investment, and Government Expenditures in 22 OECD Countries, 1955–1990

Year	Observed Income (Y)	Human Capital (H)	International Openness (O)	Investment Expenditure (I)	Government Expenditure (G)
1	2	3	4	5	6
1955	0.1688	0.0096	0.03041	0.2235	0.1967
1956	0.1591	0.0090	0.2953	0.1934	0.1963
1957	0.1443	0.0099	0.2858	0.1511	0.2010
1958	0.1314	0.0091	0.3000	0.1364	0.1942
1959	0.1344	0.0104	0.2822	0.1519	0.1845
1960	0.1227	0.0192	0.2680	0.1240	0.1735
1961	0.1086	0.0112	0.2347	0.0960	0.1689
1962	0.1069	0.0147	0.2268	0.1029	0.1653
1963	0.0988	0.0168	0.2231	0.0953	0.1532
1964	0.0961	0.0164	0.2255	0.0897	0.1480
1965	0.0990	0.0189	0.2154	0.0997	0.1439
1966	0.0943	0.0205	0.2008	0.0877	0.1508
1967	0.0881	0.0178	0.2031	0.0756	0.1562
1968	0.0827	0.0190	0.2036	0.0717	0.1522
1969	0.0774	0.0219	0.2139	0.0716	0.1460
1970	0.0712	0.0222	0.2013	0.0661	0.1398
1971	0.0684	0.0228	0.1866	0.0699	0.1215
1972	0.0671	0.0213	0.1765	0.0697	0.1232
1973	0.0674	0.0232	0.1707	0.0658	0.1165
1974	0.0624	0.0205	0.1601	0.0554	0.1132
1975	0.0580	0.0164	0.1516	0.0467	0.1065
1976	0.0583	0.0169	0.1571	0.0478	0.1010
1977	0.0595	0.0195	0.1615	0.0493	0.0976
1978	0.0633	0.0231	0.1769	0.0684	0.0924
1979	0.0646	0.0224	0.1877	0.0704	0.0923
1980	0.0629	0.0241	0.1526	0.0670	0.0897
1981	0.0653	0.0238	0.1450	0.0754	0.0898
1982	0.0608	0.0228	0.1433	0.0655	0.0897
1983	0.0629	0.0224	0.1461	0.0696	0.0896
1984	0.0675	0.0236	0.1392	0.0876	0.0932
1985	0.0680	0.0252	0.1475	0.0832	0.0960
1986	0.0655	0.0269	0.1515	0.0762	0.0954
1987	0.0639	0.0279	0.1388	0.0767	0.0968
1988	0.0652	0.0178	0.1335	0.0831	0.0953
1989	0.0654	0.0185	0.1347	0.0901	0.0935
1990	0.0593	0.0222	0.1287	0.0873	0.0878

where p_i is the population share of country i (=1, . . . , 22), and y_i is the income share of country i.

Inequality measures can be calculated for other variables besides per capita income. For example, average inequalities over time can be calculated for the human-capital index, for investment expenditures, for government expenditures, and for international openness. These aggregate inequality measures along with those of observed per capita income are reported in Table 5. That income levels of these countries are converging as a group is evident; the income inequality measure decreased by over 60% from 1955–1990; thus, it is clear that these countries are becoming more similar in terms of real per capita income levels over the time period. The inequality in the human-

capital index initially decreased and then increased, indicating that the OECD countries converged initially in these variables and then diverged. From 1955 to 1975, investment expenditure inequality steadily decreased by over 75%. Although it increased thereafter, 1990 investment inequality was only 60% of 1955 investment inequality. The inequalities in openness and government expenditure decreased over the period indicating that the 22 OECD countries became more similar in these two aspects. By looking at Table 5, it is clear that income inequality and those of investment, international openness, and government expenditure all declined steadily from 1955 to 1975. At that point, income inequality essentially leveled off from 1975 to 1990. Investment inequality increased from 1975 to 1990 while the openness-inequality measure increased from 1975 to 1979 and then continued its earlier decreasing trend until 1990. The inequality in government expenditure continued to decline after 1975, leveled off in the early 1980s, and then increased slightly thereafter.

In terms of size, the openness inequality is the largest throughout the period followed by the inequality in government expenditure and investment expenditure in that order. Income inequality in 1955 was smaller to that of international openness, government expenditure, and investment, but larger than that of human capital. From 1960 until 1975, income and investment inequalities were approximately the same size, but after 1975 that of investment increased while that of income stayed essentially level. Although it increased slightly over the time period, human-capital inequality was much smaller than that of the others. This indicates that, though human capital in the 22 countries became slightly more dissimilar over the entire period, these countries are still more similar in terms of human capital than in terms of the other variables.

These results support the fact that convergence in income is contributed to by all of its determinants. Thus, a low rate of convergence in income after 1980 could be due to a rapid rate of convergence in openness, a high rate of divergence in investment, a modest rate of convergence in government expenditure, and a slow rate of divergence in human capital (which influenced income more positively than the other determinants).

Conclusions and Discussion

This study estimates a latent-variable formulation depicting the effect of human capital on per capita income for 22 OECD countries from 1955 to 1990. The model indicates that human-capital formation has a positive effect on per capita income, as does international openness, government expenditure, and investment expenditure. These results correspond to the contemporary evidence presented by Barro; Mankiw, Romer, and Weil; Tallman and Wang; Lucas (1988, 1993); and Romer (1990) who conclude that human-capital accumulation is vital to the growth of an economy. In addition, the results also indicate that international openness has a positive effect on per capita income and may explain the continued expansion in per capita income after investment in human capital slowed in the 1970s.

The inequality measures indicate that income inequality certainly converged over the entire period but leveled off after 1980. The inequality measures of investment, government expenditure, and especially international openness declined until 1975 and surely contributed to the rapid income convergence. After 1975, investment inequality and human-capital inequalities grew larger. These results suggest that income convergence is not automatic for these countries but that these countries must continue to become more similar in terms of investment, government expenditure, openness, and human capital if they are to continue to converge in terms of real per capita income levels.

References

Barro, R.J. "Economic Growth in a Cross Section of Countries." *Quarterly Journal of Economics* 106(1991):407–43.

Barro, R.J., and X. Sala-i-Martin "Convergence." *Journal of Political Economy* 100 (1992):223–51.

Bartlett, M.S. "Methods of Estimating Mental Factors." *Nature* 141(1938):609–710.

Bollen, K. *Structural Equations with Latent Variables.* New York: John Wiley & Sons, 1989.

Kuznets, S. "Economic Growth and Income Inequality." *American Economic Review* 45 (1955):1–28.

Lucas, R.E., Jr. "On the Mechanics of Development." *Journal of Monetary Economics* 22(1988):3–42.

Lucas, R.E., Jr. "Making a Miracle." *Econometrica* 61(1993):251–72.

Mankiw, N.G., D. Romer, and D.N. Weil. "A Contribution to the Empirics of Economic Growth." *Quarterly Journal of Economics* 106(1991): 407–37.

Moss, C.B., H. Theil, and S.D. Deepak. "The GDPs and Populations of the G-7 Countries, 1950–1990." *Price Policies and Economic Growth.* Antonio Jorge and Jorge Salazar-Carillo, eds. Westport, CN: Praeger, 1997.

Rebelo, S. "Long-Run Policy Analysis and Long-Run Growth." *Journal of Political Economy* 99(1991):500–21.

Romer, P.M. "Capital Accumulation in the Theory of Long-Run Growth." *Modern Business Cycle Theory.* R. Barro, ed., pp. 51–127. Cambridge, MA: Harvard University Press.

Romer, P.M. "Endogenous Technological Change." *Journal of Political Economy* 98(Suppl. 1990): 71–102.

Romer, P.M. "The Origins of Endogenous Growth." *Journal of Economic Perspectives* 8(1994):3–22.

Seale, J.L., Jr., H. Theil, and S.D. Deepak. "Growth and Its Disparity in Rich and Poor Regions." *Economics Letters* 45(1994):467–70.

Summers, R., and A. Heston. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons. 1950–1988." *Quarterly Journal of Economics* 106(1991):327–68.

Tallman, E.W. "Human Capital Investment and Economic Growth: New Routs in Theory Address Old Questions." *Economic Review* (1992):1–12.

Tamura, R. "Income Convergence in an Endogenous Growth Model." *Journal of Political Economy* 99(1991):522–40.

Theil, H. "The Development of International Inequality." *Journal of Econometrics* 42(1989): 145–55.

Theil, H., and D. Chen. "The Geographic Distribution of Gross World Product, 1950–1990." *Studies in Global Econometrics.* H. Theil. Dordrecht, Netherlands: Kluwer Academic Publishers, 1996.

Theil, H., and S.D. Deepak. "The GDPs of Seven Major Regions, 1950–1990." *Empirical Economics* 19(1994):517–22.

Theil, H., and S.D. Deepak "How Affluent Are the Neighbors of Affluent Countries?" *International Working Paper Series,* IW93-21. Gainesville, FL: Food and Resource Economics Department, University of Florida, 1993a.

Theil, H., and S.D. Deepak. "Visiting the GDPs of the Western Pacific and Three Regions in Western Europe." *International Working Paper Series,* IW93-25. Gainesville, FL: Food and Resource Economics Department, University of Florida, 1993b.

Theil, H., and J.L. Seale, Jr. "The Geographic Distribution of World Income, 1950–1990." *De Economist* 142(1994):387–419.

United Nations Educational, Scientific and Cultural Organization (UNESCO). *Basic Facts and Figures: International Statistics Relating to Education, Culture and Mass Communication.* Paris: UNESCO, 1951–1961.

United Nations Educational, Scientific and Cultural Organization (UNESCO). *Statistical Yearbook (UNESCO).* Paris: UNESCO, 1963–1993.

Weatherspoon, D.D., J.L. Seale, Jr., and C.B. Moss. "Extending Theil's Inequality Index: Addressing Dynamic Convergence in the OECD." *Journal of Agricultural and Applied Economics* (2002): 183–94.