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Why Development Levels Differ: The Sources of Differential Economic Growth in a Panel of High and Low Income Countries

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June, 2006

In his 1967 book, Edward F. Denison examined the question of “Why Growth Rates Differ.” Since his work, and that of Angus Maddison’s early work, this question has been asked over and over again, with a longer list of countries, better data, and ever more sophisticated analytical techniques. Despite the many advances and growing insights into the problem described in the recent review by Bosworth and Collins (2003), the answer remains elusive. Many of the poorest countries of the world are falling behind the world leaders, and some have even regressed in recent years. At the same time, other poor countries have shown the capacity to make dramatic improvements in income per capita.

Past studies of differential growth rates and their causes have tended to use time series data from individual countries, while studies of the difference of income per capita levels have typically used cross-sectional data. Moreover, the growth-rate studies tend to use an output growth accounting approach, while the cross-sectional studies are usually grounded in growth-theoretical models of income convergence or divergence. This study is intended to populate the space between these approaches. It joins the debate by jointly examining the growth rates and the evolution of the corresponding levels in a range of high and low-income countries. It aims at the broadness of coverage and deals with the resulting problem of data accuracy by combining the data into six meta-countries, each representative of a different level or path of economic development.

We start by estimating the conventional growth-rate statistics for the years 1970-2000, based on the framework developed by Solow (1957) and Jorgenson and Griliches (1967), and the productivity level statistics developed by Jorgenson and Nishimizu (1978) and Caves, Christensen, and Diewert (1982). These estimates provide a retrospective view of the sources of economic growth. To address the issue of where the meta-countries are heading in the future, and not just where they are at present or have been in the past, we turn to a modified version of the Mankiw, Romer, and Weil (1992) – henceforth MRW – model of steady-state growth. This framework allows us to estimate the equilibrium level of output per worker that is consistent with the basic parameters of growth in each meta-country (technology change, saving rates, and population growth). These estimates then permit us to compare past and future growth paths and address issues about convergence and divergence in the levels of economic development, as well as the quantitative significance of long-run factors that promote or inhibit growth.

2. The Theory of Empirical Growth Modeling

The conventional approach in the literature on international growth comparisons assumes that the production possibilities of an economy can be characterized by a stable aggregate production function. This function relates output (Y) to inputs of labor (L) and capital (K), with allowance for improvements in the productivity of these inputs. Under the assumption of constant returns to scale, it can be written in intensive form as $y_t = F(k_t,t)$, with the variables expressed relative to labor: $y_t = Y_t/L_t$ and $k_t = K_t/L_t$, and the time index 't' included to allow for shifts in the function over time. This framework has the advantage that it appropriates the large literature on production and productivity to the problem of explaining cross-national differences in income per capita. However, this approach comes at a cost. The production function relates the inputs to output, not income to population. Output is not the same as income (a point evident in Appendix Table A.1), nor is population the same as labor input. There are differences among countries in the rate of unemployment, the size of the underground sector, and the nature of household and family production, and measured output per worker, y_t, is therefore unlikely to be proportional to income per capita across countries or over time (although they are correlated). We will nevertheless follow empirical practice and adopt the production function framework.

The standard graphical representation of the production model is shown in Figure 1. This figure portrays an economy initially located at the point a on the production function prevailing in that year (1970 in this example). This production function has the Hicksian form, $y_t = A_t F(k_t)$, indicating that productivity change affects all combinations of k_t proportionately. An increase in the efficiency index, from A_{70} to A_{00} in the year 2000, causes the production function to shift upward as in the figure. This shift is often associated with the adoption of better technologies over time. However, it actually represents a costless improvement in the effectiveness with which capital and labor are used, and it is more appropriately characterized as a change in total factor productivity (TFP). TFP excludes the systematic development of technology paid for by R&D expenditures, but includes the part resulting from R&D externalities, learning, or pure inspiration. In addition, it includes changes in organizational efficiency, and institutional factors such as the legal and regulatory environment, geographic location, political stability, as well as deeper cultural attitudes that affect the work place. It also sweeps in all other factors not explicitly included in measured input: omitted variables like infrastructure capital, variations in the utilization of capital and labor (e.g., unemployment), and measurement errors (for further discussion, see Hulten (2001)).

Output gets a further boost, in this example, from an increase in the capital-labor ratio from k_{70} to k_{00}. Because of diminishing returns to capital, the production function is shown with a concave shape. Each increment of capital per worker yields a proportionately smaller increase in output per worker. With technology held constant, this increase is represented by the move from point a to point b on the lower A_{70} branch of the production function. The total change in output per worker in Figure 1 is from y_{70} to y_{00}, that is, from point a to point c, and is the sum of the capital deepening effect, from point a to point b, and the TFP effect, from point b to point c. The relative size of these two effects is the point at issue in the capital versus efficiency controversy, and it is this split that we attempt to measure in this paper.

3. Estimation Procedures

A number of different approaches have been used in empirical growth analysis. Some studies use an econometric approach in which the production function in Figure 1 is given an explicit functional form and the parameters of that form are estimated. Various methods are available, but those that make use of times-series data are sensitive to measurement error and incomplete data, while those based on cross-sectional data typically impose a common production function across countries and may be sensitive to which countries are included in the sample. Neither is entirely suitable for the study of low income countries, which tend to have both inadequate and incomplete data.

Non-parametric techniques tend to be more forgiving of weak data, and are widely used. The two main alternatives are the Solow (1957) growth-accounting model and the Data Envelopment Analysis approach. We use the Solow model in this paper, as extended by Jorgenson and Griliches (1967), to facilitate comparison with the literature. The Solow model provides an accounting framework, based on the Divisia index, in which the growth rate of output per worker (y_t) is equal to the growth rate of capital per worker (k_t) weighted by its share in GDP, plus a residual factor that accounts for all the remaining growth in y_t not explained by the weighted growth of k_t.[1] Solow shows that, under the assumption that prices are equal to marginal costs, the income shares are equal to output elasticities, and the share-weighted growth rate of k_t is associated with the movement along the production function from a to b in Figure 1, i.e., with capital deepening, and the residual is associated with the shift in the production from b to c. The Solow sources-of-growth decomposition thus provides a method of resolving the total change in y_t into the capital-deepening effect and the TFP effect.

4. Sources-of-Growth Data and Estimates

The sources-of-growth framework requires times series data on real output, labor input, capital stocks, and labor's share of income. These data are constructed for a total of 97 countries over the period 1970-2000. The list of countries, along with selected statistics, is shown in Table A.1 of the Data Appendix. In order to facilitate comparison, these countries are grouped into six 'meta' countries, based on the World Bank classification by income level. The 31 Low Income countries are located in Africa, with only three exceptions. The 22 Lower-Middle Income countries are developing economies spread throughout the world, as are the 14 Upper-Middle Income countries. The 23 High-Income countries are basically those of the OECD. In addition, we have constructed two small meta-countries: four "Tigers" (Hong Kong, South Korea, Singapore, and Taiwan), and three Large Countries (Brazil, China, and India).

Our principal data source is the Penn World Tables 6.1 (Heston, Summers and Aten, 2002), from which real GDP (chain weighted) and real investment are obtained (both in power

[1] Since accounting data do not come in a continuous time format, the discrete time Tornqvist approximation is typically used in the actual calculations. Growth rates are approximated by the change in the natural logarithms of the variables, weighted by the average income share from one period to the next.

purchasing parity 1996 US dollars), as well as our labor force estimates. Real investment is used to compute the capital stock in international prices (details of this computation are given in the Appendix).[2] These data yield the estimates of y_t and k_t required by the sources-of-growth model. The final piece of data used in the paper, the country labor income shares, β, is obtained from the United Nations Statistical Yearbook (various issues) and is simply computed as Compensation to Employees in GDP.

The estimates of β suffer from the well-known problem that they are implausibly low. Indeed, the average shares shown in Figure A.2 indicate an average labor share of only 0.30 for the low income countries, ranging upward to 0.55 for those in the High Income category. This situation undoubtedly reflects an undercount of the income accruing to labor, especially in low income countries where there are many self-employed and family workers, and many undocumented workers in the underground economy (see Gollin (2002), and the additional remarks in the appendix of this paper). As with other studies, these data limitations force us to adopt the assumption that income shares are the same for all countries, and set labor's share at two-thirds of income. This is a common assumption in the literature, and it is more a matter of necessity than accuracy since the implausibility of the published data does not necessarily imply that the true labor share should be the same in every economy, much less a two-thirds share.[3]

[2] In the few cases where there were missing end years to the data series we have used the growth rate of real GDP in US$, published in the World Bank's World Development Indicators 2004, and extrapolated our data based on these. For a more thorough discussion of the data and some adjustments made to the data on labor force, we refer the reader to Isaksson (2006).

[3] If, for example, the elasticity of substitution between labor and capital is low, a low wage economy will tend, all else equal, to have a smaller share of its income given to labor than a higher-wage economy with the same technology. A constant labor share is therefore not a theoretical necessity, even if technologies were there same across countries in every industry, and the composition of industries happened to be the same.

We will therefore present two sets of sources-of-growth estimates, one set calculated with a two-thirds labor share and another based on the average measured shares for each meta country.

These estimates are shown in Tables 1 and 2, respectively. The first column of Table 1 indicates that output per worker grew strongly over the period 1970 to 2000 in the High Income countries, but was actually negative in the Low Income group. The Lower Middle and Upper Middle Income meta countries display a positive growth experience, but still lag the growth rate of High Income leader. The Tiger and Large meta countries, on the other hand, outperformed the leader in terms of growth. However, it is also the case that they started from a lower level of output per worker.

The second and third columns of Table 1 show the sources-of-growth decomposition of the growth rate of output per worker into its capital-deepening and TFP components, based on the assumption that labor's income share is 0.67 for all countries. It is evident that capital deepening is the predominant source of growth in the Low, Lower Middle, and Upper Middle Income countries, that it accounts for about half of the growth in output per worker in the High Income and Tiger countries, and is slightly less than half of the growth of the Large countries. This speaks directly to the question posed in Figure 1 about the relative magnitudes of the *growth rates* associated with the effects (a to b) and (b to c): capital deepening, not TFP, is the dominant effect, although TFP is an important contributor in half of the meta groups.

However, there is an important caveat. A comparison of the Low Income and High Income cases indicates that two-thirds of the *cross-sectional difference* in the growth rate of y_t is due to the difference in TFP growth rates. Moreover, the TFP effect accounts for more that half of the corresponding growth differential in the other countries. In other words, capital deepening is the dominant source of growth *over time* in all but the most rapidly growing countries, but TFP is a more important factor in explaining *cross-sectional* differences in growth performance. These results are very consistent with the estimates of Bosworth and Collins, who use a similar set of assumptions and methods.

The results shown in Table 2 replay Table 1 using the average measured share of labor income, β, as estimated from the data (see Table 7). Since the share in the sources-of-growth model is a surrogate for the associated output elasticity, the shift to the actual β greatly decreases the output elasticity of labor and increases that of capital, thereby giving greater weight to the growth rate of k_t and strengthening the capital-deepening effect. In the case of Low Income countries, for example, the increase in the capital elasticity is from 0.33 to 0.70, with a slightly smaller increase for other countries. The effect of this change is evident in the second and third columns of Table 2. Capital deepening is now the overwhelmingly dominant source of growth over time in all the meta countries, although TFP is a still an important factor in explaining cross-sectional differences in growth performance, with the exception of the most rapidly growing countries. The results do not have an equal footing with those of Table 1, in our view, because of the implausibility of the measured shares. However, there are plausibility issues with the assumption that all countries have the same constant labor share, given the structural differences among the economies of the world. The fact that the two approaches give such different results highlights the importance of 'getting the shares right' in order to have an accurate picture of the growth process.

5. Levels Versus Growth Rates

Tables 1 and 2 approach the analysis of growth by examining the *rate* of growth of y_t and the fraction explained by capital deepening and TFP. There is a parallel issue about the corresponding levels: what fraction of the *level* of y_t is explained by the *level* of the capital-deepening effect and the TFP effects. In other words, what is the actual magnitude of the distances (a to b) and (b to c) in Figure 1, and how much of the overall gap (a to c) do they explain? The answers to these questions can be very different from the one obtained in the preceding section with growth rates. Compare, for example, two economies that start with different levels of productive efficiency. Economy A is on the higher of the two production functions in Figure 1 at point e, and economy B on the lower one at point a. Both have the same initial capital-labor ratio, k_{70}, but different levels of output per worker, y_{70} versus y_{00} in the figure. Suppose that, from this staring point, both economies only grow by capital deepening at the same rate of growth. That is, they move along their respective production functions at the same rate, but neither experiences any growth in productivity (neither function shifts). In this example, the entire *growth rate* in output per worker is due to capital deepening, but all the difference in the *level* of output per worker is due to the different level of productive efficiency.

Table 3 suggests that something like this occurs for many of the countries in our sample. The first column of this table reports the level of output per worker in the first five meta countries relative to the level of the High Income countries. This column conveys the same sense of the gap between rich and poor countries seen in Figure 2, which plots the paths of y_t over time for the four largest groups of countries and the Tigers. The second column of Table 3 shows the relative levels of TFP, based on the extension of the sources-of-growth model to levels pioneered by Jorgenson and Nishimizu (1978), and developed by Caves, Christensen, and Diewert (1982). The CCD model is a Törnqvist index of the level of productivity in each country relative to the average of all countries. It measures the TFP of any country, relative to the average of all countries, but compares the percentage deviation of y_t from its international mean with the percentage mean deviation of k_t, weighted by the average of the country's own income share and the international average. It is clear from this table that the level of TFP in the first five meta countries is significantly below that of the High Income countries, and, while similar in pattern, are somewhat more compressed than the relative levels of output per worker. The latter is 16 times greater in the High Income countries compared to the Low, while the gap in productive efficiency is 'only' a factor of 5. Figure 3 displays the time series trends that correspond to column 2. It reveals the same general magnitude as the relative TFP estimates of Table 3, and also indicates that the gap has widened over time for the Low, Lower Middle, and Upper Middle countries, but that the Tiger countries are narrowing the gap in the relative TFP level, though not shown, the same is true of the Large meta country.

The last three columns of Table 3 decompose the level of output per worker into its capital-deepening and TFP components. This decomposition is based on the assumption that the production function has the simple constant-returns Cobb-Douglas form $y_t = A_t k_t^{(1-\beta)}$ (this is implicit in the assumption of a constant value of the labor share, β). The variable A_t is the basis for TFP in the Solow model, and the level of TFP can thus be estimated as the ratio $y_t/k_t^{(1-\beta)}$. This 'CD' index is not necessarily equivalent to the CCD index, but when the β shares the same value for each country, and the Cobb-Douglas index is normalized to the High Income countries, it gives the same values as the CCD index (thus, the numbers in columns 2 and 3 are identical).

To assess the relative importance of capital deepening and TFP on the level of (unnormalized) output per worker, the logarithm y_t is divided between the logarithms of A_t and $k_t^{(1-\beta)}$. This decomposition is shown in the last three columns of Table 3, where it is apparent that the TFP is the predominant factor explaining the level of output per worker. Moreover, a little more than half of the cross-sectional variation among countries is explained by the difference in the level of TFP. This result shows that the potential disconnect between the growth-rate analysis of Table 1 and the level analysis of Table 3 noted at the start of this section is apparent in the actual data. For the Upper Middle meta country, TFP *growth* explains 12 % of the output *growth rate*, but the corresponding TFP *level* explains 65% of the *level* of output per worker. For the Lower Middle meta country, these numbers are 30% and 65%, for the High Income case, they are 46% and 64%. This disconnect is absent only in the high growth meta countries.

This finding points to a fundamental problem faced by the lower income countries. Table 1 suggests that their growth is propelled more by capital deepening rather than TFP growth, but Table 3 indicates that the main factor in explaining the large gap in output per worker is the persistently low levels of TFP in these countries (compare Figures 2 and 3). Not all of the 67 countries in the Low, Lower Middle, and Upper Middle income meta groups are subject to this pattern. And, significantly, the Tiger and Large countries display a convergence in both output per worker and TFP level, powered in part by a rapid rate of TFP growth. The finding that TFP grew rapidly stands in stark contrast to Young (1992, 1995), who found that the contribution of TFP was small or even negligible.

These conclusions must be tempered by the reminder that they are based on the assumption that labor's income share is 0.67 in all countries. Again, the use of labor's actual income share assigns a much greater role to capital formation. The actual shares may be implausibly low, but they reveal that the sources-of-growth analysis is sensitive to this variable, and that much more needs to be known about it before the capital versus productivity issue is settled.

6. Two Alternative Paradigms

The dichotomy shown in Figure 1 is based on Solow's 'Hicksian' approach, that is, it measures the shift in the production function at a constant capital-labor ratio (at k_{00} in the figure). However, this is not the only way to proceed. Hulten (1975, 1979) argues that the shift could equally be measured from the Harrodian perspective of a constant capital-output ratio, as it is in neoclassical growth theory. This involves measuring the shift along the ray, P, from the origin. In the example of Figure 1, this way of measuring the shift in the production function explains *all* of the growth in output per worker because the terminal point c lies on P. Capital per worker still grows from k_{70} to k_{00}, but the increase in capital has been 'induced' by the shift in technology through the savings effect. This is the *induced accumulation* effect of Hulten (1975), and it must be counted as belonging to productivity change in order to accurately portray the contribution of TFP to the growth process.[4]

The Harrodian version of the growth decomposition is shown in the last two columns of Table 1. In practical terms, Harrodian TFP in column 5 is computed by dividing the corresponding Hicksian estimate in column 3 by labor's income share. This procedure results in a larger effect attributed to productivity, since part of the growth k_t is reassigned to TFP.

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[4] The induced accumulation effect arises because an increase in productivity leads to more output per worker for a given level of input, and some of this extra output is saved, leading to more output, more saving and so on, until the point c in Figure 1 is reached. This extra output is the result of the shift in the production function and should be counted as part of TFP, not as exogenous capital formation.

Technical change need not be Harrod neutral for this approach to work. If the actual equilibrium point y_{00} were to lie somewhere to the right of c, the shift in the function would still be measured along the line P from a to c. The increase in y_{00} beyond c would be attributed to autonomous capital formation.

The Hicksian and Harrodian approaches clearly give very different results, leading to the question of which is the 'right' one to use. The answer is that both are right, but for different questions. In order to find out how efficiently existing labor and capital are used, the Hicksian approach is the right way to proceed. Two countries may have the same amount of labor and capital, but different levels of output per worker. The gap is due to productive efficiency and its magnitude and causes are worth knowing. However, if the question is about the relative importance of capital deepening versus efficiency change as the *cause* of growth, the Harrodian model gives the right answer, since capital formation is endogenous. We will study this issue more deeply in the following section on growth theory.

Endogenous growth theory offers a third approach that interprets the efficiency shift in Figure 1 entirely in favor of capital formation. In the framework developed in Lucas (1986) and Romer (1986), capital throws off externalities that explain the apparent shift in the production function in Figure 1. As capital per worker grows from k_{70} to k_{00}, the direct effects to the owners of capital appear to be a move from point a to point b. But output is also affected by spillover externalities created by the capital that the owners do not recognize, and it is these externalities that account for the apparent change in productive efficiency, b to c.[5] What seems to be a shift in the production function is actually the movement along the line P, which can therefore be interpreted as the effective production function itself. Thus, what appears to be TFP in previous frameworks is really the unobserved effect of capital formation in the endogenous growth approach.

Since TFP is endogenous in this approach, it presents a different decomposition than the

[5] In a variant of this formulation, the gap b to c is the result of the unobserved coinvestment that depends on k_t (e.g., Barro (1990)).

Hicksian and Harrodian cases recorded in Table 1. An endogenous-growth decomposition might therefore be added to this table, with the capital-deepening effect shown in a sixth column and the TFP effect in a seventh. However, the new column 6 would equal the entire growth rate of output per worker, and the column 7 would contain nothing but zeroes, so this addition is unnecessary.

The endogenous growth explanation of the growth process is a competitor of the other two approaches, not a complementary way of viewing that process. It imposes a very different interpretation of TFP, one that is the reverse of the Harrodian induced-accumulation effect. The resulting growth dynamics are also different: in the endogenous growth world, capital deepening is a necessary precursor of TFP growth, not the other way around. A synthesis of the two models would endogenize both capital and TFP, and split both capital-deepening *and* TFP into endogenous and exogenous components. Unfortunately, such a model is not available for empirical purposes. It is perhaps best *not* to impose either view on the data *a priori*, and start by measuring TFP in the conventional Solow way. TFP is, in any case, measured as a residual and, in the famous words on Abramovitz (1956), is therefore the 'measure of our ignorance' about the growth process. It is also well to heed the words of one of the seminal contributors to the field of productivity analysis, John Kendrick:

> 'Informal incentive and innovative activity, including the myriad small technological improvements devised by plant managers and workers, was the chief source of technological progress in the nineteenth century, and is still significant (cited in Maital (1980), page 194).'

7. The Predictions of Growth Theory

The divergence pattern seen in Figure 2 for the period 1970-2000 invites speculation about the economic future of the various meta countries. Unfortunately, the insights offered in the preceding sections are inherently retrospective. They are based on the experience of past decades, but do not answer to the following question: if past trends persist into the future, will they be enough to lift a poor nation out of poverty? This question is inherently about future outcomes, and the answer requires a fully-specified model of growth that takes into account the full range of factors that determine the future growth path.

We have already encountered the two main contenders for this role: the endogenous growth model and the neoclassical model of steady-state growth. The growth dynamics of the former stress the role the capital formation and predict that those countries that are able to build an initial lead in capital per worker will be able to exploit the advantage and pull away from the others. This prediction accords well with the pattern seen in Figure 2, and implies a fairly bleak outlook for the growth of the lower income countries. However, it does not fit well with the experience of 'transition' economies like the Tigers that are able to accelerate growth by a combination of increased capital formation and more importantly, according to Table 1, by even stronger TFP growth. The latter is due, in large part, to the opportunity to import technologies from countries near the best-practice frontier. This, in turn, may be associated with increased capital formation, which allows for the import of more advanced technologies ('appropriate' technologies in the words of Basu and Weil (1998)). There is undoubtedly a relation between the increased capital formation and the higher rate of TFP growth seen in Table 1 for the transition economies, one that operates in both directions. However, the deeper causes and mechanisms that trigger this transition (the subject of much debate) probably involve non-economic factors like societal attitudes, political and social institutions, and geography. The endogenous growth interpretation by itself, while offering important insights, does not seem rich enough to capture the deeper determinants of change.

Much the same might be said of the main alternative, the neoclassical model of growth. Indeed, no quantitative model successfully endogenizes cultural and institutional factors into explanations of growth. However, neoclassical growth theory is more hospitable to the exogeneity of these factors because it also treats TFP as an exogenous variable that may depend on a set of deeper causes.

The neoclassical model has two main variants: the Solow-Swan model of exogenous saving and the Cass-Koopmans optimal growth model. We will use the former because we want to appropriate the empirical application of this model by MRW (1992). In the simplest version of the Solow growth model, output per worker converges to a steady-state growth path along which the growth rates of output and capital are equal to the growth rate of the labor force. Convergence occurs according to the following mechanism, described above in the discussion of induced accumulation: a constant fraction of the output per worker, σ, is set aside in each year for investment. If the resulting amount of investment, σy_t, is greater than the amount of capital per worker needed to equip the growth in the labor force, η, and the depreciation of capital, δ, $(\eta+\delta)y_t$, then capital per worker expands, thereby increasing output per worker in the following year (but at a diminishing rate). This process is portrayed in Figure 4, as the transition from is the actual level of y_t in 1970 (the point a)), and to the steady-state level of output per worker y^* (the point c). The state-state y^* is at the intersection of the capital-deepening line, S, and the production function, where any further savings are eaten up by the depreciation of the stock of capital and by the need to equip the growth of the work force.

Exogenous changes in the level of productivity can be represented in this steady-state model by assuming that productivity change is both labor augmenting and Harrod neutral, and grow at a rate λ. Under this assumption, advances in technology improve the productivity of labor but not capital.[6] When 8 is positive, the production function in Figure 4 shifts outward over time. If the economy is at its steady-state equilibrium, y*, a well-known property of the model causes y* to move outward along the line S, maintaining the steady state at a constant capital-output ratio. As the economy move along the steady-sate path S, y* and k* therefore grow at the same rate λ. The Harrodian measure of TFP measures the shift along the path S, and its growth rate is also λ. The equivalent Hicksian measure is βλ.

The *steady-state* sources-of-growth analogue to Table 1 would look rather different than the actual estimates shown in that table. The first column of a steady-state version of Table 1 would record the λ appropriate for each country, and the Hicksian dichotomy in the second and third columns would be (1- β)λ and βλ, respectively. The Harrodian decomposition in the fourth and fifth columns would have the values 0 and λ.

However, the true utility of the steady-state framework lies not in the light it sheds on the sources-of growth analysis of Table 1, but in the analysis of future levels of output per worker, that is, in extending Figure 2 into the future to the corresponding steady growth paths. To accomplish this, we adopt a variant of the Solow growth model developed by MRW (1992). The MRW model assumes that the production function in Figure 4 has the Cobb-Douglas form with constant returns to scale, $y_t = A_t k_t^{(1-\beta)}$. This equation holds in steady-state growth and allows us

[6] In this approach, labor input is redefined to incorporate changes in its efficiency. A variable E_t is created that equals L_t times the labor-efficiency index $e^{\lambda t}$, where λ is the rate of labor-augmenting efficiency change; output per worker is then defined in terms of E_t rather than L_t, as is capital per worker. The axes of Figure 4 are reinterpreted accordingly, and no further modifications to the diagram are needed. This solution maintains the nice graphical representation of Figure 4, but, since our purpose in this paper is to explain the ratio Y_t/L_t rather than Y_t/E_t, we express the steady-state solution in natural units of labor.

to solve for an explicit value of y* as a function of the variables λ, A, η, σ, δ, and β.[7] We have estimates of the first four of these variables, and have made assumptions about the remaining two.

The steady-state solution for y* in each of the six meta countries is shown in the first column of Table 4 for the last year in our sample, 2000. The actual level of output per worker in 2000 is shown for comparison in the adjacent column. The salient result is that there is a huge gap in output per worker between the Low and High income countries (a ratio of 23 to1 in 2000), and this gap is set to persist into the indefinite future. Moreover, this is true *even if the Low Income meta country's rate of productivity growth* λ *were to improve to the rate prevailing in the high income case*. In fact, the Low Income country would have to improve the growth rate of TFP to that of the High Income country just to maintain the year 2000 gap. If the λ's shown in last column of Table 1 persist into the future, the gap will widen. Similar remarks apply to a lesser extent for the Lower Middle and Upper Middle Income meta countries. The steady-state picture is only bright for the Tiger countries, whose y^*_{2000} is three-quarters of the High Income amount, and whose λ is larger.

The sources of the gap are examined in Table 5, which decomposes the gap between *steady-state* output per worker in the rich and poor countries into the separate contributions of capital-deepening and TFP. This analysis is parallel to the sources-of-growth decomposition shown in Tables 1 and 2, but the novelty here is that the decomposition refers to the long-run equilibrium contributions of the two sources when capital formation is endogenous (relative to a

[7] Our approach differs from MRW in that we allow for the production function in Figure 4 to shift over time, while they adopt the approach of the preceding footnote.

given rate of saving). Since this is not a familiar decomposition, the graphical intuition behind the decomposition may be helpful.

In Figure 5, an economy L is located on a production function with a lower level of productive efficiency than economy H. Moreover, economy L is on a steady-state path, S_L, with a steeper slope than the corresponding path of economy H, S_H, implying that the capital-deepening effect is stronger in the latter.[8] Economy L is thus at a relative disadvantage in both its level of TFP and its long-run capital-deepening potential. As a result, L converges to point b from a, while H is moving to a higher point d from c. The difference in the *level* of steady-state output per worker is (y^*_H - y^*_L), which can be decomposed into two effects: (1) the gap (y^*_L - y_f), the distance between the L's steady-state and the point on its own production function that economy L would attain if it operated along the path S_H rather than its own S_L; and (2) the distance between the two production functions, (y_f - y^*_L), as measured in the Harrodian way along the path S_H.

Column 1 of Table 5 shows the dollar magnitude of the total gap (y^*_H - y^*_L) for each of the meta countries in the year 2000, while the next column gives the portion of the gap due to the difference in capital-deepening propensities, (y_f - y^*_L), and the last column gives the portion of the gap due to the difference in the level of technology, (y^*_H - y_f).

Two conclusions emerge from these estimates. First, the large gap between the High Income countries and the others evident in Figure 2 appears to be a long-run situation as long as the basic parameters of growth remain unchanged (the exception here, as before, is the Tiger countries). Second, the gap in output per worker is largely explained by the technology gap, not

[8] The slope of the steady-state line S_L can be shown to equal $(\eta_L+\delta)/\sigma_L$. The slope increases with the rate of population growth and the rate of depreciation, which reduces net capital formation, and falls with an increase in the rate of saving, which increases it. A higher slope thus translates into a lower steady-state y* in Figure 4.

differences in the propensity to accumulate capital relative to the growing labor force. Moreover, the forward-looking role played by TFP is even stronger than the role suggested by Figure 3.

However, this result must be qualified by the fact that the decomposition is not unique, but instead depends on the growth path actually followed. One could just as well divide the gap (y^*_H - y^*_L) into be and ed, rather than the bf and fd split on which the estimates of Table 5 are based. This second decomposition follows the path S_L between the two production functions, rather than S_H. The third and fourth columns in Table 6 show the split for this alternative path, and are seen to be quite different from the Table 5 split shown in the first and second columns. The average values for the two cases are shown in the last two columns of the table, and support the conclusion that the TFP effect is still the most important source for explaining the gap (y^*_H - y^*_L).

8. Conclusion

Our analysis points to the persistently low levels of technology (in its broadest sense) as the primary source of the gap between the rich and poorer countries in our sample. The conventional analysis of past growth rates tends to understate the problem, which only becomes fully apparent when the difference in levels is analyzed. Moreover, the standard steady-state growth model predicts that the large gap will not close in the future for most of the underdeveloped countries unless they are able to dramatically improve the growth rates of the capital and TFP to the magnitudes attained by the transitional Tiger countries.

It is important to emphasize, again, that not all the countries in the Low, Lower Middle, and Upper Middle income groups are subject to this pessimistic conclusion. The Tiger and

Large countries in our sample prove that success is possible. It is also important to restate the warning that our conclusions must be viewed in light of significant gaps in the data. This said, however, the gaps in the levels of output per worker and TFP are simply too large to be ignored or dismissed as artifacts of mismeasurement. This suggests that even more attention should be focused on the factors that explain these gaps, for example investment in core infrastructure capital. Even though this issue has received a great deal of attention, it is not a debate that can be considered as settled.

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TABLE 1

SOURCES OF GROWTH
COMMON SHARES
1970-2000

	CONVENTIONAL			HARROD	
META COUNTRY	AAGR Y/L	AAGR K/L	AAGR TFP	AAGR K/L	AAGR TFP
Low Income	-0.12%	0.32%	-0.44%	0.54%	-0.66%
Low-Middle	1.25%	0.88%	0.37%	0.70%	0.55%
Upper-Middle	0.57%	0.50%	0.07%	0.47%	0.10%
Tiger	4.89%	2.38%	2.51%	1.14%	3.75%
Large	3.50%	1.49%	2.01%	0.50%	3.00%
High	1.95%	1.05%	0.90%	0.61%	1.34%

AAGR = Average Annual Growth Rate

TABLE 2

SOURCES OF GROWTH
1970-2000
ACTUAL SHARES

	CONVENTIONAL			HARROD	
META COUNTRY	AAGR Y/L	AAGR K/L	AAGR TFP	AAGR K/L	AAGR TFP
Low Income	-0.12%	0.69%	-0.80%	2.56%	-2.67%
Low-Middle	1.25%	1.60%	-0.35%	2.12%	-0.88%
Upper-Middle	0.57%	0.84%	-0.27%	1.17%	-0.60%
Tiger	4.89%	3.96%	0.93%	2.83%	2.06%
Large	3.50%	2.94%	0.56%	1.90%	1.60%
High	1.95%	1.43%	0.52%	1.01%	0.94%

AAGR = Average Annual Growth Rate

TABLE 3

LEVELS OF GROWTH AND PRODUCTIVITY
1970-2000
COMMON SHARES

META COUNTRY	LEVEL Y/L	LEVEL CCD-TFP	LEVEL CD-TFP	LOG Y/L	LOG K/L	LOG TFP
Low Income	6.23%	20.19%	20.19%	7.78	2.60	5.18
Low-Middle	26.83%	47.67%	47.67%	9.25	3.21	6.04
Upper-Middle	51.11%	68.98%	68.98%	9.89	3.48	6.41
Tiger	49.56%	67.54%	67.54%	9.83	3.45	6.38
Large	9.35%	24.51%	24.51%	8.19	2.82	5.37
High	100.00%	100.00%	100.00%	10.57	3.79	6.78

TABLE 4

COMPARISON OF STEADY-STATE AND ACTUAL
LEVELS OF OUTPUT PER WORKER, 2000
COMMON SHARES

META COUNTRY	STEADY STATE y*	ACTUAL y	REMAINING GAP (y*-y)/y*
Low Income	$2,321	$2,232	4%
Low-Middle	$13,889	$12,226	8%
Upper-Middle	$23,012	$21,816	5%
Tiger	$44,347	$36,922	17%
Large	$8,213	$6,618	19%
High	$60,327	$52,223	13%

TABLE 5

DECOMPOSITION OF STEADY-STATE OUTPUT GAPS
INTO CAPITAL-DEEPENING AND TFP COMPONENTS
ALONG HIGH-INCOME GROWTH PATH
COMMON SHARES, 2000

META COUNTRY	TOTAL GAP ($y^*_H - y^*_i$)	CAPITAL-DEEPENING GAP ($y^*_H - y^*_{if}$)	HARROD TFP GAP ($y^*_{if} - y^*_i$)
Low Income	$58,006	$1,683	$56,322
Low-Middle	$47,038	$4,161	$42,877
Upper-Middle	$37,315	$6,257	$31,058
Tiger	$15,980	$37	$15,943
Large	$52,113	$2,109	$50,004
High	$0	$0	$0

TABLE 6

PERCENTAGE DECOMPOSITION OF STEADY-STATE INCOME GAPS
INTO CAPITAL-DEEPENING AND TFP COMPONENTS
WITH DIFFERENT GROWTH PATHS
COMMON SHARES, 2000

META	HIGH INCOME PATH		ACTUAL INCOME PATH		AVERAGE PATH	
COUNTRY	% CAPITAL	% TFP	% CAPITAL	% TFP	% CAPITAL	% TFP
Low Income	3%	97%	44%	56%	23%	77%
Low-Middle	9%	91%	31%	69%	20%	80%
Upper-Middle	17%	83%	35%	65%	26%	74%
Tiger	0%	100%	0%	100%	0%	100%
Large	4%	96%	24%	76%	14%	86%

TABLE 7

COMPARISON OF STEADY-STATE PARAMETERS
AVERAGE VALUES 1970-2000

META COUNTRY	LABOR'S SHARE β	SAVING RATE σ	LABOR GROWTH η	POPULATION GROWTH
Low Income	0.30	0.093	0.024	0.027
Low-Middle	0.40	0.166	0.026	0.021
Upper-Middle	0.45	0.180	0.027	0.020
Tiger	0.45	0.281	0.024	0.013
Large	0.35	0.169	0.020	0.017
High	0.55	0.231	0.011	0.007

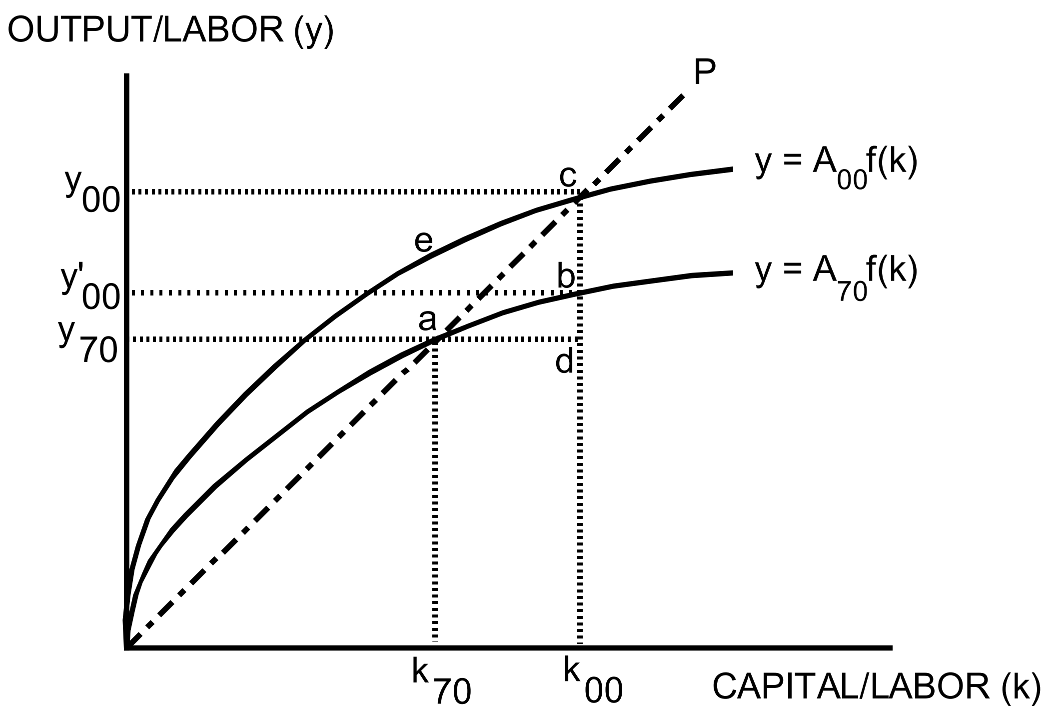

OUTPUT/LABOR (y)
P
y = A00f(k)
y = A70f(k)
y00
y'00
y70
c
e
b
a
d
k70
k00
CAPITAL/LABOR (k)

Figure 1

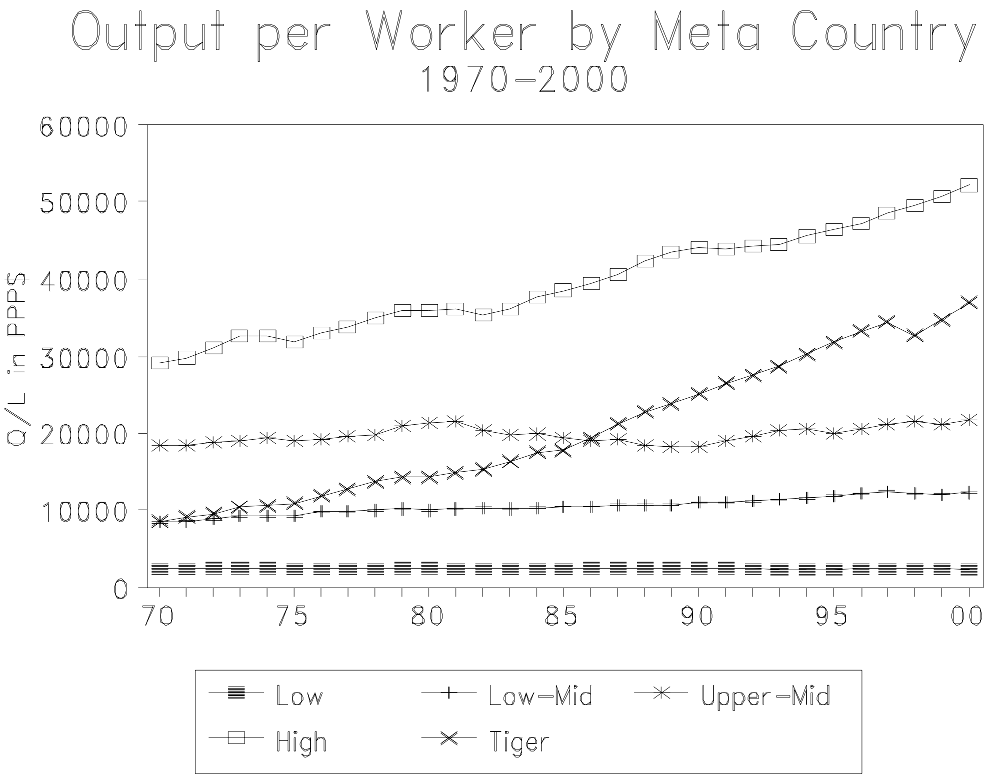

Output per Worker by Meta Country
1970-2000
Q/L in PPP$
60000
50000
40000
30000
20000
10000
0
70
75
80
85
90
95
00
Low
Low-Mid
Upper-Mid
High
Tiger

FIGURE 2

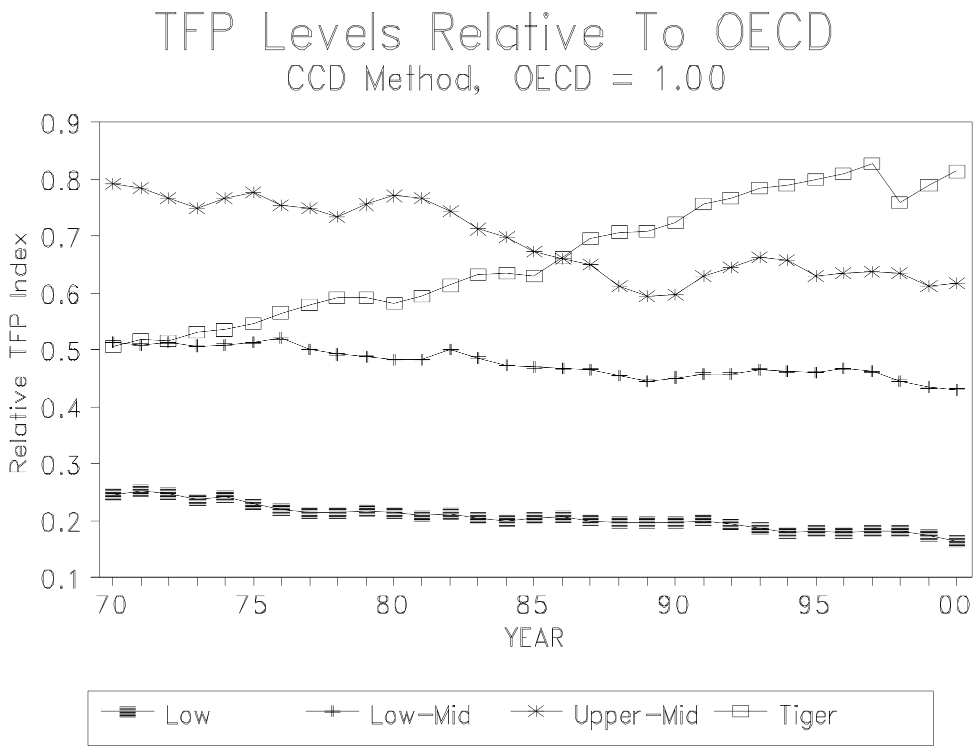

TFP Levels Relative To OECD
CCD Method, OECD = 1.00
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Relative TFP Index
70
75
80
85
90
95
00
YEAR
Low
Low-Mid
Upper-Mid
Tiger

FIGURE 3

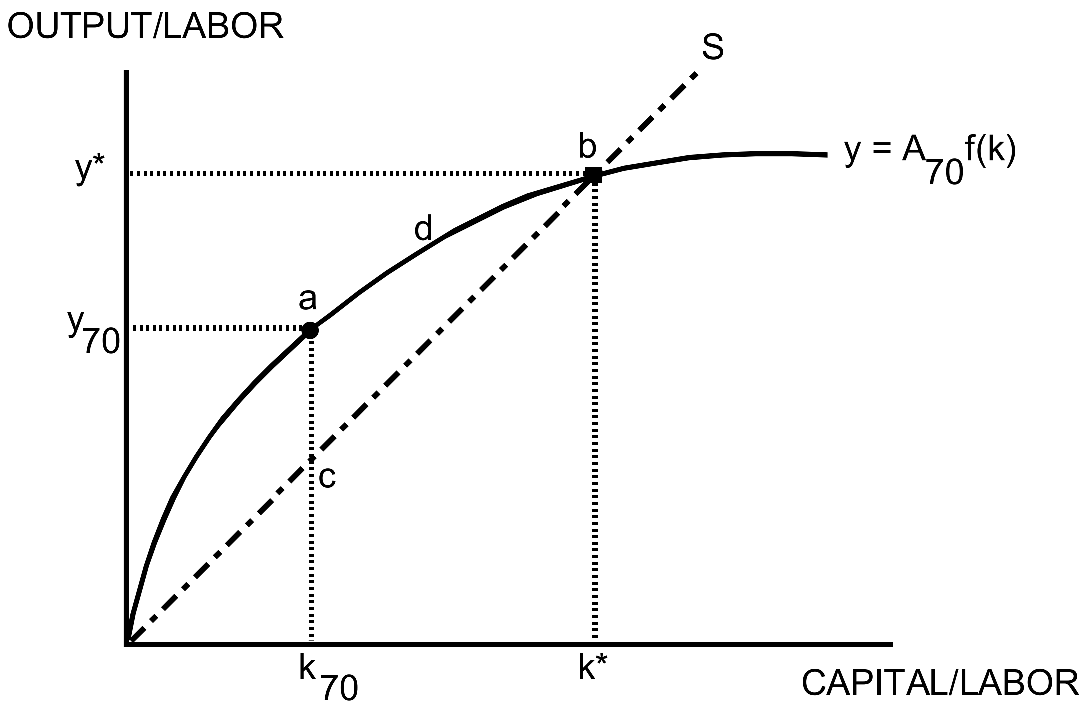


Figure 4

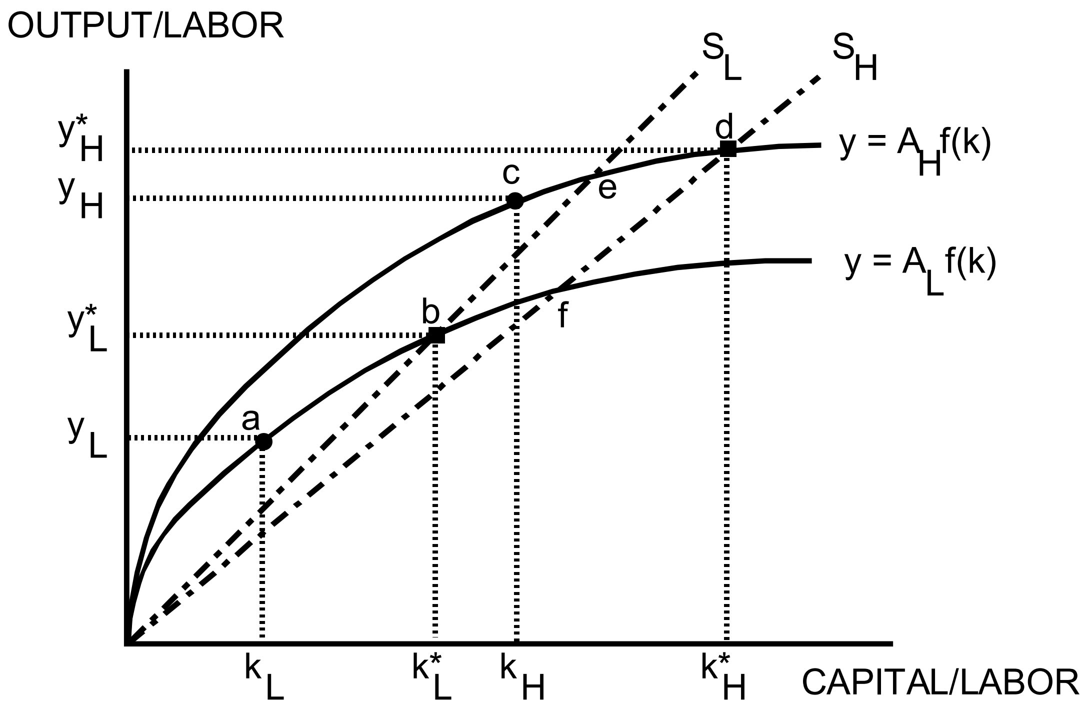

OUTPUT/LABOR
S_L
S_H
y^*_H
y_H
y^*_L
y_L
a
b
c
d
e
f
y = A_Hf(k)
y = A_Lf(k)
k_L
k^*_L
k_H
k^*_H
CAPITAL/LABOR

Figure 5

Data Appendix

1. Capital stocks

We use a perpetual inventory method (PIM) to estimate the stock of capital from the investment data (the capital stock is denoted K05+S in Figure A.1.). Under the PIM, the stock of capital at the end of year t that is available for production in the following year, K_{t+1}, is equal to the depreciated amount of capital left over from the preceding year, $(1-\delta)K_t$, plus the amount of new capital added through investment during the year, I_t
:

$$K_{t+1} = (1-\delta) K_t + I_t , \qquad \text{(A.1)}$$

The δ denotes the depreciation rate here, as in the text. By substituting backward in time to some initial period, equation A.1 can be expressed in terms of the depreciated stream of investment plus the initial capital stock, K_0 :

$$K_t = (1-\delta)^t K_0 + \sum_{i=1}^{t} (1-\delta)^{t-i} I_i . \qquad \text{(A.2)}$$

This method of estimating the stock of capital requires time-series data on real investment, which we obtain from the Penn World Tables 6.1 (Heston, Summers and Aten, 2002, in power purchasing parity 1996 US dollars. We have no information as to country-specific depreciation rates, so we assume a common 5 percent rate for each country.

To obtain a starting value for the capital stock of each country, we assume the country is at its steady state capital-output ratio. The steady-state benchmark value is obtained from the equation:

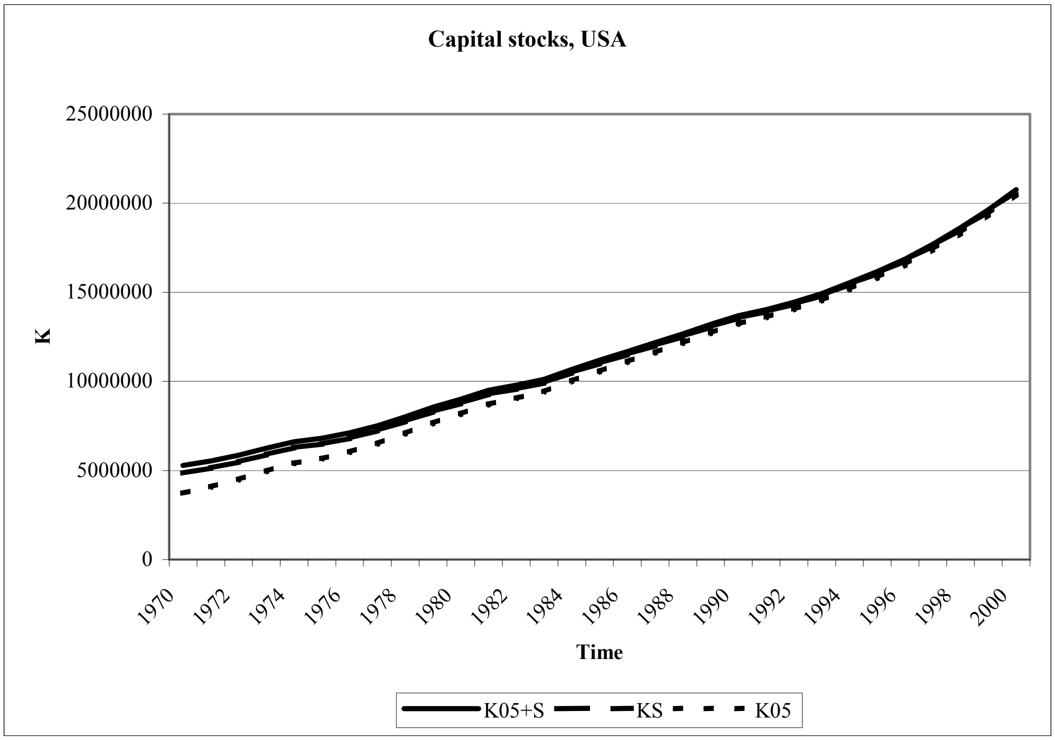
$$k = i/(g+\delta), \qquad \text{(A.3)}$$

where k = K/Y (i.e. capital-output ratio), g = the growth rate of real Y (i.e. growth of GDP), and i = I/Y (i.e. investment rate). The steady-state growth of GDP (g) and the investment rate (i), respectively, are calculated as the annual average over 10 years (1960-1969). Inserting these into (A.3) gives k and the benchmark is obtained by multiplying k by initial GDP. Thereafter, we add 10 years of investment to the benchmark and this marks the initial capital stock, K_0.

We have also investigated the robustness of this procedure against two other computational methods. The first alternative is to use the steady-state approach discussed above to compute the initial capital stock, K_{1970}, and thereafter apply the perpetual inventory method to the remaining years (KS). Our second procedure is to use the perpetual inventory method, but this time without the steady-state approach to obtaining a benchmark, i.e. the benchmark is zero in 1960. The accumulation of 10 years of investment is then taken to represent the initial capital stock in 1970 (K05).

Figure A.1 shows how the three capital stocks actually tend to converge over time and this leads us to have faith in our choice of calculating capital stock, implying a reasonably high degree of robustness to our method of estimating the initial level of capital.

Figure A.1. Capital Stocks Under Three Assumptions.



Labor shares

It is standard in cross-country analysis to assume common labor shares across countries, with a two-thirds share commonly assigned to labor (Gollin (2002)). However, the labor shares are calculated from published data reveal very large differences across countries. Figure A.2 reveal just how large the differences are, and how far short of the two-thirds share the actual estimates are. In general, labor shares increase with income level if the meta country, although they remain fairly constant within meta countries.

Figure A.2. Labor's Income Share for 6 Meta-Countries

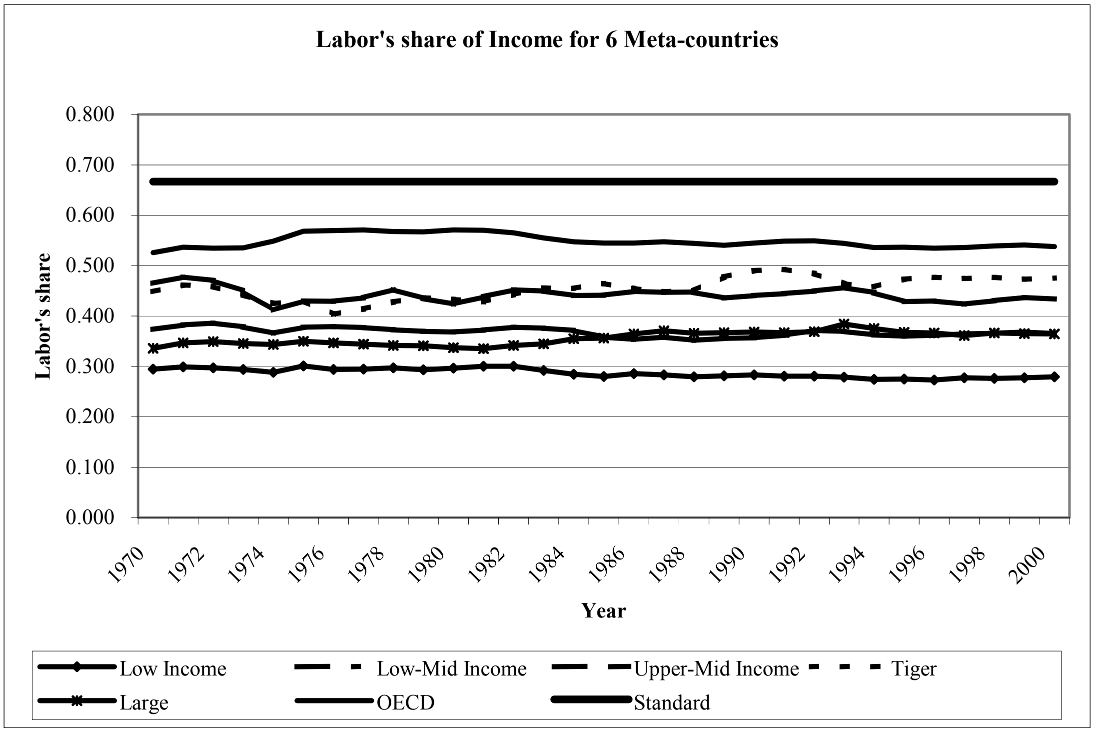


Table A.1. Basic Statistics

COUNTRY HIGH-INCOME	DPOP 1970-2000	Y/L 1970	Y/L 2000	DY/L 1970-2000	I/Y 1970-2000	K/L 1970	Y/POP 1970	Y/POP 2000	DY/POP 1970-2000
Australia	0.013	34747	51568	0.013	0.238	86703	14820	25559	0.018
Austria	0.003	26736	50591	0.021	0.260	66469	11176	23676	0.024
Belgium	0.002	32427	56752	0.018	0.231	81200	12143	23781	0.022
Canada	0.012	34692	52295	0.013	0.228	61994	14102	26904	0.021
Denmark	0.003	33218	48255	0.012	0.229	83723	16038	26608	0.016
Finland	0.004	23899	47281	0.022	0.260	64823	11412	23792	0.024
France	0.005	28960	49136	0.017	0.246	65718	12336	22358	0.019
Greece	0.006	21755	33783	0.014	0.247	50713	8441	14614	0.018
Iceland	0.010	25205	45055	0.019	0.258	77138	10925	24777	0.026
Ireland	0.008	19079	65054	0.040	0.192	28880	7260	26381	0.042
Israel	0.024	24021	38762	0.015	0.271	54458	8837	16954	0.021
Italy	0.002	28883	53949	0.020	0.233	74156	11294	21780	0.021
Japan	0.007	18098	38737	0.025	0.322	34551	11474	24675	0.025
Luxembourg	0.008	39277	103133	0.031	0.225	115514	15121	43989	0.034
Netherlands	0.006	33112	52230	0.015	0.234	84187	13320	24313	0.019
New Zealand	0.010	35083	39360	0.004	0.211	78165	13665	18816	0.010
Norway	0.005	27024	54032	0.022	0.318	91446	11188	27060	0.028
Portugal	0.004	14823	35008	0.028	0.213	25056	6296	15923	0.030
Spain	0.005	23675	44113	0.020	0.242	47853	9076	18047	0.022
Sweden	0.003	31990	45453	0.011	0.213	79456	14828	23635	0.015
Switzerland	0.004	43346	47412	0.003	0.266	129962	20611	26414	0.008
UK	0.002	26272	44649	0.017	0.181	58109	12085	22190	0.020
USA	0.010	38432	64537	0.017	0.197	60506	16351	33293	0.023
AVERAGE	0.007	29123	52223	0.019	0.240	57191	13297	26604	0.022
LOW-INCOME									
Angola	0.023	5767	3050	-0.021	0.075	4223	3329	1612	-0.023
Benin	0.028	2041	2489	0.006	0.074	816	1094	1214	0.003
Burkina Faso	0.022	1159	1939	0.017	0.099	717	669	957	0.012
Burundi	0.021	1467	990	-0.013	0.057	326	848	523	-0.016
Cameroon	0.026	2552	4125	0.015	0.078	1445	1580	2042	0.008
Central African Rep	0.022	3964	2144	-0.020	0.045	2529	2240	1045	-0.025
Chad	0.024	2352	1837	-0.008	0.089	4196	1180	909	-0.008
Congo	0.028	1612	3686	0.027	0.173	4476	929	1808	0.021
Cote d'Ivoire	0.034	4823	4679	-0.001	0.076	3547	2391	1869	-0.008
Ghana	0.026	2277	2775	0.006	0.073	3091	1282	1351	0.002
Guinea Bissau	0.027	577	1287	0.026	0.206	2628	332	688	0.024
Haiti	0.017	1827	5569	0.036	0.051	523	930	2416	0.031
Kenya	0.031	1450	2476	0.017	0.108	2072	821	1244	0.013
Lesotho	0.021	1730	3365	0.021	0.189	536	883	1592	0.019
Madagascar	0.026	2546	1772	-0.012	0.028	896	1274	836	-0.014
Malawi	0.027	871	1631	0.020	0.138	1337	455	784	0.018
Mali	0.023	1485	2033	0.010	0.075	1812	784	969	0.007
Mauritania	0.024	3397	2912	-0.005	0.067	761	1881	1447	-0.008
Mozambique	0.020	2807	2000	-0.011	0.027	615	1571	1037	-0.013
Nicaragua	0.028	12280	4367	-0.033	0.117	10451	3980	1767	-0.026
Niger	0.031	2653	1823	-0.012	0.073	2052	1519	875	-0.018
Nigeria	0.028	1997	1479	-0.010	0.089	781	1113	707	-0.015
Papua New Guinea	0.023	5247	5924	0.004	0.124	6473	2862	2866	0.000

Rwanda	0.027	1676	1786	0.002	0.039	325	887	895	0.000
Senegal	0.027	2949	3389	0.004	0.072	2758	1627	1622	0.000
Sierra Leone	0.021	3649	1910	-0.021	0.033	645	1496	695	-0.025
Tanzania	0.029	1056	938	-0.004	0.243	2356	565	482	-0.005
Togo	0.026	3109	2149	-0.012	0.078	1129	1397	870	-0.015
Uganda	0.026	1144	1835	0.015	0.023	161	608	941	0.014
Zambia	0.028	2946	2141	-0.010	0.169	8255	1335	892	-0.013
Zimbabwe	0.028	3723	5127	0.010	0.199	9226	2155	2486	0.005
AVERAGE	0.027	2311	2232	-0.001	0.096	1932	1077	1256	-0.005
LOW-MID									
Algeria	0.026	13369	14527	0.003	0.190	16093	3433	4896	0.011
Bolivia	0.022	6036	6829	0.004	0.094	8409	2498	2724	0.003
Colombia	0.020	7651	11477	0.013	0.116	7860	3159	5383	0.017
Dominican R.	0.021	7488	16173	0.025	0.138	6156	2018	5270	0.031
Ecuador	0.024	7069	9023	0.008	0.189	16442	2292	3468	0.013
Egypt	0.021	5603	10970	0.022	0.076	2553	1970	4184	0.024
Fiji	0.014	11620	13580	0.005	0.147	19314	3433	4971	0.012
Guyana	0.002	8628	8243	-0.001	0.163	23071	2432	3532	0.012
Honduras	0.029	5608	5415	-0.001	0.127	6318	1861	2050	0.003
Iran	0.026	18304	19560	0.002	0.197	17202	5225	5995	0.004
Jamaica	0.011	10177	7310	-0.011	0.173	24743	3867	3693	-0.001
Jordan	0.038	8120	13087	0.015	0.146	6841	2228	3895	0.018
Morocco	0.020	6815	9301	0.010	0.139	5460	2261	3717	0.016
Namibia	0.025	13955	14689	0.002	0.182	26608	4770	4529	-0.002
Paraguay	0.027	6183	10439	0.017	0.121	3930	2874	4684	0.016
Peru	0.021	11927	10095	-0.005	0.170	26080	4686	4589	-0.001
Philippines	0.023	6548	8374	0.008	0.152	8197	2396	3425	0.012
South Africa	0.021	18415	18488	0.000	0.120	23582	6878	7541	0.003
Sri Lanka	0.014	3745	7646	0.023	0.119	2090	1557	3300	0.024
Thailand	0.017	3758	11308	0.036	0.309	7486	1822	6857	0.043
Tunisia	0.020	8573	17124	0.022	0.160	20720	2568	6776	0.031
Turkey	0.020	8017	14125	0.018	0.162	8040	3619	6832	0.021
AVERAGE	0.021	8451	12276	0.012	0.154	10302	3200	5203	0.016
UPPER-MID									
Argentina	0.014	19967	25670	0.008	0.173	37276	9265	11006	0.006
Barbados	0.004	15935	32961	0.023	0.148	31065	6040	16415	0.032
Botswana	0.029	3126	23926	0.066	0.188	2896	1193	8241	0.062
Chile	0.015	15345	25084	0.016	0.151	25676	4794	9926	0.023
Costa Rica	0.025	13639	14827	0.003	0.151	13398	4181	5870	0.011
Gabon	0.029	11293	17645	0.014	0.140	8597	6857	8402	0.007
Malaysia	0.025	8377	23994	0.034	0.223	10090	2884	9919	0.040
Mauritius	0.012	13162	32241	0.029	0.126	13700	4005	13932	0.040
Mexico	0.022	17965	21111	0.005	0.182	27956	5522	8762	0.015
Panama	0.021	11357	14382	0.008	0.207	17391	3824	6066	0.015
Seychelles	0.013	8470	23552	0.033	0.149	4934	4091	10241	0.030
Trinidad & Tobago	0.009	19842	25188	0.008	0.106	13058	6582	11175	0.017
Uruguay	0.006	13579	21150	0.014	0.121	19073	6131	9622	0.015
Venezuela	0.026	35399	15705	-0.026	0.168	44808	10528	6420	-0.016
AVERAGE	0.020	18379	21816	0.006	0.159	28938	6429	9070	0.011
TIGERS									

Hong Kong	0.018	15587	51469	0.039	0.249	28329	6506	26699	0.046
Korea, Republic of	0.012	7676	31239	0.045	0.311	9584	2716	15876	0.057
Singapore	0.021	15085	50809	0.039	0.454	32892	5279	28869	0.055
Taiwan	0.013	7282	42402	0.057	0.194	6392	2790	19034	0.062
AVERAGE	0.013	8513	36922	0.047	0.302	11132	3120	18312	0.057
LARGE									
Brazil	0.019	11006	19220	0.018	0.207	18028	3620	7190	0.022
China	0.014	1583	6175	0.044	0.178	1564	815	3747	0.049
India	0.020	2454	5587	0.027	0.118	2470	1073	2479	0.027
AVERAGE	0.017	2314	6618	0.034	0.167	2628	1096	3460	0.037

Note: The averages have been computed based on the meta-country averages. For example, output per worker in 2000 has been obtained by first summing income and workers separately for a given meta country, thereafter dividing total income with total workers and then dividing this ratio by the number of countries. An alternative way, leading to a slightly different result, is to first compute income per worker for each country, sum the country results and then divide this total by the number of countries.