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

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ABSTRACT: Average income per capita in the countries of the OECD was more than 20 times larger in 2000 than that of the poorest developing countries. Two general explanations have been offered to account for the gap: one view stresses the role of the efficiency of production, while a competing explanation gives primary importance to capital formation. Based on data for 112 countries over the period 1970-2000, we find that differences in the efficiency of production are the dominant factor accounting for the difference in development levels, and that the gap is likely to persist under prevailing rates of saving and productivity change.

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The question of why economic growth differs among countries question has been asked over and over again, with increasingly better data and ever more sophisticated analytical techniques.[1] However, the answer remains elusive despite the many advances and growing insights into the problem. Average income per capita in the countries of the OECD was more than 20 times larger in 2000 than that of the poorest countries of sub-Sahara Africa and elsewhere, and many of the latter are not only falling behind the world leaders, but have even regressed in recent years.[2] At the same time, other low-income countries have shown the capacity to make dramatic improvements in income per capita.

Two general explanations have been offered to account for the observed patterns of growth. One view stresses differences in the efficiency of production are the main source of the observed gap in output per worker, which is the main source of income per capita. At the heart of this view is the idea that improvements in technology and the organization of production lead to higher levels of total factor productivity (TFP) in countries with institutions that support innovation and promote economic efficiency, along with factors like favorable geography,

[1] This question is the organizing theme of the 1998 volume by David Landes "The Wealth and Poverty of Nations." Landes examines the historical and institutional context of the income disparities that are so apparent today, and describes many of the theories and perceptions that accompanied the emergence of this gap. All research on this issue owes a great debt to the pioneering work of Simon Kuznets, both for his historical insights and for his contributions to the development of the national accounting data that make quantitative analysis possible. The sources-of-growth analysis emerged from this effort, greatly advanced by Solow (1957), and applied international growth by Edward F. Denison (1967) and Maddison (1987).

[2] These estimates are based on the country groupings shown in the appendix to this paper, and the data on income per capita in derived from the Penn World Tables (Heston, Summers and Aten, 2002).

climate, and political stability. Lower levels of TFP are associated with institutions that inhibit or retard innovation and the diffusion of technology, or which have unfavorable environmental factors. In either case, differences in the level of TFP, and not differences in capital formation, largely explain observed differences in income per capita in this view. [3]

A competing explanation reverses this conclusion and gives primary importance to capital formation. In this paradigm, capital is defined broadly to include human and knowledge capital, infrastructure systems, as well as the traditional categories of structures and equipment. TFP differences among countries are thought to be extinguished by the rapid diffusion of knowledge, and many papers in this branch of the literature then assume that technology is the same in every country. Some papers also treat technology growth as largely endogenous via investments in knowledge and human capital, and stress the role of the associated externalities. To the extent that institutional differences play a role in explaining the income gap, they tend to be expressed through the rate of capital formation.[4]

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[3] See Hall and Jones (1999), Klenow and Rodriguez-Clare (1997), and Easterly and Levine (2001) for recent examples of this approach, and for reviews of the literature. Bosworth and Collins (2003) also provide an extensive survey of recent work in this area, though their own empirical work focuses on rates of growth rather than productivity levels. Contributions to the measurement of international difference in the TFP levels were made by Dowrick and Nguyen (1989), while Färe et al (1994) is an important paper that uses Data Envelopment Analysis to measure technical efficiency (relative to best-practice) among countries. The translog index number approach used in this paper was developed by Jorgenson and Nishimizu (1978), Christensen, Cummings, and Jorgenson (1981), and Caves, Christensen, and Diewert (1982a, 1982b).

[4] This literature is somewhat diverse. It includes Mankiw, Romer, and Weil (1992) and the other papers in what Klenow and Rodriguez-Clare (1997) term the “Neoclassical Revival.” See, also, Gollin (2002) for an argument supporting this view. Some of the AK endogenous growth models also fit into this category.

The apportionment of the income gap between capital formation and TFP is ultimately an empirical issue. However, this issue has not proved easy to resolve, in part because of parallel disputes about which theoretical models of growth are appropriate, the chief protagonists being endogenous growth theory and neoclassical growth theory. There is also a question of whether it is differences in the rate of growth of output per worker or the corresponding levels that should be explained, and, with respect to the latter, the measurement of the TFP gap using Hicksian versus Harrodian measures of technical change. Not surprisingly, a reading of the literature reveals that different assumptions and methods give different results, and one goal of this paper is to examine just how large the difference is for a sample of high and low income countries over the period 1970 to 2000. Our procedure is to decompose the *growth rate* of output per worker into its TFP and capital-deepening components using competing methods, and compare the results. We follow a similar procedure for the corresponding *levels* of output per worker, which we also decompose into TFP and capital-deepening components. We then carry out a similar decomposition for the Solow steady-state growth model, in order to examine whether the current gap in output per worker between rich and poor countries is likely to persist into the future given current parameters and policies, or whether the process of convergence can be expected to significantly narrow the gap.

The second goal of this paper is to examine the problem of data quality. If there is a dispute about the size of the TFP gap between rich and poor countries, there can be little doubt about the corresponding gap in the data quality. Low-income countries tend to have large non-market sectors for which data are problematic or non-existent, and a market sector with a large family business component in which labor income can appear as profit. One result is an implausibly low share of income attributed to labor in national income statistics of some of these countries: labor's share averages around 30 percent of income in the poorest countries in the sample of this paper, compared to 50 to 60 percent in the richest. Income shares typically serve as proxies for the corresponding output elasticities, which in turn are key determinants of the growth path in most models in the literature (generally, the larger the share of capital, the more important capital formation is relative to TFP as a source of growth). As a result, many researchers reject the published data and either estimate the shares using econometric techniques using the assumption that the shares are constant over time and the same for all countries, or impose an external estimate of the labor and capital shares, typically around two-thirds and one-third. These procedures essentially imply that every country has a Cobb-Douglas production function, which are identical up to a scalar multiple which is associated with the level of TFP (which is also assumed to be the same for all countries in some formulations). There is a certain irony in this situation, in view of the debate over the extent to which the variation in output per worker is due to differences in technology versus differences in capital formation. One objective of this paper is to reexamine the implications of the two-thirds/one-third share rule and robustness of the various growth decompositions to changes in this rule.

II. Empirical Growth Modeling

The diverse models in the empirical growth literature share certain common features that can be used to classify and compare them. One core assumption is that the production possibilities of an economy can be characterized by a stable aggregate production function (or a variant of the production function like the cost function or the factor demand equations). Since many of the differences in the literature can be traced to variations on this theme, we will attempt to organize the various dimensions of the growth debate using this production framework. Since the discussion is largely about fundamentals, we will use a simple graphical exposition adopted by Solow in his seminal paper on the sources of growth.

A. The Aggregate Production Function

The aggregate production function relates aggregate output (Y) to total inputs of labor (L) and capital (K), with allowance for improvements in the productivity of these inputs. This formulation is so widely used that its implications have become almost invisible in the analysis of growth. However, it is important to acknowledge that any analysis based on the aggregate production function asserts, in effect, that the complex technologies of the various firms and sectors that make up an economy can be summarized accurately by a single functional representation. The difficulty, here, is that the technical conditions for consistent aggregation are so restrictive as to be intuitively implausible (see, for, example, Fisher (1965,1969)). Thus, the use of the aggregate production functions can only be justified as a useful parable for organizing the data in a way that makes economic sense, and as a framework for interpreting empirical results. The debate in the literature over which specification of the aggregation production function is 'factually' appropriate for the analysis of cross-national income differences must therefore be viewed accordingly.

Technical change can be introduced into the aggregate production function in different ways, but the most common are variants of the model in which the production function is written as $Y_t = F(K_t,L_t,t)$. The time index t allows the production function to shift over time in order to capture improvements in the efficiency with which the inputs are used, and 'technical change' is conventionally defined as the partial derivative of $F(K_t,L_t,t)$ with respect to t. In the special case in which technical change augments both input proportionately, the production function has the

Hick's-neutral form $Y_t = A_tF(K_t,L_t)$. This is the most common form used in empirical growth accounting, following Solow (1957).

Under the assumption of constant returns to scale, the Hicksian production function can be expressed in 'intensive form' as $y_t = A_tF(k_t)$, with the variables expressed relative to labor: $y_t = Y_t/L_t$ and $k_t = K_t/L_t$. This form provides an explicit decomposition of output per worker, y_t, into the two effects of interest, the level of TFP, A_t , and the capital-deepening effect, $F(k_t)$. 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). 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 is often associated with the adoption of better technologies over time, but 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 TFP.[5]

Output gets a further boost, in Figure 1, 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

[5] 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 Barro (1999) and Hulten (2001)).

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 Figure 1 provides a framework for interpreting and measuring the two effects.

B. Levels versus growth rates

The empirical growth literature provides two ways to implement the intuition of Figure 1, one based on growth rates (growth accounting) and the other on levels (development accounting). The answers can be very different, as the following example illustrates. Suppose that there two economies, A and B, that both start with the same capital-labor ratio, k_{70}. However, A and B have different levels of output per worker, because they start with different levels of productive efficiency, that is, 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. Suppose that, from this starting point, both economies only grow by capital deepening, which proceeds at the same rate of growth. They then move along their respective production functions at the same rate, but neither experiences any growth in productivity (neither function shifts). In this example, the *growth rate* in output per worker is due entirely to capital deepening, but all the difference in the *level* of output per worker is due to the different level of productive efficiency. Moreover, economy B may become richer over time, but will never narrow the gap with economy A.

This simple example illustrates the insufficiency of studying comparative growth rates in isolation from the corresponding levels. Studying comparative levels at a given point in time is also insufficient, since it cannot indicate the growth dynamics and future prospects of the rich and poor countries.

C. Econometrics versus Nonparametrics

A number of different estimation procedures 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.[6] Flexible functional forms like the translog and generalized-Leontieff forms are common in pure production function studies (or dual cost function and factor demand studies), but are not entirely suitable for the study of low-income countries, which tend to have both inadequate and incomplete data. The Cobb-Douglas form $Y_t = A_t K_t^{\alpha} L_t^{\beta}$ is often used, either explicitly or implicitly.

Direct estimation of the production function suffers from another well-known problem. The production function is only one equation in a larger system that determines the evolution of the system. K_t is determined endogenously in the larger system through the savings/investment process, and direct estimation can lead to simultaneous equations bias. The use of instrumental variables is one way to deal with this problem, while another approach is to estimate the reduced form of the growth system. This second option is the used in Mankiw, Romer, and Weil (1992) to estimate the parameters of a Cobb-Douglas function indirectly from the reduced form of the Solow (1956) growth model.

However, both approaches have their drawbacks (e.g., it is difficult to find good instruments) and nonparametric techniques provide an alternative. The two main alternatives are the Solow (1957) growth-accounting model and the Data Envelopment Analysis approach,

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[6] The specification of the error structure of the production function is also an important issue in the growth and production literature. The common approach is to assume an i.i.d. error structure, which is symmetrically distributed around the production function. An alternative approach is to use a one-sided error term, which then allows the error to be associated with departures from the efficiency frontier.

although the former (as extended by Jorgenson and Griliches (1967)) is much more widely used in the growth analysis. 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 capital's income 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.[7] 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 growth rate of y_t into the capital-deepening effect and the TFP effect.

The non-parametric growth accounting approach was extended to the analysis of growth rate to the analysis of the corresponding levels by Jorgenson and Nishimizu (1978), and developed by Caves, Christensen, and Diewert (CCD, 1982a). 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, by comparing 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. Because deviations are computed relative the average of all countries, the frame-of-reference problem implicit in using any one country as the base is avoided. The result is a non-parametric

[7] Since accounting data do not come in a continuous time format, the discrete time Törnqvist 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.

decomposition of the relative gap in y_t between into its TFP level and capital deepening components, which complement the sources-of-growth rate analysis.[8]

D. Hicks versus Harrod neutrality.

The concept of productivity underlying the Solow residual in one in which a given amount of capital and labor become more productive. The combination k_{00} Figure 1 yield more output as a result of the shift in the production function, measured vertically at that capital-labor ratio. However, like the econometric approach, this non-parametric approach also suffers from a form of simultaneous equations bias because of the endogeneity of capital. This bias arises from the fact that a shift in the production function at a given capital-labor ratio leads to an increase in output per worker and some of this extra output is saved, leading to more output, more saving and so on. This "induced accumulation effect" is a consequence of TFP growth and should be attributed to TFP when assessing the importance of productivity change as a driver of growth (Hulten (1975)).[9]

The induced accumulation effect can be captured by measuring the shift in the production function along a constant capital-output ratio, rather than at a constant capital-labor ratio. This idea, which can be traced back to Harrod (1948), is represented in Figure 1 by the movement along the pay from the origin (OP) from a to c. It is clear from this figure that *all* of the growth in output is accounted for by the shift in the production function, measured along the constant K/Y ray. However, since the Harrodian gap is measured along a given K/Y ratio, it is not a pure

8 The non-parametric and functional-form approaches are operationally separate, but Diewert (1976) shows that in order for the Törnquist index to be an exact representation of the technology, there must exist an underlying production function of the translog form. This parallels the result by Hulten (1973) that there must be an underlying Hicksian production function in order for the Solow-Jorgenson-Griliches index of TFP to be path independent.

9 See, also, Rymes (1971) and Hulten (1979).

measure of the efficiency with which existing resources are used (the normal conception of productivity). Thus, it does not measure a country's distance to the best-practice technology frontier, nor the difference in the technological opportunities separating two countries. It does, however, measure the consequence of a country's move to a higher level of technology.

These two approaches measure the shift in a technology along different paths, and can be implemented for a neoclassical technology of the general form $F(K_t,L_t,t)$, without any special assumptions about the "neutrality" of the technology. When the shift in the production function happens to be Hicks neutral, "technical change" augments both marginal products of capital and labor equally, and the production function has the form $Y_t = A_tF(K_t,L_t)$. This is the case assumption in Solow's 1957 formulation, and it amounts to assuming that the shift in the technology is invariant to the choice of the capital-labor ratio along which the vertical shift is measured (e.g., the proportional shift in the production function in Figure 1 is the same the point a and b). This is the case in which the residual has the property of path independence.

The shift in the production function can also be Harrod neutral (or both, in the Cobb-Douglas case in which the elasticity of substitution between capital and labor is equal to one). In this case, Harrodian rate and bias of technical change are evaluated at a constant marginal product of capital, which, in effect, measures the shift in the production function along the constant K/Y ratio when the Harrodian bias is zero.[10] This case can be parameterized with a production function that exhibits labor-augmenting technical change, $Y_t = F(K_t,a_tL_t)$.

The Hicksian formation has traditionally been assumed for purposes of measuring the Solow residual, and the Harrodian approach for steady-state growth theory (though the papers by

[10] The essay by Solow (1967) provides a succinct summary of the definitions and interrelations among the various concepts of neutrality and bias, including what subsequently came to be known as Solow neutrality and bias.

Klenow and Rodriquez-Care (1997) and Hall and Jones (1999) both apply the Harrodian convention to TFP measurement, as does Hulten and Nishimizu (1980)). A Solow residual can be calculated under either assumption, but only with the Hicksian form of neutrality does the residual retrieve the shift parameter A_t (given the other assumptions about competition and returns to scale). When the shift in the production function is Harrod neutral, the Solow Hicksian residual retrieves the labor-augmenting parameter a_t when divided by labor's share of income. The index formed by dividing TFP by labor's share is not path independent except in the Cobb-Douglas case.[11] In any case, the analyst has to decide before-hand which form of neutrality to impose on the problem, which, from the practical standpoint, is a decision about whether or not to divide the TFP residual by labor's income share.

This choice has to be made in light of the near certainty that the shift is neither Harrod nor Hicks neutral (consider the capital-augmenting technical change associated with the revolution in information technology). Moreover, from the standpoint of measuring the induced-accumulation effect, no specific form about neutrality is needed.[12] This effect can be captured by measuring the shift in the production function along the K/Y ray through the initial point (y_0, k_0), regardless of the assumption about neutrality. Indeed, both the Hicksian and Harrodian forms of the residual can be computed from the same set of data. The former is useful

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[11] In the labor-augmenting case, $Y_t = K_t^{\alpha} (a_t L_t^{\beta})$, which can be written as $Y_t = a_t^{\beta} K_t^{\alpha} L_t^{\beta}$. The Solow residual is then equal to β time the growth rate of a_t. The Hicks-neutral form $Y_t = A_t K_t^{\alpha} L_t^{\beta}$ gives a Solow residual equal to the growth rate of A_t. With the Cobb-Douglas form, labor's share of income is constant at β, making both forms path independent. In general, labor's share is variable, so only the Hicksian form is path independent.

[12] For example, if the actual equilibrium point y_{00} in Figure 1 were to lie somewhere to the right of c, the shift in the Harrodian shift would still be measured along the line P from a to c, regardless of the underlying technology. In this case, the increase in y_{00} beyond c would be attributed to autonomous capital formation, even though technical change is Harrod-biased.

for measuring the "technological distance" between the old and the new levels of technology, in the sense of the additional output that the old level of factor inputs could produce because of the new level of technology. This is particularly important for cross-sectional studies comparing countries at different levels of economic development, where the question of the distance to the best-practice frontier is highly relevant. The Harrodian approach is useful for addressing the question of how much of the observed growth in output per worker is the result of the shift in the technology, inclusive of the induced accumulation effect. Because they address different questions, neither approach is inherently better than the other.

E. Endogenous Growth

Capital is not the only growth factor that is endogenous. Much of technical innovation is the result of systematic investments in education and research, and is thus part of overall (endogenous) capital formation. Moreover, in the framework developed in Lucas (1988) and Romer (1986), investments in education and research generate spillover externalities. These externalities may be sufficiently large that growth becomes endogenously self-sustaining, yielding the "AK" version of the model.

All the growth rate of output is due to capital formation in the pure AK model, and the sources-of-growth analysis would attribute all of output per worker to capital, both in the rate of change and the level. However, this presumes that the extent of the externality is known. When it is not, and this is the normal case when growth-accounting data are derived from observed market transactions, it is not hard to show that the Solow residual measures the externality component of capital's contribution.[13] The TFP residual now registers the externality effect, and

TFP is reinterpreted accordingly. By implication, differences in the growth rates and levels of TFP across countries are explained by externalities and driven by capital formation.

F. Steady-State Growth Models

The decompositions discussed thus far provide a backward-looking diagnosis of economic growth performance and its causes. Past performance is certainly a guide to the economic future, but it is not sufficient for forecasting the path ahead. It may be the case that a current income gap exists between two countries, but if they are converging to the same steady-state level of output per worker, their long-run economic futures will be the same. On the other hand, if one country is on a higher level of technology than another, both now and in the future, there will continue to be an income gap despite the convergence of k_t to its steady-state path.

To study where countries are heading in the future requires a model that specifies more that just the production function, since the evolution of capital, labor, and technology must also be specified. The most fully developed empirical model that fits these requirements is the Mankiw, Romer, and Weil (1992) – henceforth MRW – model of neoclassical steady-state growth. MRW start with an augmented version of the Solow (1956) steady-state growth model and assume that all countries have the same Cobb-Douglas production function. They then solve the Solow model for its reduced form, which makes steady-state output per worker, y*, a function of the following variables and parameters: the rate of saving in each country, σ_i, the rate of growth in the labor force, η_i, the depreciation of capital, δ, and the Harrodian rate of

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[13] Barro (1999) analyzes the case where $y_t = A_0 k_t^{\gamma} k_t^{\alpha}$. The Solow residual is based on the formulation $y_t = A_t k_t^{\alpha}$, implying that the TFP level index is $A_t = A_0 k_t^{\gamma}$. In other words, TFP growth is entirely a function of capital formation in a pure endogenous growth situation. Conceptually, the apparent shift in the neoclassical production function is the result of the spillover externality. Endogenous growth theory can therefore be regarded as supplying one rationale for the shift in the production function, a shift that has been termed 'a measure of our ignorance' by Abramovitz (1956).

technical change, λ. MRW then observe that actual output per worker, y_t, converges to the steady-state value according to an error-correction process that involves the rate of convergence. They proceed to use their reduced form equation to estimate the Cobb-Douglas output elasticities, α and β, and the rate of convergence to steady state.

This approach is useful for the current purpose of decomposing steady-state output per worker into its long-run technology and capital formation components. The left-hand variable, y^*, can be estimated for each country given estimates of σ_i, η_i, δ, λ, as well as estimates of the elasticities α and β using income shares. The estimated y^* is the level of output per worker toward which the actual level at any point in time, y_t, is converging. Like y_t, the estimated y^* must necessarily satisfy the production constraint, $y^* = A_0(k^*)^{\alpha}$, where k^* is the steady-state value of capital per worker. This permits a simple decomposition of y_t into the steady-state level toward which it is converging, y^*, and the gap between the two (which measures the opportunity for growth due to convergence). Beyond this, the steady-state income gaps between any two countries, or groups of countries, can be decomposed into a capital-deepening effect and a Harrodian TFP effect. We carry out both types of level comparison in the empirical section which follows.

III. Data and Empirics

The various theoretical approaches reviewed in the preceding section present a rich set of options for empirical work. They also present a challenge, because they offer different views and competing estimates of the same underlying growth process. We will explore, in this section, just how much the competing estimates differ. We start with the neoclassical sources-of-growth model and the Hicksian convention for measuring TFP. This is by far the most common approach in the empirical growth literature and the one with the largest body of results.

A. The Data Sources and Data Problems

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 112 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, mainly based on the World Bank classification by income per capita (not output per worker, which is highly correlated but not identical). The 40 Low Income countries are located in Africa, with eight exceptions. The 22 Lower-Middle Income countries are developing economies spread throughout the world, as are the 17 Upper-Middle Income countries. The 24 High-Income countries are basically those of the OECD. In addition, we have constructed two small meta-countries: four "Old Tigers" (Hong Kong, South Korea, Singapore, and Taiwan), and five "New Tigers" (China, India, Indonesia, Malaysia, and Thailand).

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 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).[14,]

The PWT 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, can be obtained

[14] 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 adjustments made to the data on labor force, we refer the reader to Isaksson (2007).

from the United Nations Statistical Yearbook (various issues) and is simply computed as Compensation to Employees in GDP. As noted in the introduction, these estimates are suspiciously low, ranging from 0.30 for the Low Income countries to 0.55 in the High Income (see Figure A.2). As noted in the introduction, 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. This has led a number of researchers to work with an externally imposed estimate of the factor shares, and a labor share of two-thirds and capital share of one-third is the sometimes employed. There is evidence to support this assumption (Gollin (2002)), but also evidence against it (Harrison (2002), Bentolila and Saint-Paul (1999) for the OECD). And, in a recent paper, Rodriguez and Ortega (2006) find that capital's income share in manufacturing industry declines by 6.25 percentage points for each log-point increase in GDP per capita.[15] We will not attempt to sort out this issue, but instead present three sets of sources-of-growth estimates, one set calculated with a two-thirds labor share, another based on the average measured share, and a third using the Rodriguez-Ortega rule.

B. Sources-of-Growth Estimates

These estimates of the conventional Solow residual are shown in Tables 1a, 1b, and1c, respectively. The first column of Table 1a, which uses the two thirds/one third share rule as the basis for comparison, indicates that output per worker grew strongly over the period 1970 to 2000 in the High Income countries, but was close to zero in the Low Income group. The Lower Middle and Upper Middle Income meta countries display a positive growth experience, but still

[15] By contrast, Duffy and Papageorgiou (2000) find that the elasticity of substitution – and hence the labor share – *falls* as income increases. A recent paper by Goldar (2004) seems to lend support to their finding, as it reports a falling share over time in Indian manufacturing industry, and a low terminal value of just below 0.3 (a value consistent with the national income approach).

lag the growth rate of the High Income leader. The Old and New Tigers, 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 1a show the sources-of-growth decomposition of the growth rate of output per worker into its capital-deepening and TFP components. It is apparent that capital deepening is the predominant source of growth in the Low, Lower Middle, and Upper Middle Income countries, and that it accounts for about half of the growth in output per worker in the High Income. The Tiger countries are the exception to this pattern with TFP as the main source of growth, but not by a very large margin. These estimate speak 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 in the poorer low-growth countries, but this changes as the growth rate of output per worker rises. These results also speak to the debate whether capital deepening or productivity change is the main driver of growth (the 'perspiration versus inspiration' issue, as Krugman (1994) puts it). The estimates of Table 1a suggest that both perspiration and inspiration have important roles in a successful program of economic development. The finding that TFP grew rapidly in the (Old) Tigers stands in stark contrast to Young (1992, 1995), who argued that the contribution of TFP was only a negligible part of the East Asian miracle, and is more in line with Hsieh (2002).

However, there is an important caveat. A comparison of the Low Income and High Income cases indicates that nearly sixty percent of the *cross-sectional difference* in the growth rate of y_t between the high income meta country and the others is due to differences in TFP growth rates. 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 (2003), who use a similar set of assumptions and methods.

The results shown in Table 1b replay Table 1a using the average measured share of labor income, β, as estimated from the data (see Table 6). Since the share in the sources-of-growth model is a surrogate for the associated output elasticity, the shift to the measured 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 0.71, and the effect of this change is evident in the second and third columns of Table 1b. 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 estimates of Table 1c offer a view of the sources of growth that is intermediate between the fixed 1/3-2/3 shares of Table 1a and the average measured labor shares of Table 1b. The shares in this case are based on the Rodriguez and Ortega (2006) finding that capital's income share in manufacturing industry declines by 6.25 percentage points for each log-point increase in GDP per capita. We apply this factor to the base value of capital's share in the High Income meta country, which we take to be 0.33. Because the Rodriguez-Ortega adjustment generally increases capital's weight, capital deepening is now the leading source of growth in every meta country. However, estimates are much closer to those of Table 1a than 1b, and a major change occurs only in the New Tiger countries.

These three tables are based on estimates of capital stock derived using PPP price deflators. However, Bosworth and Collins (2003) warn of the sensitivity of the results to the choice of price deflator. The use of national price deflators does give a somewhat different view of the problem, and this should be borne in mind when interpreting the results. This is one more data issue to which more attention needs to be paid. [16]

C. The Sources of Development Estimates

Tables 1a, 1b, and 1c approach the analysis of growth by examining the *rate* of growth of y_t and the fraction explained by capital deepening and TFP. The sources-of-development analysis examines the 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, that is, 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?

Table 2 presents "level" results that differ from the preceding analysis based on growth rates. The first column of this table, which uses the 1/3-2/3 income share convention, reports the level of output per worker in the first five meta countries relative to the level of the High Income countries, and portrays the same large 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 2 shows the relative levels of TFP, based on Caves, Christensen, and Diewert (1982a). It is clear from this table that the level of TFP in the first five meta countries is

[16] Bosworth and Collins (2003) argue that capital goods valued in national prices are a better reflection of the capital costs faced by each country. They show that PPP-based capital stocks estimates have higher growth rates than the corresponding estimates using national prices, and that the former thus lead to an understatement of the TFP performance of poor countries. Our estimates based on national prices obtained from World Development Indicators (World Bank, 2004), for the 83 (out of 112) are shown in Table A2 of the Appendix, for our six meta countries. While Table A2 generally supports the findings of Bosworth and Collins, the differences are not large enough to alter the results based on the more widely accepted PPP approach. The main difference arises in the Low Income meta country, where TFP growth does come to dominate. However, all of the growth rates for this case are quite close to zero. We have therefore opted to use the conventional PPP approach in this paper, but note that this is yet another area where data issues are important.

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 2 displays the time series trends that correspond to column 2. It reveals the same general magnitude as the relative TFP estimates of Table 2, and also indicates that the gap has widened over time for the Low, Lower Middle, and Upper Middle countries, but that the Tiger countries (Old and New) are narrowing the gap in the relative TFP level.

The last three columns of Table 2 decompose the level of output per worker into its capital-deepening and TFP components. Following Easterly and Levine (2001), we assume that the production function has the simple constant-returns Cobb-Douglas form $y_t = A_t k_t^{(1-\beta)}$. The variable A_t is the basis for growth of TFP in the Solow model, and the level of TFP can be estimated by computing the ratio $y_t/k_t^{(1-\beta)}$. This 'CD' index is not necessarily equivalent to the CCD index, but when the β shares have 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 2, 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 is the disconnect between the growth-rate analysis of Table 1a and the level analysis of Table 2 noted above. For example, TFP *growth* explains none of the *growth rate* in output per worker in the Low Income meta country, but the corresponding TFP *level* explains 66% of the *level* of output per worker. For the Lower and Upper Middle meta countries, these numbers are 40% and 65%, and for the High Income case, they are 49% and 64%. This disconnect is diminished, but not absent, in the high growth Tiger meta countries.

In other words, Table 1a suggests that their growth is propelled more by capital deepening rather than TFP growth, but Table 2 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, also, 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 countries display a convergence toward the High Income case, in both output per worker and in TFP levels, powered in part by a rapid rate of TFP growth. This pattern suggests that, in the large, successful development programs are powered by an acceleration in TFP growth relative to that of the High Income leaders, and that the gap in TFP levels in thereby narrowed. An acceleration in capital per worker is also an important (albeit lesser) factor. Whether the former drives the latter, as in the Harrodian view, or vice versa, as in the endogenous growth view, cannot be learned from sources-of-growth estimates, but whatever the dynamics associated with TFP growth and levels, the estimates of Tables 1a and 2 assign a centrally important role to *measured* TFP.

D. Empirical Results from the Harrodian and Endogenous Technology Approaches

The Harrodian version of the growth decomposition is shown in the last two columns of Tables 1a-1c. 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 (the induced accumulation) is reassigned to TFP. This result carries over from growth rates to levels, which are not shown, since in the common-share Cobb-Douglas case, the Harrodian levels are a simple power transformation (based on β) of the Hicksian level estimates of Table 2.

Endogenous growth theory implies a very different sources-of-growth decomposition. Where the Harrodian approach reallocates the induced-accumulation part of capital formation to TFP growth, the endogenous growth view reallocates the capital-induced part of TFP growth to capital formation. In the most extreme form, all of TFP growth is endogenous. If additional (endogenous growth) columns were added to Tables 1a, 1b, and 1c, with the capital-deepening effect shown in a sixth column and the TFP effect in a seventh, the new column 6 would equal the entire growth rate of output per worker, and the column 7 would contain nothing but zeroes. Since this decomposition is essentially trivial, from an expositional standpoint, it is not included in the various tables.

IV. The Predictions of Growth Theory

The insights offered in the preceding sections about the growth process and the income gap 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? Are the trends in TFP and capital formation such that the poorest countries will ultimately converge to the levels achieved by the rich and thereby extinguish the income gap? These questions are inherently about future outcomes, and the answers require a fully-specified model of growth that takes into account the full range of factors that determine the future growth path.

A. Decompositions Based on Growth Models

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, in its AK form, predicts 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 1a, by even stronger TFP growth.

The neoclassical model, as interpreted by MRW (1992), does allow for some countries to catch up to the leaders while others stagnate. MRW solve for the reduced form of the Solow steady-state model when the technology of every country has the same Cobb-Douglas form and output elasticities. They use the equation for steady-state output per worker, adjusted to allow convergence to steady-state, to estimate the elasticities. In this paper, we take this equation to estimate steady-state output per worker for each meta country, y*, by using the 'two-thirds/one-third' rule for the income share as an estimate of the Cobb-Douglas elasticities, and by estimating the other variables in the reduced form: the investment rate, σ, the rate labor force growth, η, the rate of depreciation, δ, the Harrodian rate of technical change, λ, and the level of TFP in the comparison year 2000, A_{2000}.

The MRW model assumes the Cobb-Douglas form with constant returns to scale, so that $y^*_t = A_t k^{*}_t{}^{(1-\beta)}$. The steady-state solution for y* in each of the six meta countries is shown in the first column of Table 3 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 17 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 1a 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 Old Tiger countries, whose y^*_{2000} is around one half of the High Income amount, and whose λ is larger.

The sources of the gap are examined in Table 4, 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-development level decomposition shown in Table 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 given rate of saving).

The sources of the income gap are further examined in Table 4. The difference in the *level* of steady-state output per worker is in the High Income meta country (H) compared to the Low Income (L) country is $(y^*_H - y^*_L)$, which can be decomposed into two effects. The first is the gap $(y_f - y^*_L)$, the distance between L's steady-state y^*_L and the point y_f. on its own production function that it would attain if it operated with the saving and population growth parameters of economy H rather than its own parameters. The second component of the decomposition is the distance between the two production functions, $(y^*_H - y_f)$, as measured in the Harrodian way along the high income growth path. The two terms decompose the steady-state output per worker gap into capital-deepening and efficiency effects based on the saving and population growth parameters of the high income country.

A look at column 1 of Table 4 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 columns gives capital-deepening, the difference (y_f - y^*_L), and technology effects, (y^*_H - y_f). Several 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 differences in the propensity to accumulate capital relative to the growing labor force (this is also apparent in the first two columns of Table 5, which express the Table 4 decomposition in percentage terms). Finally, 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. We could equally decompose the steady-state output per worker gap into capital-deepening and efficiency effects based on the saving and population growth parameters of the *low* income country. The third and fourth columns of Table 5 show the splits for these alternative paths (the 'Actual Income Path" for each country). The alternative results are quite different, suggesting a high degree of path dependence, and to arrive at a single index, the average values for the two cases are shown in the last two columns of the table. The results support the overall conclusion that the TFP effect is still the most important source for explaining the gap (y^*_H - y^*_L), as well as the conclusion that the gap looks set to persist into the future.

B. Steady-State Sources-of-Growth Rate Estimates

Tables 4 and 5 decompose the steady-state levels of output per worker into its long-run capital and Harrodian TFP components. For the sake of completeness, we now return to Table 1a and add the sources-of-growth *rates* decomposition implied by the steady-state framework.

The steady-state analogue to Table 1a can be calculated from the basic parameters and estimates of the steady-state growth, since, along the steady-state path, output per worker, y*, and capital per worker, k*, grow at the same rate λ. In other words, *Harrodian* productivity is the sole driver of the steady-state growth in output per worker in the neoclassical model. Thus, the first column of a steady-state analogue to Table 1a would record the λ appropriate for each country, and Harrodian decomposition in the fourth and fifth columns would have the values 0 (for the capital-deepening effect) and λ (for the TFP effect), since all capital formation is induced accumulation and is assigned to TFP. This represents the true picture of growth, conditional on accepting the validity of the experiment with the neoclassical model.

In the steady-state version of the standard sources-of-growth model developed by Solow, the growth rate of output per worker is y* and the capital-deepening effect is (1- β) k*, and the TFP effect is the residual y* - (1- β) k*. This implies that the Hicksian decomposition would record (1- β)λ for the capital effect and βλ for the TFP contribution in an analogue to Table 1. However, these are not the correct numbers with which to assess the relative contribution of each effect, and this establishes the fact that the Solow residual growth model, so widely used in empirical growth theory, is asymptotically biased. Again, this bias is the counterpart of the simultaneous equations bias arising is econometrics from the endogeneity of capital.

V. Conclusion

Our analysis points to the persistently low levels of technological efficiency as the proximate source of the gap between the rich and poorer countries. In this, we confirm many other studies of this issue. We have not attempted to explain the causes of the technology gap, be they due to institutional and environmental factors, the externalities associated with capital formation, or whatever. We have chosen, instead, to examine the prior issue of how to measure the gap, and have compared different techniques and assumptions using a common set of data. This examination has led us to the following conclusions.

First, the conventional analysis of differential growth rates needs to be supplemented by a parallel analysis of productivity levels. Capital deepening explains more than half of the growth *rate* of output per worker in a majority of countries, while TFP explains more than half of the corresponding gap. Only in the rapid-growth Tiger countries does TFP growth outweigh capital formation, and then only by a small margin.

Second, the Hicks and Harrod ways of measuring the relative levels of the technology gap are both relevant, but they are relevant for answering different questions. The former measures the extra output that could be obtained from the current quantities of capital and labor by moving to a higher level of TFP, while the latter includes the additional output arising from the savings generated by the gain in productive efficiency. The latter is larger and is relevant for understanding the overall impact of TFP, but if the goal is to understand the causes of a low level of productive efficiency, *per se*, the Hicksian approach seems better suited to the task.

Third, in the endogenous growth approach, the induced-technology effect appears as a shift in the production function in the conventional Hicks-Solow measurement framework, so a positive gap in measured TFP is not inconsistent with the endogenous growth model. Indeed, endogenous growth effects are among the factors than can be adduced to explain the gap.

Fourth, the measurement procedures used in the literature to measure the income and technology gaps are inherently backward looking. A large income gap between rich and poor countries is less of a concern if the growth paths of the two will converge in the future. This can only be learned from a modeling exercise that endogenizes the growth path, rather than taking the sources of growth as being exogenously determined as in the Solow residual model. We use the neoclassical model for this purpose, and develop a steady-state decomposition of output per worker into capital deepening and Harrodian-TFP components. We find that this forward-looking model predicts that the large gap will not close in the future for most of the developing countries unless they are able to significantly improve both the growth rates of the capital per worker and TFP. This conclusion must be tempered by the highly abstract nature of the neoclassical growth model, but the size of the predicted long-run gaps are suggestive of the potential magnitude of future income gaps. The steady-state analysis is also useful in pointing out the existence of an asymptotic bias in the conventional Solow approach to the sources of growth.

Finally, it is important to emphasize, once again, that there are significant gaps in the data. The problem is most apparent in the implausibly low labor shares implied by national accounting data for lower income countries, and the resulting practice of imposing a common two-thirds share on all countries. The output elasticities of capital and labor, as proxied by the share, are a key determinant of output growth, and the consequences of using different measures of the labor share are evident in the estimates of Tables 1a, 1b, and 1c of this paper. It is intellectually disturbing that our understanding of the growth process should rest on such shaky data foundations. And, data issues are by no means limited to the problem with measured income shares. The accuracy of capital measures is also an issue, particularly with the Bosworth-Collins point about the large difference that arises when national prices are substitutes for PPP price. It would be well, in closing, to recall the words of Zvi Griliches, who observed:

> "We [economists] ourselves do not put enough emphasis on the value of data and data collection in our training of graduate students and in the reward structure of our profession. It is the preparation skill of the chef that catches the professional eye, not the quality of the materials in the meal, or the effort that went into procuring them." (AER 1994)

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TABLE 1a

SOURCES OF GROWTH
COMMON SHARES
1970-2000

	CONVENTIONAL (HICKS)			HARROD	
META COUNTRY	AAGR Y/L	AAGR K/L	AAGR TFP	AAGR K/L	AAGR TFP
Low Income	0.17%	0.25%	-0.07%	0.28%	-0.11%
Low-Middle	1.01%	0.61%	0.40%	0.41%	0.60%
Upper-Middle	0.99%	0.59%	0.40%	0.39%	0.60%
New Tigers	3.79%	1.70%	2.09%	0.68%	3.12%
Old Tigers	4.89%	2.37%	2.52%	1.13%	3.76%
High	1.95%	1.00%	0.95%	0.53%	1.42%

AAGR = Average Annual Growth Rate

TABLE 1b

SOURCES OF GROWTH
1970-2000
MEASURED SHARES

	CONVENTIONAL (HICKS)			HARROD	
META COUNTRY	AAGR Y/L	AAGR K/L	AAGR TFP	AAGR K/L	AAGR TFP
Low Income	0.17%	0.52%	-0.35%	1.37%	-1.19%
Low-Middle	1.01%	1.17%	-0.16%	1.45%	-0.44%
Upper-Middle	0.99%	1.05%	-0.06%	1.14%	-0.15%
New Tigers	3.79%	3.53%	0.26%	2.97%	0.83%
Old Tigers	4.89%	3.92%	0.97%	2.76%	2.13%
High	1.95%	1.36%	0.58%	0.88%	1.07%

AAGR = Average Annual Growth Rate

TABLE 1c

SOURCES OF GROWTH
1970-2000
RODRIGUEZ-ORTEGA SHARES

	CONVENTIONAL (HICKS)			HARROD	
META COUNTRY	AAGR Y/L	AAGR K/L	AAGR TFP	AAGR K/L	AAGR TFP
Low Income	0.17%	0.38%	-0.20%	0.59%	-0.41%
Low-Middle	1.01%	0.79%	0.22%	0.62%	0.39%
Upper-Middle	0.99%	0.68%	0.31%	0.49%	0.50%
New Tigers	3.79%	2.49%	1.31%	1.27%	2.52%
Old Tigers	4.89%	2.67%	2.23%	1.36%	3.54%
High	1.95%	1.00%	0.95%	0.53%	1.42%

AAGR = Average Annual Growth Rate

TABLE 2

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	6.05%	19.84%	19.84%	7.76	2.61	5.15
Low-Middle	22.46%	43.41%	43.41%	9.08	3.14	5.93
Upper-Middle	44.47%	63.30%	63.30%	9.76	3.45	6.31
New Tigers	8.50%	23.57%	23.57%	8.09	2.78	5.31
Old Tigers	49.53%	67.24%	67.24%	9.83	3.48	6.35
High	100.00%	100.00%	100.00%	10.57	3.81	6.77

TABLE 3

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	$2,452	$2,340	5%
Low-Middle	$9,924	$8,811	11%
Upper-Middle	$18,617	$17,402	7%
New Tigers	$7,059	$3,531	51%
Old Tigers	$26,383	$20,905	23%
High	$48,538	$39,954	18%

TABLE 4

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	$56,783	$1,743	$55,040
Low-Middle	$48,393	$4,570	$43,823
Upper-Middle	$38,926	$5,282	$33,644
New Tigers	$47,648	$10	$47,639
Old Tigers	$16,029	$36	$15,993
High	$0	$0	$0

TABLE 5

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

META COUNTRY	HIGH INCOME PATH % CAPITAL	HIGH INCOME PATH % TFP	ACTUAL INCOME PATH % CAPITAL	ACTUAL INCOME PATH % TFP	AVERAGE PATH % CAPITAL	AVERAGE PATH % TFP
Low Income	3%	97%	44%	56%	23%	77%
Low-Middle	9%	91%	36%	64%	23%	77%
Upper-Middle	14%	86%	31%	69%	23%	77%
New Tigers	0%	100%	0%	100%	0%	100%
Old Tigers	0%	100%	0%	100%	0%	100%

TABLE 6

COMPARISON OF STEADY-STATE PARAMETERS
AVERAGE VALUES 1970-2000

META COUNTRY	LABOR'S SHARE β_{STD}	LABOR'S SHARE $\beta_{MEASURED}$	LABOR'S SHARE β_{R-O}	SAVING RATE σ	LABOR GROWTH η	POPULATION GROWTH
Low Income	0.667	0.294	0.493	0.093	0.024	0.026
Low-Middle	0.667	0.367	0.576	0.144	0.027	0.024
Upper-Middle	0.667	0.412	0.618	0.178	0.025	0.020
New Tigers	0.667	0.316	0.518	0.281	0.021	0.017
Old Tigers	0.667	0.455	0.630	0.281	0.024	0.013
High	0.667	0.548	0.667	0.231	0.011	0.007

β_{STD} = Standard approach; $\beta_{MEASURED}$ = As reported; β_{R-O} = As implied by Rodriguez-Ortega (2006)

Figure 1. Output per Worker, Level of TFP and Capital-deepening effect

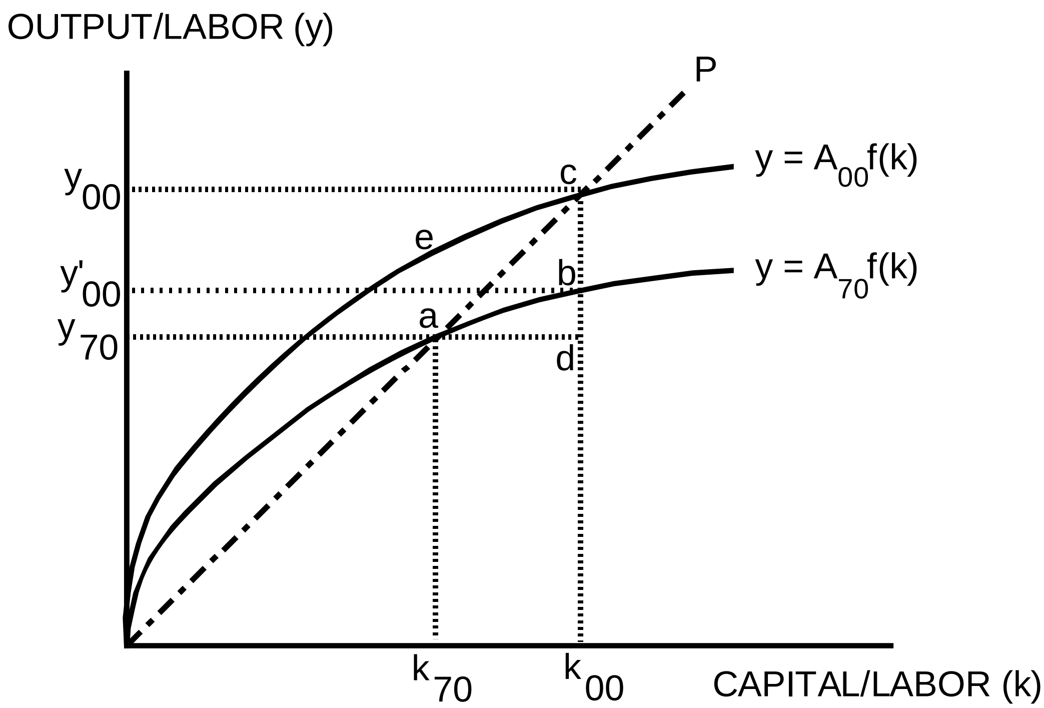


Figure 2. Output per Worker, by Meta Country, 1970-2000

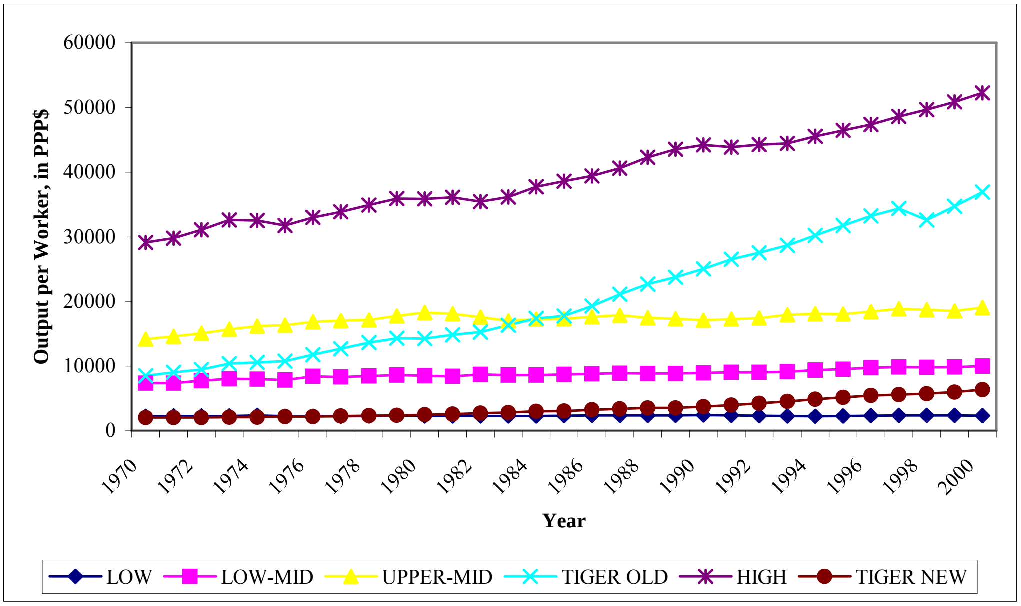
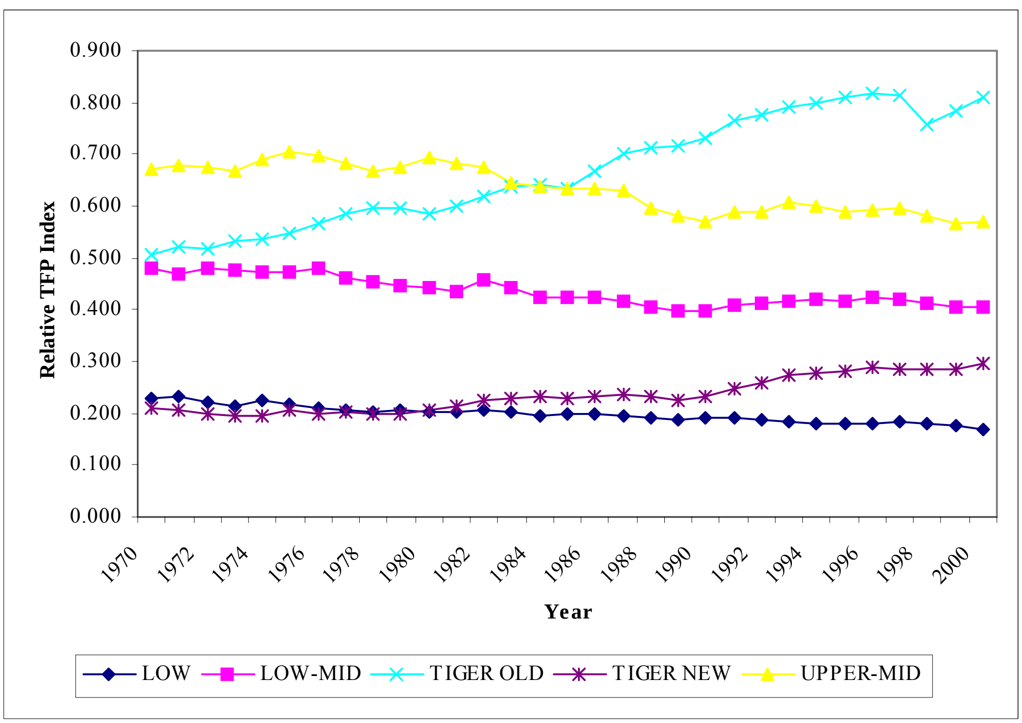


Figure 3. TFP Levels Relative to High Income, CCD Method, OECD=1.00



Data Appendix

Table A.1. Basic Statistics and Countries, Organized by Meta Country

HIGH INCOME	**DPOP 1970-2000**	**Y/L 1970**	**Y/L 2000**	**DY/L 1970-2000**	**I/Y 1970-2000**	**K/L 1970**	**K/L 2000**	**DK/L 1970-2000**	**Y/POP 1970**	**Y/POP 2000**	**DY/POP 1970-2000**
Australia	0.013	34747	51568	0.013	0.238	86703	148660	0.017	14820	25559	0.018
Austria	0.003	26736	50591	0.021	0.260	66469	169797	0.030	11176	23676	0.024
Belgium	0.002	32427	56752	0.018	0.231	81200	176457	0.025	12143	23781	0.022
Canada	0.012	34692	52295	0.013	0.228	61994	152421	0.029	14102	26904	0.021
Cyprus	0.008	12603	39218	0.037	0.249	34347	92786	0.032	5275	17742	0.039
Denmark	0.003	33218	48255	0.012	0.229	83723	151198	0.019	16038	26608	0.016
Finland	0.004	23899	47281	0.022	0.260	64823	145963	0.026	11412	23792	0.024
France	0.005	28960	49136	0.017	0.246	65718	160775	0.029	12336	22358	0.019
Greece	0.006	21755	33783	0.014	0.247	50713	103785	0.023	8441	14614	0.018
Iceland	0.010	25205	45055	0.019	0.258	77138	138571	0.019	10925	24777	0.026
Ireland	0.008	19079	65054	0.040	0.192	28880	115744	0.045	7260	26381	0.042
Israel	0.024	24021	38762	0.015	0.271	54458	113059	0.024	8837	16954	0.021
Italy	0.002	28883	53949	0.020	0.233	74156	169291	0.027	11294	21780	0.021
Japan	0.007	18098	38737	0.025	0.322	34551	161357	0.050	11474	24675	0.025
Luxembourg	0.008	39277	103133	0.031	0.225	115514	243753	0.024	15121	43989	0.034
Netherlands	0.006	33112	52230	0.015	0.234	84187	152928	0.019	13320	24313	0.019
New Zealand	0.010	35083	39360	0.004	0.211	78165	115780	0.013	13665	18816	0.010
Norway	0.005	27024	54032	0.022	0.318	91446	200385	0.025	11188	27060	0.028
Portugal	0.004	14823	35008	0.028	0.213	25056	96372	0.043	6296	15923	0.030
Spain	0.005	23675	44113	0.020	0.242	47853	134732	0.033	9076	18047	0.022
Sweden	0.003	31990	45453	0.011	0.213	79456	133786	0.017	14828	23635	0.015
Switzerland	0.004	43346	47412	0.003	0.266	129962	192283	0.013	20611	26414	0.008
UK	0.002	26272	44649	0.017	0.181	58109	113065	0.021	12085	22190	0.020
USA	0.010	38432	64537	0.017	0.197	60506	161391	0.032	16351	33293	0.023
AVERAGE	***0.007***	***29108***	***52211***	***0.020***	***0.240***	***57171***	***154321***	***0.033***	***13290***	***26595***	***0.023***
LOW INCOME (up to YPOP 3,000 in year 2000)											
Angola	0.023	5767	3050	-0.021	0.075	4223	3428	-0.007	3329	1612	-0.023
Bangladesh	0.022	2243	3187	0.011	0.098	3193	3707	0.005	1105	1684	0.014
Benin	0.028	2041	2489	0.006	0.074	816	2079	0.030	1094	1214	0.003
Bolivia	0.022	6036	6829	0.004	0.094	8409	9053	0.002	2498	2724	0.003
Burkina Faso	0.022	1159	1939	0.017	0.099	717	2509	0.040	669	957	0.012
Burundi	0.021	1467	990	-0.013	0.057	326	1028	0.037	848	523	-0.016
Cameroon	0.026	2552	4125	0.015	0.078	1445	3981	0.033	1580	2042	0.008
Central African Rep.	0.022	3964	2144	-0.020	0.045	2529	1959	-0.008	2240	1045	-0.025
Chad	0.024	2352	1837	-0.008	0.089	4196	2285	-0.020	1180	909	-0.008
Comoros	0.024	4811	3498	-0.010	0.078	3005	4090	0.010	2353	1578	-0.013
Congo	0.028	1612	3686	0.027	0.173	4476	4968	0.003	929	1808	0.021
Cote d'Ivoire	0.034	4823	4679	-0.001	0.076	3547	4179	0.005	2391	1869	-0.008
DR Congo	0.029	1835	252	-0.064	0.052	702	636	-0.003	1056	118	-0.071
Ethiopia	0.026	1293	1483	0.004	0.041	763	787	0.001	608	635	0.001
Gambia	0.033	2104	2393	0.004	0.064	451	2044	0.049	1113	1217	0.003
Ghana	0.026	2277	2775	0.006	0.073	3091	2360	-0.009	1282	1351	0.002
Guinea	0.021	4304	5977	0.011	0.113	10496	7794	-0.010	2282	2831	0.007
Guinea Bissau	0.027	577	1287	0.026	0.206	2628	2859	0.003	332	688	0.024
Haiti	0.017	1827	5569	0.036	0.051	523	1834	0.040	930	2416	0.031
Honduras	0.029	5608	5415	-0.001	0.127	6318	10234	0.016	1861	2050	0.003
Kenya	0.031	1450	2476	0.017	0.108	2072	2743	0.009	821	1244	0.013
Lesotho	0.021	1730	3365	0.021	0.189	536	10260	0.095	883	1592	0.019

LOW INCOME	DPOP 1970-2000	Y/L 1970	Y/L 2000	DY/L 1970-2000	I/Y 1970-2000	K/L 1970	K/L 2000	DK/L 1970-2000	Y/POP 1970	Y/POP 2000	DY/POP 1970-2000
Madagascar	0.026	2546	1772	-0.012	0.028	896	741	-0.006	1274	836	-0.014
Malawi	0.027	871	1631	0.020	0.138	1337	1722	0.008	455	784	0.018
Mali	0.023	1485	2033	0.010	0.075	1812	1896	0.001	784	969	0.007
Mauritania	0.024	3397	2912	-0.005	0.067	761	2892	0.043	1881	1447	-0.008
Mozambique	0.020	2807	2000	-0.011	0.027	615	875	0.011	1571	1037	-0.013
Nepal	0.023	1511	3144	0.024	0.135	824	5028	0.058	816	1459	0.019
Nicaragua	0.028	12280	4367	-0.033	0.117	10451	9274	-0.004	3980	1767	-0.026
Niger	0.031	2653	1823	-0.012	0.073	2052	1501	-0.010	1519	875	-0.018
Nigeria	0.028	1997	1479	-0.010	0.089	781	2383	0.036	1113	707	-0.015
Papua New Guinea	0.023	5247	5924	0.004	0.124	6473	9592	0.013	2862	2866	0.000
Rwanda	0.027	1676	1786	0.002	0.039	325	971	0.035	887	895	0.000
Senegal	0.027	2949	3389	0.004	0.072	2758	2977	0.002	1627	1622	0.000
Sierra Leone	0.021	3649	1910	-0.021	0.033	645	1468	0.026	1496	695	-0.025
Tanzania, U. Rep. of	0.029	1056	938	-0.004	0.243	2356	2405	0.001	565	482	-0.005
Togo	0.026	3109	2149	-0.012	0.078	1129	2784	0.029	1397	870	-0.015
Uganda	0.026	1144	1835	0.015	0.023	161	537	0.039	608	941	0.014
Zambia	0.028	2946	2141	-0.010	0.169	8255	4457	-0.020	1335	892	-0.013
Zimbabwe	0.028	3723	5127	0.010	0.199	9226	10738	0.005	2155	2486	0.005
AVERAGE	***0.026***	***2239***	***2359***	***0.002***	***0.095***	***2142***	***2843***	***0.009***	***1176***	***1138***	***-0.001***
LOW-MID (from YPOP 3,001 to YPOP 6,000 in year 2000)											
Algeria	0.026	13369	14527	0.003	0.190	16093	29706	0.020	3433	4896	0.011
Cape Verde	0.016	4061	10078	0.029	0.171	4652	15448	0.039	1387	4027	0.034
Colombia	0.020	7651	11477	0.013	0.116	7860	16847	0.025	3159	5383	0.017
Costa Rica	0.025	13639	14827	0.003	0.151	13398	26203	0.022	4181	5870	0.011
Dominican Republic	0.021	7488	16173	0.025	0.138	6156	20717	0.039	2018	5270	0.031
Ecuador	0.024	7069	9023	0.008	0.189	16442	22049	0.009	2292	3468	0.013
Egypt	0.021	5603	10970	0.022	0.076	2553	7379	0.034	1970	4184	0.024
El Salvador	0.018	12578	10368	-0.006	0.072	7532	10390	0.010	4141	4435	0.002
Equatorial Guinea	0.015	8094	8641	0.002	0.130	3091	15860	0.053	3758	3604	-0.001
Fiji	0.014	11620	13580	0.005	0.147	19314	24384	0.008	3433	4971	0.012
Guatemala	0.025	8673	10611	0.007	0.081	6972	10314	0.013	2991	3914	0.009
Guyana	0.002	8628	8243	-0.001	0.163	23071	18465	-0.007	2432	3532	0.012
Iran	0.026	18304	19560	0.002	0.197	17202	38541	0.026	5225	5995	0.004
Jamaica	0.011	10177	7310	-0.011	0.173	24743	21030	-0.005	3867	3693	-0.001
Jordan	0.038	8120	13087	0.015	0.146	6841	21156	0.036	2228	3895	0.018
Morocco	0.020	6815	9301	0.010	0.139	5460	14654	0.032	2261	3717	0.016
Namibia	0.025	13955	14689	0.002	0.182	26608	28559	0.002	4770	4529	-0.002
Pakistan	0.027	2729	5360	0.022	0.117	4024	6412	0.015	943	2008	0.024
Paraguay	0.027	6183	10439	0.017	0.121	3930	15810	0.045	2874	4684	0.016
Peru	0.021	11927	10095	-0.005	0.170	26080	25698	0.000	4686	4589	-0.001
Philippines	0.023	6548	8374	0.008	0.152	8197	15312	0.020	2396	3425	0.012
Sri Lanka	0.014	3745	7646	0.023	0.119	2090	10726	0.053	1557	3300	0.024
AVERAGE	***0.024***	***7374***	***9984***	***0.010***	***0.143***	***8417***	***15835***	***0.021***	***2560***	***3846***	***0.013***
UPPER-MID (from YPOP 6,001 and above in year 2000, excluding OECD + Israel)											
Argentina	0.014	19967	25670	0.008	0.173	37276	58223	0.014	9265	11006	0.006
Barbados	0.004	15935	32961	0.023	0.148	31065	41302	0.009	6040	16415	0.032
Botswana	0.029	3126	23926	0.066	0.188	2896	32356	0.078	1193	8241	0.062
Brazil	0.019	11006	19220	0.018	0.207	18028	43954	0.029	3620	7190	0.022
Chile	0.015	15345	25084	0.016	0.151	25676	49286	0.021	4794	9926	0.023
Gabon	0.029	11293	17645	0.014	0.140	8597	23958	0.033	6857	8402	0.007
Mauritius	0.012	13162	32241	0.029	0.126	13700	39386	0.034	4005	13932	0.040
Mexico	0.022	17965	21111	0.005	0.182	27956	46815	0.017	5522	8762	0.015

UPPER-MID	DPOP 1970-2000	Y/L 1970	Y/L 2000	DY/L 1970-2000	I/Y 1970-2000	K/L 1970	K/L 2000	DK/L 1970-2000	Y/POP 1970	Y/POP 2000	DY/POP 1970-2000
Panama	0.021	11357	14382	0.008	0.207	17391	37650	0.025	3824	6066	0.015
Seychelles	0.013	8470	23552	0.033	0.149	4934	44543	0.071	4091	10241	0.030
South Africa	0.021	18415	18488	0.000	0.120	23582	25070	0.002	6878	7541	0.003
Syria	0.031	26235	28817	0.003	0.190	34728	14163	-0.029	7542	9193	0.006
Trinidad and Tobago	0.009	19842	25188	0.008	0.106	13058	33090	0.030	6582	11175	0.017
Tunisia	0.020	8573	17124	0.022	0.160	20720	26610	0.008	2568	6776	0.031
Turkey	0.020	8017	14125	0.018	0.162	8040	29528	0.042	3619	6832	0.021
Uruguay	0.006	13579	21150	0.014	0.121	19073	34882	0.019	6131	9622	0.015
Venezuela	0.026	35399	15705	-0.026	0.168	44808	36511	-0.007	10528	6420	-0.016
AVERAGE	***0.020***	***14566***	***19492***	***0.009***	***0.159***	***22076***	***40132***	***0.019***	***5184***	***7924***	***0.014***
OLD TIGERS											
Hong Kong, SAR of China	0.018	15587	51469	0.039	0.249	28329	138086	0.051	6506	26699	0.046
Korea, Republic of	0.012	7676	31239	0.045	0.311	9584	98424	0.075	2716	15876	0.057
Singapore	0.021	15085	50809	0.039	0.454	32892	187383	0.056	5279	28869	0.055
Taiwan, P. of China	0.013	7282	42402	0.057	0.194	6392	78537	0.081	2790	19034	0.062
AVERAGE	***0.013***	***8513***	***36922***	***0.048***	***0.302***	***11132***	***102174***	***0.074***	***3120***	***18312***	***0.059***
NEW TIGERS											
China	0.014	1583	6175	0.044	0.178	1564	10624	0.062	815	3747	0.049
India	0.020	2454	5587	0.027	0.118	2470	6729	0.032	1073	2479	0.027
Indonesia	0.019	2865	7677	0.032	0.146	1635	13772	0.069	1087	3642	0.039
Malaysia	0.025	8377	23994	0.034	0.223	10090	54710	0.055	2884	9919	0.040
Thailand	0.017	3758	11308	0.036	0.309	7486	36890	0.051	1822	6857	0.043
AVERAGE	***0.017***	***2036***	***6355***	***0.037***	***0.195***	***2052***	***10587***	***0.054***	***966***	***3367***	***0.041***

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.

DPOP = Average annual growth rate (AAGR) of population; **Y/L** = GDP per worker; **DY/L** = AAGR of GDP per worker; **I/Y** = Investment share in GDP; **K/L** = capital-labor ratio; **DK/L** = AAGR of capital-labor ratio (i.e. capital deepening); **Y/POP** = GDP per capita; and **DY/POP** = AAGR of GDP per capita.

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 purchasing power 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.

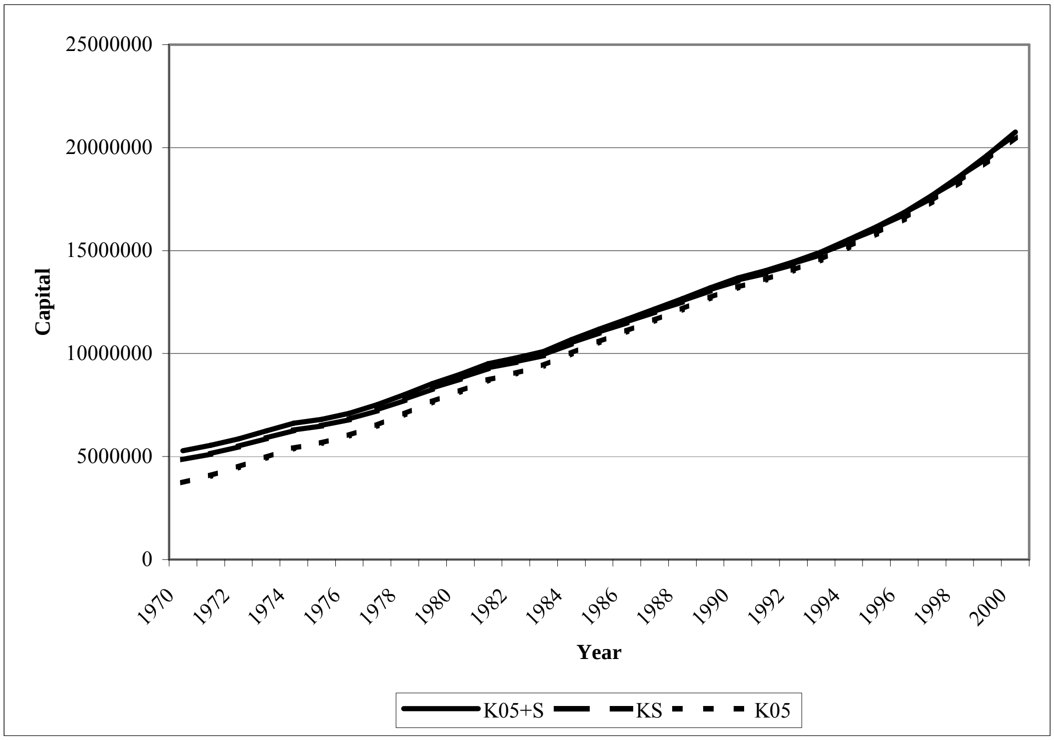


Table A.2. Comparison of Capital Stocks Based on PPP ($) and National Prices ($).

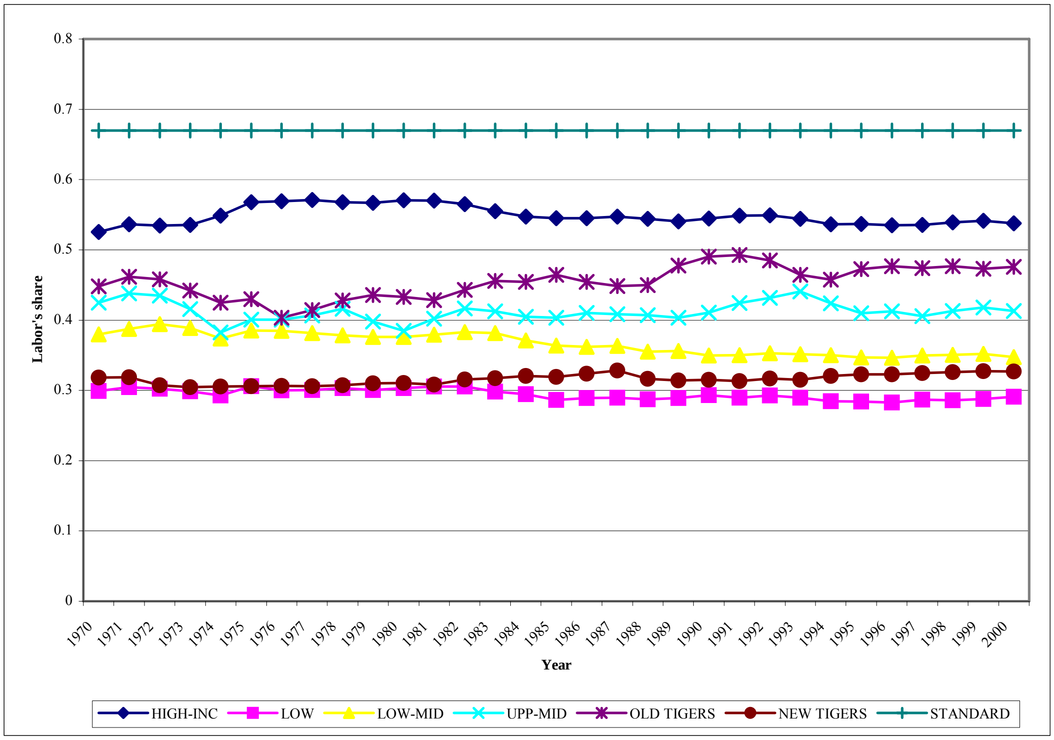
Meta-countries	PPP, $ AAGR	Meta-countries	National prices, $ AAGR
Low	0.61	Low	0.85
Low-Mid	1.94	Low-Mid	1.90
Upper-Mid	1.70	Upper-Mid	1.47
Old Tigers	7.12	Old Tigers	6.84
New Tigers	5.44	New Tigers	5.16
High	3.30	High	2.53

AAGR = Average annual growth rates in percent for the period 1970-2000.
Note: The difference between the two columns, when multiplied by .33, gives the change in TFP growth rates in Table 1a that would occur if national prices were substituted for PPP prices.

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.[17] Figure A.2 reveals 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 of the meta country, although they remain fairly constant within meta countries.

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



[17] Data on labor shares are not available for all countries. The average labor shares are therefore based on meta countries excluding the following countries: HIGH Cyprus; LOW Bangladesh, Comoros, D.R. Congo, Ethiopia, Gambia, Guinea and Nepal; LOW-MID Cape Verde, El Salvador, Equatorial Guinea, Guatemala, Pakistan and Syria; NEW TIGERS Indonesia.