

# Capital fundamentalism, economic development, and economic growth\*

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## Abstract

This paper critically evaluates the roles of investment and physical capital accumulation in economic growth and development. Should a modern version of capital fundamentalism – where capital and investment are viewed as the primary determinants of economic development and long-run growth – guide our research and policy advice? Our analysis suggests that the answer is “no.” Capital accumulation seems to be part of the process of economic development and growth, not the igniting source.

## 1 Introduction

Few economic ideas are as intuitive as the notion that increasing investment is the best way to raise future output, either for an individual or a nation. In the 1950s and 1960s, this idea formed the basis for the dominant theory of economic development, sometimes termed “capital fundamentalism.” Under

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this view, differences in national stocks of capital were the primary determinants of differences in levels of national product. Correspondingly, capital fundamentalists viewed rapid capital accumulation as central to increasing the rate of economic growth. Capital fundamentalism provided a coherent foundation for giving advice on development problems: national and international policies designed to increase a nation's physical capital stock were the best way to foster economic development.

Since the capital fundamentalist view held sway, the problems of economic development and economic growth have twice thrust themselves onto center stage of the economic research agenda.<sup>1</sup> In the first of these episodes, neoclassical growth theory and growth-accounting research in the 1950s and 1960s indicated that differences in patterns of investment and capital formation were *not* the major factors which led nations to be rich or poor, to be fast-growing or slow-growing. These findings suggested that improvements in technology — not capital accumulation — drive improvements in living standards in the long-run. Since most of the evidence for capital fundamentalism, however, was based on case studies of mainly less-developed countries, while most of the contrary evidence was obtained for advanced countries, aspects of capital fundamentalism lived on in development economics.

The second of these episodes, the recent explosion of research in growth and development, has reinstated elements of capital fundamentalism at the forefront of economic and policy discussions. In particular, recent research has lent support to two conclusions the capital fundamentalists would find attractive: (i) that differences in national patterns of physical capital accumulation can explain much of the differences in levels of national product; and (ii) that increases in national investment rates can produce major increases in rates of economic growth.

Our objective in this paper is to critically evaluate the roles of investment and physical capital accumulation in economic growth and development. In particular, we want to learn whether a modern version of capital fundamentalism should serve as a guiding principle for economic research and economic policy advice. We thus work through the findings of the two major episodes of economic research discussed above. This discussion is placed in a historical context since, on each occasion, there has been an interaction of theoretical and empirical research with pressing policy issues. Empirically, we construct new measures of capital stocks for a large sample of countries, and carry out growth accounting exercises in the spirit of earlier analyses. In this way, we

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<sup>1</sup>This statement should be qualified since researchers did not conduct substantial and insightful work on development and growth during these episodes. Nonetheless, it seems fair to conclude that the number of dissertations by PhD economic students at major universities on development and growth has been much higher over the last 10 years than over the 10 years before that.

provide new, direct evidence on the potential fruitfulness of capital fundamentalism.

The organization of the paper is as follows. Section 2 presents the original capital fundamentalist view. In Section 3, we review the well-known “growth accounting” findings of Solow (1957), Denison (1962, 1967), and Maddison (1982) and the less well-known development-accounting findings of Denison (1967). Section 4 discusses and implements three methods for estimating capital stocks in 112 countries drawn from the Summers and Heston (1991) data set and also provides the results of development and growth-accounting exercises for these countries. In Section 5, we review how recent research fits into the debate concerning the importance of physical capital accumulation and economic growth. Section 6 concludes.

We draw three major conclusions. First, there are empirically important cross-country variations in patterns of capital accumulation. For example, with several different methods of estimating capital stocks, we find that capital-output ratios are strongly positively associated with the level of economic development. Second, variations in national patterns of capital formation explain little of the differences in national output levels, when we impose the production function restrictions used by the accountants of growth and development. Third, while there is a strong and robust correlation ~~of~~ between the investment rate and the growth rate in the international cross-section, there is little reason to believe that this constitutes evidence that higher investment rates cause increases in growth rates. Overall, our results lead us to conclude that capital accumulation is not a fundamental *cause* of economic growth and development; rather, it is one important feature of these processes.

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## 2 Capital fundamentalism in theory and practice

Capital fundamentalism embodies the belief that the rate of physical capital accumulation is the crucial determinant of economic growth. The Harrod (1939)-Domar (1946) growth model formed the original theoretical basis for capital fundamentalism. In the Harrod-Domar framework, there was a fixed capital requirement per unit of output,  $K = \kappa Y$ , where  $K$  is the stock of capital,  $Y$  is the flow of output, and  $\kappa$  is the capital-output ratio. Hence, if an economy undertook at date  $t$  a given rate of net investment,  $sY_t = dK_t/dt$  for some  $s > 0$ , the implications for output growth would be:

$$(dY_t/dt)Y_t = s/\kappa. \quad (1)$$

For example, with a capital-output ratio of 3 and a net investment rate of 0.09, the economy grows at 3% per year. But if  $s$  were 0.03, the rate of growth would be just 1%. Consequently, variations in net investment rates

could importantly determine the rate of growth. Measurement of the capital-output ratio,  $\kappa$ , became important because its value dictated the size of the effect of the rate of investment on economic growth.

An important difficulty with this theory of long-run growth was its implication for employment, which gave rise to the Harrod-Domar consistency condition. If one posited that employment growth ultimately was constrained by population growth, then the experiment above (exogenous variation in  $s$ ) was not possible. To see this, let  $\eta$  denote the population growth rate; then steady-state growth *only* arises if

$$s = \kappa\eta. \tag{2}$$

Solow (1956) argued that (i) employment must grow at the same rate as population in the long run; and (ii) steady-state growth appeared to be a good first approximation to reality. Hence, the Harrod-Domar consistency condition (equation (2)) ruled out the independent variation in net investment rates considered above. It was this “knife-edge” character of the Harrod-Domar steady state that motivated Solow to develop the neoclassical growth model. Solow’s theory featured a production function with smooth substitution between factors of production in contrast to the fixed proportions structure of the Harrod-Domar model. Solow’s production function implied that capital-output ratios could vary across time and countries in response to variations in saving behavior.

Arthur Lewis, perhaps the leading proponent of capital fundamentalism, took the Harrod-Domar model and went in a different direction from that of Solow (1956). Lewis (1954) saw condition (2) as empirically irrelevant for developing countries: he articulated an alternative view in which growth took place in a setting with unlimited supplies of labor. In this setting, capital accumulation was fundamental to growth:

The central problem in the theory of economic development is to understand the process by which a community which was previously saving and investing 4 or 5 percent of its national income or less, converts itself into an economy where voluntary saving is running at about 12 to 15 percent of national income or more. This is the central problem because the central fact of development is rapid capital accumulation (including knowledge and skills with capital). We cannot explain any “industrial” revolution (as the economic historians pretend to do) until we can explain why saving increased relatively to national income. (p. 155)

Lewis found the resolution to this problem in changes in income distribution toward those with higher marginal propensities to save. He argued that:

... saving increases relatively to the national incomes because the incomes of the savers increase relatively to the national income. The central fact of economic development is that the distribution of incomes is altered in favor of the saving class." (pp. 156-157)

Although Lewis does not systematically present evidence to support his view, he uses anecdotal accounts from England, the United States, Japan, India, and the U.S.S.R.

Similarly, the economic historian W.W. Rostow (1960) argued that a sharp jump in the investment rate was necessary to achieve sustained growth. Specifically, in describing the five stages of economic development, Rostow posited that countries begin from a stage where "... a ceiling existed on the level of attainable output per head ..." (p. 4). Then there is a period of "take-off" where

... the old blocks and resistances to steady growth are finally overcome. The forces making for economic progress, which yielded limited bursts and enclaves of modern activity, expand and come to dominate the society. Growth becomes its normal condition. (p. 7)

As with Lewis, Rostow (1960) saw physical capital accumulation as the fundamental determinant of economic take-off:

... a necessary but not sufficient condition for the take-off ... that the proportion of net investment to national income (or net national product) rises from, say, 5% to over 10% ... (p. 9)

In *The World Economy: History and Prospect*, Rostow discusses the economic development of twenty countries and how they conform to his five stages of development.

Thus, an influential strand of the development literature focused on the investment rate as a key factor in steady growth. As noted by Yotopoulos and Nugent (1976) and Gillis, et al. (1992), capital fundamentalism furnished a coherent foundation for development strategies: it was possible to accelerate economic development by increasing domestic physical capital accumulation. Clearly, foreign-aid donors and advisers could play a crucial role in implementing this development strategy. In fact, Yotopoulos and Nugent (1976) list evidence that international organizations during the 1950s, 1960s, and 1970s implemented a battery of policies that embodied the principles of capital fundamentalism.<sup>2</sup>

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<sup>2</sup>We were alerted to the work of Yotopoulos and Nugent (1976) by Blomstrom, Lipsey, and Zejan (1993).

More recently, capital fundamentalism has returned to the forefront of economic research and policy prescriptions. Romer (1986, 1987), for example, develops an endogenous growth model in which there are large externalities to capital. Although not stated directly, Romer's analysis implies an assumption that it is exogenous change in the rate of capital accumulation in combination with a very large elasticity of output with respect to capital accumulation that drives economic growth. Similarly, the analysis by Mankiw, Romer, and Weil (1992) suggests a very important role for capital in explaining differences in cross-country differences in output per person.

More explicitly, DeLong and Summers (1992, p. 114) have recently restated the capital fundamentalist doctrine:

We are led to conclude that policies to boost the share of output devoted to investment in general are worth undertaking on their own terms: they do promise benefits worth more than their costs.

But, DeLong and Summers (1992, pp. 94) refine their view:

International comparisons suggest a special role for equipment investment as a trigger of productivity growth. ...equipment investment should receive special incentives.

Given current and historic interest with the role of physical capital accumulation in explaining economic growth, the remainder of this paper examines whether capital fundamentalism should guide public policy recommendations and research strategies.

### **3 Development and growth accounting: I**

This section reviews two types of accounting exercises undertaken by Denison (1962, 1967), which built on earlier work by Solow (1957).<sup>3</sup> For a group of nine countries, Denison asked the *development-accounting* question: what part of cross-country differences in income per capita is accounted for by differences in physical capital per capita? Denison also asked the *growth-accounting* question: what part of cross-country differences in growth rates of output is accounted for by differences in growth rates of capital per capita? Although with considerable debate,<sup>4</sup> Denison and others found that (1) differences in the level of physical capital per person accounted for very little (about 25 percent) of the differences in income per capita across industrialized countries and (2) differences in the rate of physical capital accumulation per person accounted for a similarly small amount of the differences in growth

<sup>3</sup>See also Fabricant (1954) and Abramovitz (1956).

<sup>4</sup>See, for example, Jorgenson (1990), Jorgenson and Fraumeni (1989), Jorgenson and Griliches (1967), and Jorgenson, Gallop, and Fraumeni (1987).

rates of income per capita across nine industrialized countries. These results suggest a much smaller role for physical capital accumulation in economic development and growth than that advanced by capital fundamentalists.

### 3.1 *Development and growth accounting: framework*

The organizing principle of both development and growth accounting is the Cobb-Douglas aggregate production function. We begin with a discussion of how the Solow-Denison-Maddison (SDM) accounting framework employed this specification.

Suppose that the level of national output,  $Y$  for a country with  $N$  citizens, can be written as a constant-returns-to-scale function of capital and labor input:

$$Y = AK^\alpha(nN)^{1-\alpha}, \quad (3)$$

where  $K$  is the capital stock;  $n$  is the number of units of labor input per person (reflecting work patterns, extent of human capital accumulation, etc.), and  $A$  and  $\alpha$  are technical parameters. Under perfect competition, the parameter  $\alpha$  will be the share of capital income in national product.

Countries clearly differ in population size, so that a natural starting point is to normalize country output by scaling by population or the number of workers. Letting  $y = Y/N$  denote output per person, and  $k = K/N$  denote capital per person, output per person is:

$$y = Ak^\alpha n^{1-\alpha}. \quad (4)$$

The standard procedure in *growth accounting* (where the period-to-period changes in inputs and outputs are small) is to divide output growth into components attributable to changes in ~~the~~ factors of production, i.e.,

$$(\Delta y/y) = (\Delta A/A) + \alpha(\Delta k/k) + (1 - \alpha)(\Delta n/n), \quad (5)$$

based on a specific value of  $\alpha$ . As an example, suppose that the growth rate of output per person was 4%, the capital growth rate was 6%, there was no growth in  $n$  and the share of capital was .33. Then 2% of output growth is attributed to capital growth, and the remaining 2% is attributed to growth in "total factor productivity," i.e., to the residual  $\Delta A/A$ . This procedure was used by Solow (1957) to explore the evolution of economic activity within a country. It was also used to make international comparisons of rates of growth by Maddison (1982) and Denison (1967).

It is also possible to undertake *development accounting* on the basis of the production function. That is, we can take the ratio of two national measures of output per person, using equation (4):

$$[y_i/y_j] = [A_i/A_j][k_i/k_j]^\alpha [n_i/n_j]^{1-\alpha}. \quad (6)$$

Given data on relative quantities of factors production, we can measure cross-country differences in total factor productivity,  $A_i/A_j$  as residuals:  $[A_i/A_j] = [y_i/y_j]/\{[k_i/k_j]^\alpha [n_i/n_j]^{1-\alpha}\}$ . To describe the extent to which capital accounts for cross-country differences in output, we begin by constructing the ratio:

$$\phi_{ki} = \alpha \log(k_i/k_j) / \log(y_i/y_j). \quad (7)$$

The ratio  $\phi_{ki}$  is the fraction of differences in national output levels due to capital. This measure has the following desirable properties. First, if a similar procedure is applied to all of the components of international output differences, then contributions of components sum to 1. Second, this measure of the contribution of capital is linear in capital's share, so that we can easily investigate the consequences of alterations in this parameter. Further, this measure may be rewritten as follows:

$$\phi_{ki} = \alpha + \alpha \log(\kappa_i/\kappa_j) / \log(y_i/y_j) \quad (8)$$

using the fact that  $\log(k_i/k_j) = \log(\kappa_i/\kappa_j) + \log(y_i/y_j)$ . Thus if capital-output ratios were the same across countries  $\phi_{ki}$  would equal  $\alpha$ .

To describe the "sources of development," we first calculate the percentage shortfall in output for country  $i$  relative to the reference country  $j$ :  $P_i = 100*(y_j - y_i)/y_j$ . Then, we construct our contribution of capital to the level of development as  $P_i\phi_{ki}$ . This development-accounting method is based on one used by Denison; it differs at most in minor details.

### 3.2 Denison's findings on growth and development

In his classic (1967) study, *Why Do Growth Rates Differ?*, Denison compared U.S. development in 1960 and growth over 1950-1962 to that in eight European countries (Belgium, Denmark, France, Germany, the Netherlands, Norway, the United Kingdom, and Italy). Then, as now, there was a concern in the United States over the rate of economic growth; comparison with the faster growing countries of Europe suggested one avenue for potentially understanding how U.S. growth might be increased.

Like other growth-accounting experts, Denison was highly concerned with the difficulties inherent in producing indices of labor and capital input, so that descriptions of the procedures involved in this process form a central part of his report. For labor, this index included adjustments for hours worked, for education, and for age-sex composition. For capital, these indices aggregated diverse types of capital, including dwellings, non-residential structures, equipment, inventories, but, also like other growth accountants, Denison also saw the value of producing summary numbers so that the salient facts of the growth process could be readily communicated. The Salow-Denison-Maddison accounting framework led to a remarkably consistent view of the sources of development and growth.



### 3.3 *Accounting versus explanation*

There are limits to what can be learned from growth-accounting by its very nature. For example, consider the conclusion from Solow (1957) that 1/8 of the long-term variation in output per worker is capital accumulation and 7/8 is a productivity residual interpreted as technical progress. In Solow's (1956) model, a steady increase in technology at the rate  $\gamma$  will lead to increases in output per worker and in capital per worker at a common rate  $\gamma$ . Growth-accounting will attribute  $(\alpha\gamma)$  of this increase to capital formation and  $((1 - \alpha)\gamma)$  of this increase to exogenous technical change. The growth-accounting procedure will therefore state that capital accumulation accounts for  $\alpha \cdot 100$  percent of economic growth even though the growth in capital was an endogenous response to exogenous technical change. Hence, Denison's question "why do growth rates differ?" is a little misleading. Probably it should be "how do growth rates differ?" Yet, even with this caveat, growth- and development-accounting provide information on the historical association between capital and both the level of development and the rate of growth. The next two subsections review this evidence.

### 3.4 *Development accounting: the sources of international differences in income levels*

We will begin by reviewing the least familiar of these two topics: the international comparison of the level of economic development. First, Denison (1967) produced estimates of output per worker ( $y$ ) and capital per worker ( $k$ ) that were comparable to measures that he (in his (1962) work) and others had constructed for studying economic growth in the United States. For example, Denison found that Italy had about 40% of the output per worker of the U.S. output per worker and about 61% of U.S. capital per worker in 1960. Although the levels of  $y$  and  $k$  differed importantly across countries, Denison found that  $k/y$  was remarkably constant across countries, which confirmed earlier work by Kaldor (1961).

Second, Denison investigated what fraction of international differences in output per worker ( $y$ ) could be attributed to differences in capital per worker ( $k$ ), labor input per worker ( $n$ ), and the total factor productivity residual ( $A$ ). Cross-national differences in labor input (per employed individual) were estimated to be small so that these were viewed as not quantitatively important.

While cross-country differences in capital per worker were large, these differences did not account for much of the international differences in output per worker. Figure 1 displays these differences in a dramatic way. For each country, we see the extent of the shortfall from the U.S. level. For most countries, this value is around 40%, meaning that a typical country had output per worker of about 60% of the U.S. level. Of this shortfall, the

contribution of capital per worker is typically about 10%, indicating that about one-quarter of the shortfall is attributed to capital. Fundamentally, this reflects the fact that capital's share in the production function is small. However, since Denison's measurements are based on the aggregation of several capital stocks, a single value of  $\alpha$  is not imposed (as in the specification of equation (8) above); Denison's implicit value is about 0.25.

### 3.5 *Growth accounting: the sources of international differences in economic growth*

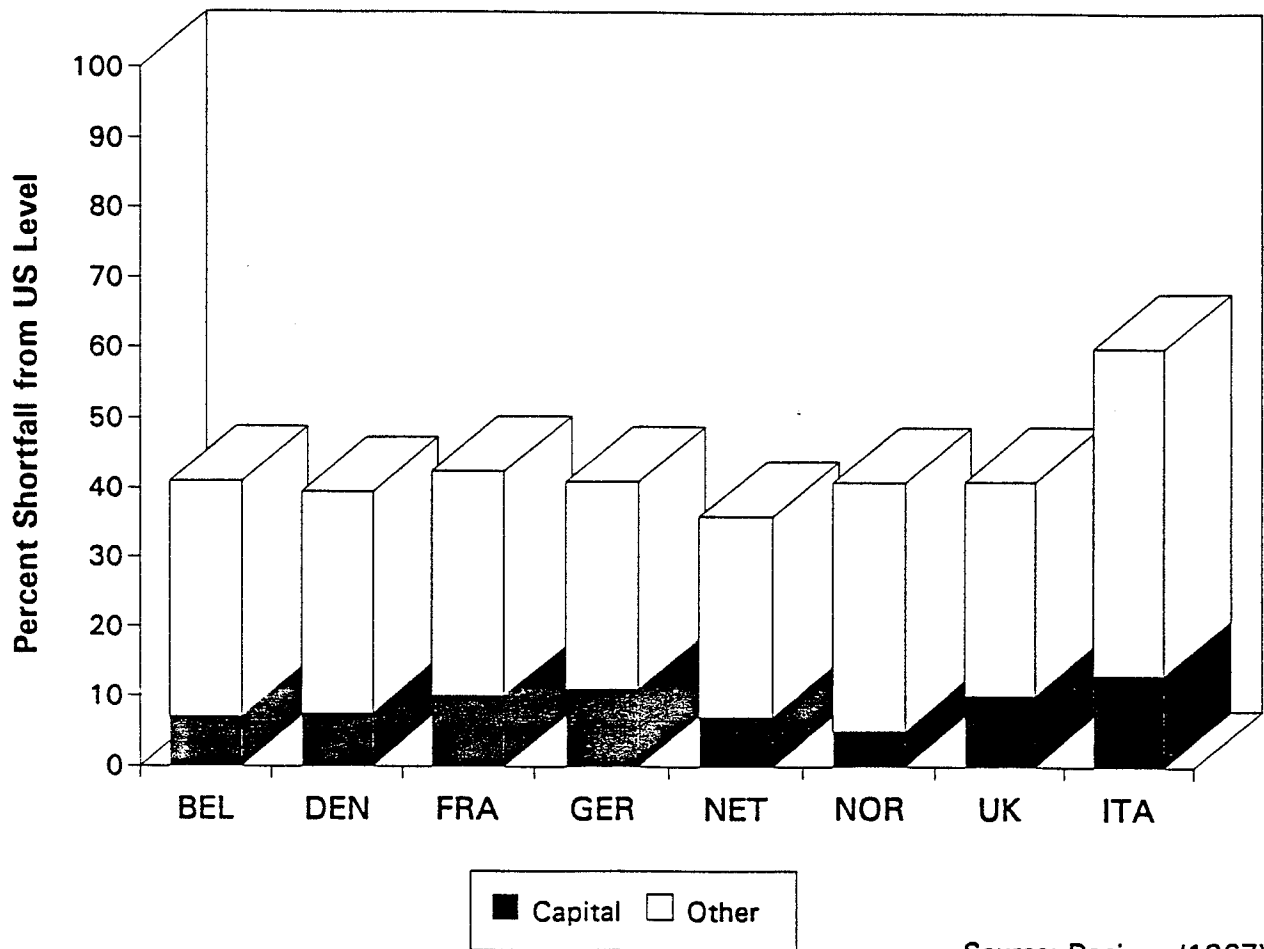
Working with data on the United States, Solow (1957) found that only a small fraction of long-term U.S. growth in output per worker could be accounted for by increases in capital per worker. Classic studies by Maddison (1982) and Denison (1967) showed that this finding also held for various European countries over the long term and the immediate postwar period. While Denison found that each country in his nine-country sample tended to have capital-growth rates that equalled output-growth rates, the growth-accounting results in Figure 2 show that growth in capital per worker accounts for only a small portion of the growth in output per worker. As with the development-accounting exercise (see Figure 1), no more than one-quarter of growth is accounted for by capital formation. Solow's (1957) findings for the United States were thus dramatically confirmed for European countries.

### 3.6 *Conclusions from earlier development and growth accounting*

These two exercises suggested that there may be a common problem to be solved in studying growth and development economics. In asking ~~why~~ <sup>how</sup> it was that some countries were poorer than others, Denison and others found that the answer did not lie in international differences in quantities of the factors of production, but rather in an unexplained productivity factor. In asking ~~why~~ <sup>how</sup> it was that some countries grew faster than others, they also found that international differences in growth rates of the factors of production were not the answer. This suggested that there could be a common explanation of the growth and development phenomena, but did not point to a specific solution. However, these complementary results indicated that the explanation proposed by the capital fundamentalists was ~~strongly ruled out~~: international differences in <sup>the</sup> patterns of physical capital accumulation did not account for much of the differences in levels of development or rates of growth. <sup>unattractive</sup>

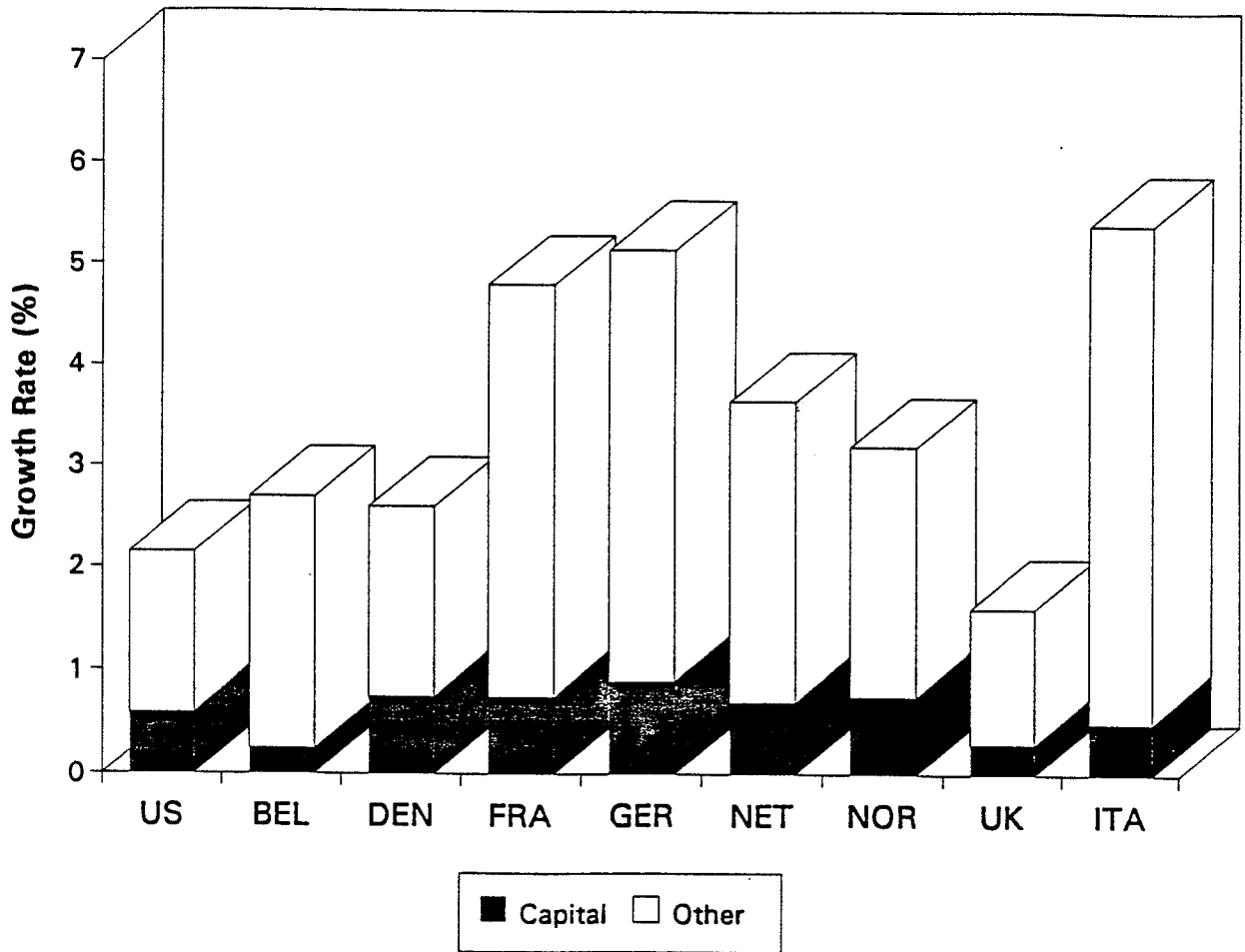
The section also emphasized a crucial distinction worth repeating. These growth-accounting exercises are just that, accounting exercises. There is no presumption of a causal behavioral relationship. Exogenous increases in technology could cause both output and capital to grow. These growth-accounting exercises would then mechanically associate the fraction  $\alpha$  of

**FIGURE 1: DEVELOPMENT ACCOUNTING**



Source: Denison (1967)

**FIGURE 2: GROWTH ACCOUNTING**



Source: Denison (1967)

output growth to capital accumulation. Thus, even if Denison had found that capital accounted for a large fraction of development and growth differences, these growth-accounting exercises alone would not imply an exploitable causal relationship from capital to growth.

These growth-accounting results did not stop many development economists, however, from continuing to emphasize physical capital accumulation as a policy objective to promote economic growth. As noted by Sen (1983), the traditional wisdom of development economists still involves the idea that the rate of economic growth is largely dependent on the savings rate. Perhaps one reason development economists rejected the Solow-Denison-Maddison growth-accounting results is that those results were based on industrialized country data and not on data from developing countries.

#### 4 Development and growth accounting: new evidence

This section takes the development- and growth-accounting procedures conducted by Denison thirty years ago on nine OECD countries and applies them to a broad cross-section of over 100 developed and developing countries. To examine the relationship between physical capital and the level of economic development for a broad cross-section of countries, we need measures of physical capital stocks at a point in time. To study the relationship between physical capital accumulation and economic growth, we need time series estimates of physical capital for the cross-section of countries. Direct survey estimates of capital stocks are generally not available. Therefore, we first estimate capital stocks from Summers and Heston's (1991) constant-price investment series which runs from 1950–1988 for most countries. Since the data and methods for computing capital stocks are potentially fraught with error, the ensuing computations should be interpreted with even more reservations than usual as emphasized by Nehru and Dhareshwar (1993). Nonetheless, we believe that expanding the study of the relationship between physical capital and growth to a broad range of countries provides compensating remuneration.

After computing and summarizing our capital stock figures, the second part of this section reexamines one of Kaldor's (1961) "stylized facts." We examine whether capital-output ratios are constant across countries. We find that the capital-output ratio varies positively and significantly with income per capita. Richer countries have higher capital-output ratios. This is consistent with findings by Nehru and Dhareshwar (1993), but inconsistent with those of Kaldor (1961) and Romer (1989). Since a constant capital-output ratio forms the basis of most growth models, this finding may have unsettling implications for our theories of economic growth.

The third and fourth parts of this section conduct the Denison-style de-

velopment and growth accounting discussed above. We find that the level of capital per person accounts for more of the differences in output per person in our sample (between 28 and 59 percent) than in the Denison sample of nine OECD countries (about 25 percent). We find that growth in capital accounts for about 40-percent of income per capita growth rates. Although we find a larger role for capital, the differences between our findings and Denison's seem to reflect our use of a much higher capital share parameter (0.4) <sup>compared to</sup> than Denison's (0.25) rather than a closer association between capital and economic development and growth in our sample of countries. x ✓

#### 4.1 Computing capital stock estimates

We use three methods for computing capital stock estimates from the Summers and Heston investment data. The first method assumes that each country is continually at a steady state with a constant capital-output ratio. The second two methods use the standard perpetual inventory method of estimating capital stocks with different guesses at the initial capital stock. The advantage of the steady-state estimate is that we do not have to assume anything about the initial capital stock; its weakness is that it assumes a constant capital-output ratio. In contrast, the perpetual inventory method requires an initial capital stock number; its strength is that it does not require assumptions about the ratios we want to study.<sup>5</sup>

*4.1.1 Steady-state estimates.* The steady-state estimate of the capital stock is based on the assumption that the capital-output ratio is constant, which implies that  $dK_t/K_t = dY_t/Y_t$ . Consequently, since  $dK_t = I_t - \delta K_t$ , then  $dK_t/K_t = I_t/K_t - \delta$ , where  $I_t$  is gross investment and  $\delta$  is capital's depreciation rate. We also define the growth rate  $\gamma_t = dY_t/Y_t = I_t/K_t - \delta$ . Letting  $i$  equal the investment rate,  $I_t/Y_t$ , the steady-state capital-output ratio for country  $j$  is

$$\kappa_j = \underline{i}_j / [\delta + \underline{\gamma}_j] \quad (9)$$

Given estimates of country  $j$ 's steady-state investment rate,  $\underline{i}$ , growth rate,  $\underline{\gamma}_j$ , and depreciation rate,  $\delta$ , we compute the steady-state capital-output ratio. Notice that this construction assumes that the capital-output ratio is constant within a country, but not necessarily across countries. Given the nature of this steady-state estimate, we primarily use it as benchmark indicator of differences in capital formation across countries.

Throughout our analysis we assume that  $\delta$  is constant across countries and time at 0.07 per year, while recognizing that there is some controversy about  $\delta$ 's value and constancy (e.g., Romer (1989) and Scott (1989)). We use

<sup>5</sup>See Nehru and Dhareshwar (1993) for a thorough description and comparison of different methods for computing capital-stock series.

each country's investment rate in the 1980s for  $\underline{i}_j$ . To compute the steady-state growth rate of country  $j$  in the 1980s, we use a weighted average growth rate. Specifically, we set the steady-state growth rate of country  $j$  as

$$\underline{\gamma}_j = \lambda \gamma_j + (1 - \lambda) \gamma_w \quad (10)$$

where  $\gamma_j$  is country  $j$ 's growth rate over the 1980s,  $\gamma_w$  is the world growth rate over the last thirty years (0.04), and  $\lambda$  is a parameter that governs the relative weight we place on the country's own experience. We set  $\lambda = 0.25$  based on the work by Easterly, et al. (1993), which documents a mean-reversion tendency in growth rates of this magnitude. Thus, given  $\gamma_j$ ,  $\delta$ , and  $\underline{i}_j$ , we estimate  $\kappa_j$ . Then, using average GDP in the 1980s,  $Y_j$ , and population in the 1980s,  $N_j$  we compute the capital-per-person ratio,  $K/N$ .

*4.1.2 Perpetual inventory method, setting initial capital to zero.* The standard perpetual inventory method of estimating capital stocks uses the formula

$$K_{t+1} = \sum_{j=0} \delta_j I_{t-j} + (1 - \delta)^t K_0 \quad (11)$$

where  $K_0$  is the initial capital stock. We use the investment series, 1950–1988, constructed by Summers and Heston. Our first estimate using the perpetual inventory method sets  $K_0 = 0$  and accumulates forward. We use this estimate to compute capital-output and capital-per-person ratios in the 1980s. Since the initial capital stock in 1950 only retains about five percent of its original value in 1990 (using a seven-percent depreciation rate), this method may yield helpful estimates of  $K/Y$  and  $K/N$  in the 1980s. The advantage of this approach is that it simply accumulates investment. The disadvantages are that (i) this method does not produce a useful time-series of capital stocks since the importance of the initial capital-stock estimate diminishes to what may be considered negligible levels very slowly, and (ii) we can probably compute a better guess of the initial capital stock for countries than zero.

*4.1.3 Perpetual inventory method: steady-state estimates of initial capital.* The second perpetual inventory method attempts to derive a better initial capital estimate than zero for all countries by modifying a method suggested by Harberger (1978). Better estimates of the initial capital stock will do more than produce slightly better estimates of capital in the 1980s. If one feels comfortable with the initial capital-stock estimate, then the long-run capital-stock time series will permit us to study the relationship between physical capital accumulation and economic growth. We compute initial capital by using the steady-state method to calculate an initial capital-stock time-series. Specifically, recall that under the assumption that the capital-output ratio is fixed,  $\underline{\kappa}_j = \underline{i}_j / [\delta + \underline{\gamma}_j]$ , where  $\underline{i}$  and  $\underline{\gamma}$  represent "steady-state" values. To calculate the initial capital stock for a country, we rewrite this formula as:

$$K_{initial} = \kappa_j Y_{initial}. \quad (12)$$

10 For countries where investment data began in 1950, we compute the average investment rate in the 1950s and use a weighted average growth rate to approximate the country's steady-state growth rate. Specifically, we use (3.2) with  $\gamma_j$  being country  $j$ 's growth rate over the 1950s,  $\gamma_w$  is the world growth rate over the entire thirty-year period ( $\gamma_w = 0.04$ ), and  $\lambda = 0.25$ . Thus we have the 1950s steady-state capital-output ratio for country  $j$ . x ✓

Now, to compute an estimate of the initial capital stock we need to multiply this 1950s steady-state capital-output ratio by an estimate of initial output. We use average real output between 1950–1952 as an estimate of initial output, producing an estimate of the initial capital stock in 1951. The perpetual inventory formula then produces a capital stock time-series for country  $j$ . We apply this process to each country, beginning with the earliest data points produced by Summers and Heston. This procedure starts the initial capital stock as far back as possible without allowing GDP in a single year to determine the initial capital-stock estimate. We label this our “preferred measure” in the discussion below, as it contains the positive features of each of the methods discussed above. x ✓

## 4.2 4.2 Capital-stock measurements: summary statistics

Our three measures of capital formation can be used to provide summary information on cross-country patterns of accumulation. We primarily use information averaged over the 1980s, since computed capital stocks in the 1980s are less sensitive to our estimate of the initial capital stock. Table 1 provides summary statistics on average values of the capital-output and capital-capita ratios for various samples of countries. In the OECD, which includes the countries in Denison's study, we have an average capital-output ratio of about 2.6 for the decade of the 1980s using our preferred method. But we find that the alternative methods (using either the steady-state assumption or the perpetual inventory method with  $K_0 = 0$ ) yield values that are broadly similar. Table 1 shows that, for the decade of the 1980s, capital per worker was about \$27,000 for the average member of the OECD. For the non-oil and non-OECD sample of 73 countries, capital per worker averaged less than \$5000. person zero x

When we look across regions of the world, using several groupings of countries, we find that the capital-output ratio is substantially smaller: for example, the average value is 1.6 for the 73 countries that are neither members of the OECD nor major oil producers. While these countries have capital-output ratios that are about 60% of the level in the OECD, they have output per worker that averages about 25% of the OECD.



Table 1

## Capital-Output and Capital-Per-Person Ratios in the 1980s

	K/Y Steady State	K/Y Perpetual Inventory K(0)=0	K/Y Perpetual Inventory K(0)=K <sub>0</sub>	K/N Steady State	K/N Perpetual Inventory K(0)=0	K/N Perpetual Inventory K(0)=K <sub>0</sub>	Y/N Real Per Capita GDP
ALL	1.94	1.81	1.87	11,517	10,013	10,353	4,631
[105]	(0.99)	(0.77)	(0.80)	(15,100)	(11,343)	(11,537)	(4,393)
Non-Oil	1.82	1.79	1.85	10,378	9,965	10,314	4,521
[97]	(0.80)	(0.78)	(0.80)	(11,875)	(11,590)	(11,782)	(4,318)
Non-Oil Adjusted	2.02	1.98	2.02	14,431	13,979	14,330	6,135
[65]	(0.70)	(0.65)	(0.66)	(12,535)	(12,252)	(12,441)	(4,406)
Non-Oil Non-OECD	1.60	1.55	1.61	5,029	4,402	4,706	2,539
[73]	(0.78)	(0.72)	(0.76)	(6,534)	(5,087)	(5,349)	(2,331)
OECD	2.51	2.54	2.59	26,651	26,885	27,374	10,549
[24]	(0.38)	(0.37)	(0.38)	(9,369)	(9,093)	(9,293)	(3,229)
Latin America	2.02	1.75	1.79	8,149	6,027	6,547	3,613
[21]	(0.85)	(0.66)	(0.68)	(7,977)	(4,073)	(4,321)	(2,004)
Africa	1.36	1.40	1.49	2,264	2,107	2,202	1,293
[35]	(0.87)	(0.79)	(0.87)	(4,043)	(3,043)	(3,108)	(1,082)

Notes:

1. Steady-State: Assumes constant capital-output ratio in the 1980s for each country.
2. Perpetual Inventory K(0): Accumulates real investment from 1950 (if possible) starting with initial capital equal to zero.
3. Perpetual Inventory K(0)=K<sub>0</sub>: Accumulates real investment from 1950 (if possible) starting with initial capital estimate that assumes a constant capital-output ratio in the first ten years for which there are investment data.
4. Standard errors in parentheses. Number of countries in brackets.
5. Non-Oil Adjusted: Non-oil countries, excluding countries with data quality graded less than C- by Summers and Heston (1991).

### 4.3 *The capital-output ratio*

To explore the association of capital-output ratios with the level of development more systematically, we regress the average capital-output ratio during the 1980s on the ratio of income per capita relative to income per capita in the United States for the cross-section of 105 non-oil countries. Hence, we are asking: did richer countries have higher capital-output ratios? The regression estimates are reported in Table 2 and show that the slope parameter enters with a t-statistic of over 7. Using our preferred capital measure, the coefficient estimates imply that: (i) a very poor country typically has a capital-output ratio of about 1.4; (ii) a country one-half as rich as the United States typically has a capital-output ratio of about 2.2; and (iii) a country as rich as the United States typically has a capital-output ratio of about 3.1. Broadly similar patterns emerge for the capital ratios constructed using our other measures: richer countries have higher capital-output ratios.<sup>6</sup>

### 4.4 *Development accounting*

We next pursue the development-accounting exercises undertaken by Denison. We break the sample of 105 non-oil countries into ten groups based on increasing levels of capital per person. We then compute average values of  $k = K/N$  and  $y = Y/N$  for each decile for the decade of the 1980s. We use as the reference value the average levels of  $y$  and  $k$  in the tenth decile (i.e., the decile with the largest capital per person). We then compute decile  $i$ 's shortfall from the reference group,  $P_i$ , and the component attributable to cross-country differences in capital  $\phi_{ki}P_i$ . We found it desirable to implement the version of the accounting that includes the separate effects of the level of output and the capital output ratio,  $\phi_{ki} = \alpha + \alpha(\log(\kappa_i/\kappa_{10})\log(y_i/y_{10}))$ . Hence, in Figure 3, we have three components: a capital-share component ( $\alpha P_i$ ); a capital-output ratio component  $\alpha(\log(\kappa_i/\kappa_{10})/\log(y_i/y_{10}))P_i$ ; and the residual. Figure 3 shows that the shortfall of output range from 95% of the top decile (for poorest countries) to about 28% (in the next-to-top decile). We now discuss each component of this decomposition.

*4.4.1 The capital-share component.* We use a value of  $\alpha = .4$  to be conservative in critiquing the potential contribution of capital accumulation to output.<sup>7</sup> With this value, if the capital-output ratio were constant, develop-

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<sup>6</sup>These results also hold when the independent variable is computed in 1980 instead of averaged over the 1980s. Furthermore, we get similar parameter estimates when these regressions are run on the adjusted sample of non-oil countries that only includes countries rated as C- or better in terms of data quality as defined by Summers and Heston (1991).

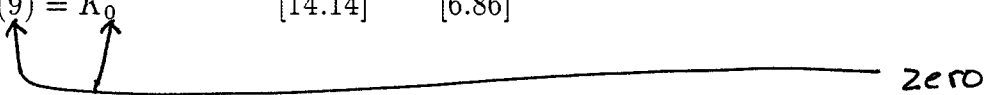
<sup>7</sup>As noted above,  $\alpha = 0.4$  is much larger than that implied in Denison's work (about 0.25). Moreover, many authors use a parameter of 1/3 for capital's share of income. Thus, we believe  $\alpha = 0.4$  may exaggerate the role of capital. See Elias (1992) for country computations of  $\alpha$  in a cross-section of Latin American countries.

Table 2:  
Stability of the Capital-Output Ratio with Respect to the  
Capital-Per-Person Ratio

**Regression Dependent Variable =**  
 $c + b \left( \frac{\text{GDP Per Capita Country } i, \text{ 1980s}}{\text{GDP Per Capita United States, 1980s}} \right)$

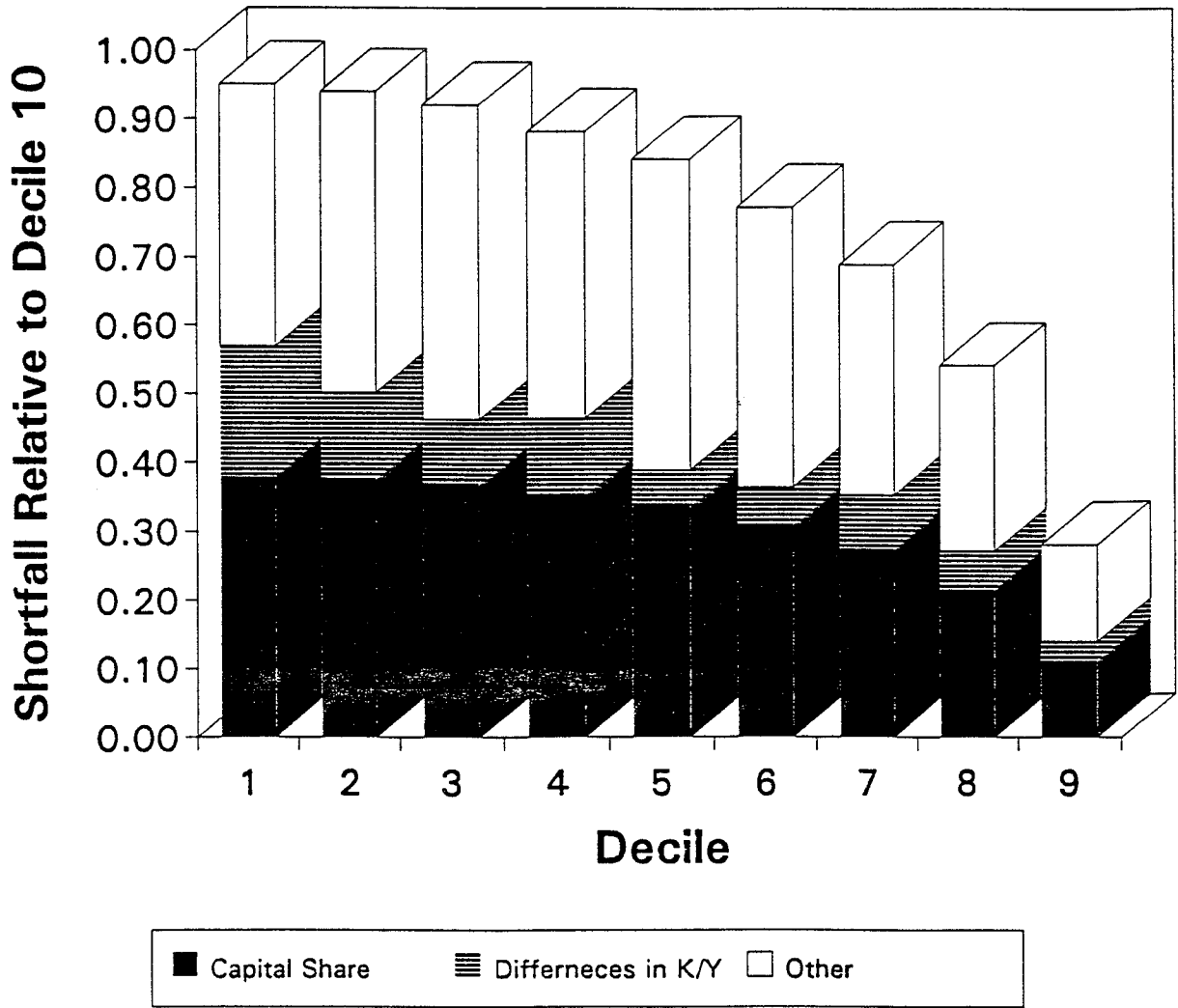
Dependent Variable:	<u>c</u>	<u>b</u>
K/Y	1.29	1.89
Steady-State	(0.09) [14.04]	(0.25) [7.54]
 K/Y	 1.30	 1.77
Perpetual Inventory $K(0) = 0$	(0.09) [14.76]	(0.24) [7.44]
 K/Y	 1.35	 1.78
Perpetual Inventory $K(9) = K_0$	(0.10) [14.14]	(0.26) [6.86]

Notes:



1. Steady-State Capital: Assumes constant capital-output ratio in the 1980s for each country.
2. Perpetual Inventory  $K(0)$ : Accumulates investment from 1950 (if possible) starting with initial capital stock at zero.
3. Perpetual Inventory  $K(0) = K_0$ : Accumulates real investment from 1950 (if possible) starting with initial capital estimate that assumes a constant capital-output ratio in the first ten years for which there are investment data.
4. Sample includes 105 Non-Oil Countries.
5. Dependent and independent variables are averages over the 1980-88 period.
6. Standard errors in parentheses. T-Statistics in brackets.

**FIGURE 3: DEVELOPMENT ACCOUNTING  
105 Non-Oil Countries**



ment accounting associates 0.4  $P$  of differences in  $y$  with differences in  $k$  at every stage of development. Hence, on these grounds, capital would account for  $11\% = 0.4 \cdot 28\%$  of the 28% shortfall for the decile 9 countries, and it would account for  $38\% = 0.4 \cdot 95\%$  of the 95% shortfall for poorest countries (decile 1).

4.4.2 *The capital-output ratio component.* We have seen above that countries with lower values of  $y$  also have lower values of  $\kappa = k/y$ . The influence of this on development accounting depends directly on  $\alpha$ . It also depends on the value of  $(\log(\kappa_i/\kappa_{10})/\log(y_i/y_{10}))$ ; the nine decile values of this ratio component range from .50 (for decile 1) to .27 (for decile 9). Hence, with a capital share of 0.4, there is an additional  $19\% = 0.4 \cdot 0.50 \cdot 95\%$  component attributed to capital for decile 1 and an additional  $3\% = 0.4 \cdot 0.27 \cdot 28\%$  attributed to capital for decile 9.

4.4.3 *The total contribution of capital.* Taking the two components together, capital accounts for  $56\% = (0.4 + 0.19) \cdot 95\%$  of the 95% shortfall in development for the poorest countries (decile 1) and  $12\% = (0.4 + 0.03) \cdot 28\%$  of the 28% of the shortfall in development for the top group (decile 9). Thus, capital accounts for between 43% and 59% of the differences in the level of income per capital in our sample of 102 countries. Capital accounts for a greater share of the shortfall in income per capita in poorer countries, since capital-output ratios are positively associated with income-per-person ratios.

These effects of capital on the level of development are more substantial than those documented by Denison [1967]. One major factor in our finding of a stronger influence of capital is that we are using a capital-share parameter  $\alpha = 0.4$ , which is an upper bound of measurements for developed countries: lower values of  $\alpha$  (of about 0.25) are implicit in Denison's results. For example, if we dropped capital's share to .25, then variations in  $k$  would account for 44% of the difference between income-per-capita in decile 1 with income-per-capita in decile 10, and capital would account for only 28% of the difference between decile 9 and 10.

## 4.5 *Growth accounting*

Given that our preferred method of measuring capital accumulation produces a time-series of capital stocks, we can explore the behavior of growth in capital per person and in output per person in our non-oil sample. To avoid too much dependence on initial conditions and on short-term economic fluctuations, we look at these relations using data from the 1980s. The findings concur closely with those of Denison (1967). We find that growth in  $y$  and  $k$  move together with close to unit elasticity; and growth of capital per person

accounts for only a small portion of output growth.<sup>8</sup>

The growth-accounting results are displayed in Figure 4. Using deciles of growth in capital in the 1980s and a value of  $\alpha = 0.4$ , we find that growth in capital per person accounts for about 40 percent of growth in output per person. In contrast to the experiences discussed in Section 3 above, however, Figure 4 displays positive and negative growth observations. When output growth is negative, capital growth still tends to under-account for output growth. Interestingly, deciles 3, 4, and 5 represent groups of countries where capital-stock growth was positive while output-growth declined!

Recall that, if the growth rate in capital and output are close to each other then, by definition, an  $\alpha$  value of 0.4 implies that 40% of growth in output per person is accounted for by growth in capital per person. Although we find that the capital-output ratio is rising in income, it is not rising fast enough to override this general characteristic of the standard growth-accounting methodology. Put differently, expanding Denison's set of 9 industrialized countries to a broad cross-section of over 100 countries does not change the general growth-accounting conclusion regarding capital fundamentalism: capital accumulation accounts for only a small fraction of income growth, suggesting an important role for technological change.<sup>9</sup> These results, however, may not hold for all countries. In a very carefully done study, Young (1993) shows that the Newly Industrializing Countries of East Asia (NICs) are unusually rapid growers but have not enjoyed unusually rapid productivity growth. He concludes that the static gains from rapid factor accumulation have fueled economic growth over the last 20 years in the NICs.

#### 4.6 *Conclusions from our development and growth-accounting exercises*

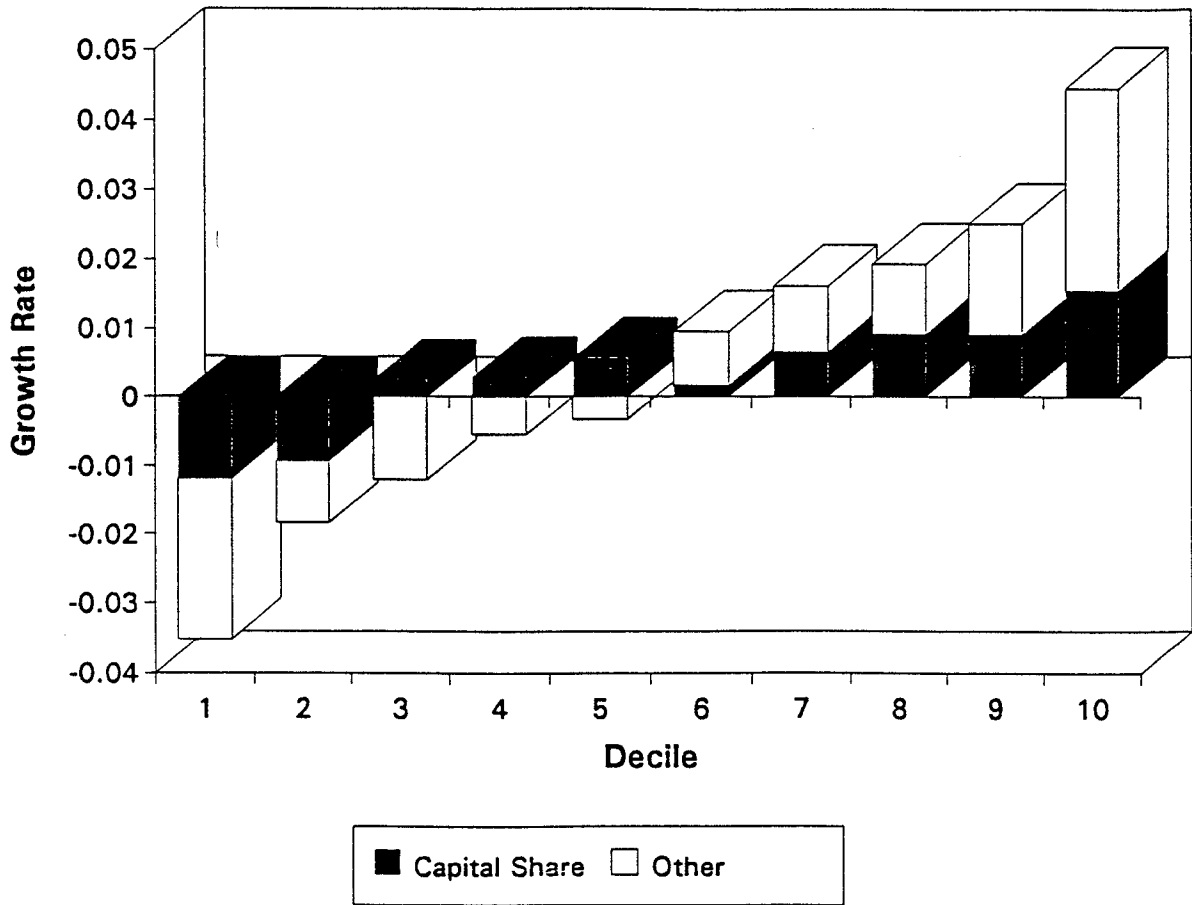
In sum, we draw two conclusions from these development and growth-accounting exercises. First, the capital-output ratio seems to be systematically related to the level of development. Second, we agree with Mankiw, Romer, and Weil (1992) that Solow was basically right about the sources of economic development and economic growth. However, unlike these authors who agree with Solow's (1956) emphasis on a variable capital-output ratio, it is Solow (1957) and the related work by Denison (1967) that we find more compelling. We reach this conclusion on conservative grounds, assuming that the share of capital is large by OECD standards. On the development side, cross-country

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<sup>8</sup>For example, for the sample of 67 non-oil adjusted countries (i.e., excluding major oil exporters and countries with data quality ranked less than C- by Summers and Heston (1991), the annual growth rates of income per capita and capital per capita were both 14 percent. For non-oil countries, capital tended to grow faster than output, 9 percent as compared to 7 percent.

<sup>9</sup>See Nishimizu and Page (1986).

**FIGURE 4: GROWTH ACCOUNTING**  
**104 Non-Oil Countries**



differences in capital-output ratios are associated with differences in levels of GDP per capita, but this component is relatively small in an accounting sense. Most of the accounting contribution of capital per person to output per person simply reflects the mechanical consequences of the assumed share of capital in production. Given the mechanics of development accounting, this association could arise from any set of forces that induce the levels of capital and output to increase. On the growth side, our conclusions mirror those of Solow and Denison: during the decade of the 1980s, growth in capital per person and growth in income per person proceeded at roughly equal rates within countries, but there were substantial cross-national variations in these growth rates. Growth in capital per person typically accounts for less than 40 percent of growth in output per person.

## 5 New growth theory and the output-capital linkage

The development- and growth-accounting evidence suggests that an unexplained residual – often labelled technological change – is importantly associated with development and growth. New theoretical work by Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992) develop formal models that view technical improvements and industrial innovation as the engines of economic growth. This stands in sharp contrast to capital fundamentalism's focus on capital accumulation. In light of the development and growth-accounting results and these recent theoretical advances, can and should capital fundamentalism be revived?

Resuscitating capital fundamentalism would require (1) rejecting or changing the growth-accounting equation and (2) making the behavioral assumption that capital causes output rather than maintaining a purely mechanical accounting device. Capital fundamentalists could view some recent models as vehicles for both changing the parameters of the accounting equation and identifying a causal link from capital to output and capital accumulation to growth.<sup>10</sup> In light of new research, this section examines whether capital fundamentalism should be resuscitated. We conclude that the answer is no: capital accumulation seems to be part of the process of economic development and growth, not the igniting source; indeed, economic growth tends to precede capital accumulation, not the other way around. As argued by the early growth accountants, further research into understanding technological progress offers the best hope for designing policies that will foster sustained economic growth.

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<sup>10</sup>The originators of some of these models do not make explicit identifying assumptions regarding causality.



## 5.1 *External effects of capital formation*

One approach that maintains a focus on capital accumulation is to highlight the potential importance of external effects of capital accumulation. Romer (1986), for example, divorces the elasticity of output with respect to capital from the share parameter,  $\alpha$ . This is accomplished by writing the production function of individual units (e.g., firms) as  $y = AK^\alpha E$ , where  $K$  is a measure of the external effect, and then sets  $E = k^{1-\alpha}$  for a representative firm. In this setting, if one makes the identifying assumption that the driving exogenous force is variation in the savings and investment rate, then we return to the capital fundamentalist world: the rate of capital accumulation is the primary determinant of economic growth.

While this possibility cannot be ruled out by aggregate evidence, the validity of external effects on capital must be strongly and credibly supported by microeconomic evidence. Thus far, however, firm- and industry-level studies do not, in general, find strong capital externalities as noted in Benhabib and Jovanovic (1991) and Griliches (1988).

Furthermore, there do not appear to exist compelling reasons for making the identifying assumption that capital accumulation is exogenous. One could just as easily assume that technological change,  $A$ , is the driving exogenous variable that simultaneously determines the rate of output and physical capital growth. Indeed, Benhabib and Jovanovic (1991) show that the same statistics that are used to justify the existence of capital externalities can be obtained from models in which technology is exogenous and both capital and income are endogenously determined.

Finally, it is worth noting that Romer (1993) describes the early external effect models as simply an initial modeling device, subsequently supplanted by explicit models of endogenous technical progress that point to specific, potentially measurable sources of international differences in development. Thus, we are still left pointed away from capital fundamentalism and toward trying to better understand technological progress as suggested by Schumpeter (1911) more than 80 years ago.

## 5.2 *Augmented Solow model*

*5.2.1 The model.* Mankiw, Romer, and Weil (1992) argue that if the Solow model is augmented to include human capital, then it does a good job of explaining differences in income levels and growth rates. They write the (per capita) production function as  $y = Ak^\alpha h^\beta n^{1-\beta}$ , where  $k$  is physical capital per person,  $h$  is human capital per person, and  $n$  is raw labor per person. Then, assuming that  $h = \phi k$  across countries (so that human capital moves one-for-one with physical capital), they arrive at a specification in which measured cross-country differences in physical capital affect output

per person with an elasticity of  $(\alpha + \beta)$ . When Mankiw, Romer, and Weil estimate this model, they obtain a parameter estimate on  $(\alpha + \beta)$  of close to 0.7 with an adjusted  $R^2$  of about 0.8. If one takes capital as the driving exogenous source of growth, then capital accumulation can have large impacts on growth directly by boosting output and indirectly by boosting human-capital accumulation. Thus, this analysis diminishes the importance of understanding technological change.

*5.2.2 Example.* Before discussing some of the unresolved issues with this model, it is worth exemplifying the importance of the parameters and showing how this model highlights the role of capital. In conducting this experiment, we presume that causality runs from capital to output and consider the effects of different parameters. Specifically, we focus on the consequence of change in the capital-output ratio  $\kappa$  for the level of development. In particular, think of varying the capital-output ratio relative to a benchmark country, then the production-function prediction is that  $y_j/y_{10} = [\kappa_j/\kappa_{10}]^\theta$ , where  $\theta \equiv \alpha/(1 - \alpha)$ . In Table 1, we previously documented that capital-output ratios in Africa were about 58% of those in the OECD. With  $\alpha = .4$ ,  $\theta = 2/3$  so the predicted difference in levels of output per person is  $y_{africa}/y_{10} = (0.58)^{(2/3)} = 0.69$ . But instead of having 70 percent of the value of OECD output per person, Africa has just 12 percent. From this perspective, the international differences in capital-output ratios documented in the prior section explain a very minor part of the pattern of development. Put alternatively, if African countries were to raise their capital output ratio to the mean OECD level, the implications for the level of their output per worker would be that it would be 44% higher (since  $1.72^{(2/3)} = 1.44$ ). Starting from output per person of \$1293, this increase would be about \$570: they would look more like Latin America (\$3613) but not much like the OECD (\$10,549).

However, if we were to use the estimates suggested by the work of Mankiw, Romer, and Weil, then the results of this exercise would be dramatically different. For example, a value of  $\alpha = .7$  would result in the finding that capital explained essentially all of the shortfall plotted in Figure 3. Further, consider increasing a country's capital-output ratio from that of a typical African country to that of a typical OECD country. We would increase its level of output per person by a factor of more than 3.4 (since  $\theta = .7/.3 = 2.33$ , and  $y_j/y_{10} = [\kappa_k/\kappa_{10}]^\theta = 1.7^\theta = 3.44$ .) With the levels discussed above, this would enable them to easily surpass Latin America and move to 40% of the output per person in the OECD. Thus, using an augmented capital-share parameter of 0.7 and taking capital variations as exogenous would reinstate capital as the driving force behind economic growth.

*5.2.3 Shortcomings.* There are at least three important reasons for being wary about using the Mankiw, Romer, and Weil, model to resurrect capital fundamentalism. First, as emphasized above, there do not seem to

be compelling reasons to take capital accumulation or human-capital accumulation as exogenous. Second, in the Solow and augmented-Solow model, the explanatory power in a cross-section regression comes from transitional dynamics (or reverse causality). But, King and Rebelo (1993) show, using a neoclassical growth model with various plausible parameter values, that the U.S. experience and postwar experience in Japan are inconsistent with transitional dynamics playing an important role.

This argument suffers from a third complication. Many theories may be advanced that posit different unobservable but potentially crucial factors of production which are presumably highly correlated with physical capital. Mankiw, Romer, and Weil choose human capital, but other factors may also be important. For example, Parente and Prescott (1991) highlight the effects of “organizational capital” on development within a framework that is, in important respects, observationally equivalent to Mankiw, Romer, and Weil.<sup>11</sup> Furthermore, Baumol et al. (1989) show that residual measures of technological change are highly correlated with the capital-labor ratios in seven OECD countries over the period 1880–1979. Thus, as suggested by the work of Benhabib and Jovanovic (1991), Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992), capital accumulation and technological change may be intimately linked. The direction of causality and the precise nature of this link, however, are still unclear. The Mankiw, Romer, and Weil results cannot yet be confidently used to minimize the role of technological change and instead focus on factor accumulation. It will require systematic use of human-capital measures – like those constructed by Barro and Lee (1993) and Nehru and Dhareshwar (1993) – to lend empirical credence to the link between human and physical capital, and additional work is certainly needed to understand how technological change and institutional arrangements interact with capital accumulation and economic growth.

*5.3 Investment.* One of the most interesting findings of recent empirical research is that the rate of investment is robustly, positively correlated with the rate of economic growth in the international cross-section. This positive correlation is interesting for three reasons. First, it is consistent with the old capital fundamentalist view of Lewis (1954) and Rostow (1960). Second, Romer (1987, 1989) argues that the correlation of growth rates and investment rates is a robust stylized fact that models of growth and development should seek to capture. Third, DeLong and Summers (1992) and others have used estimates of regression coefficients of growth on investment rates to argue for potent growth effects of policies designed to increase investment.

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<sup>11</sup>Similarly, Jones and Manuelli (1990) and Rebelo (1991) use models which are linear in capital (at least at higher stages of development). These authors, however, view the capital in their models as including physical capital, human capital, and technology. Thus, these models cannot be viewed as capital fundamentalist in nature.

Levine and Renelt (1992) show that the investment rate is positively and robustly correlated with long-run growth in a cross-section of countries over the 1960–1989 period. Investment typically enters with a coefficient of about 0.17 with a coefficient standard error of 0.03. Taking investment as exogenous, the estimated value indicates that ~~the~~<sup>a</sup> country which had an increase in its investment rate from 0.18 (the mean of the world) to 0.24 (the mean of the OECD) would increase its growth rate by  $(0.17) \cdot (0.06) = 1\%$ , or from 0.5% to 1.5%. This is substantial. Notably, it is more than half of the difference between world growth and that in the OECD. \*

Recent evidence, however, suggests that this close association does not represent a causal link running from investment to growth. Carroll and Weil (1994) and Blomstrom, Lipsey, and Zejan (1993) show that growth Granger-causes savings and investment, but that savings and investment do not Granger-cause growth.<sup>12</sup> This evidence makes it difficult to maintain the capital fundamentalist faith.

## 6 Conclusions

Although we found that the capital-output ratio varies positively with the level of income per capita, there is little support for the view that capital fundamentalism should guide our research agenda and policy advice. When we extend standard growth-accounting procedures to a broad sample of 105 countries, we confirm earlier findings: international differences in capital-per-person explain little of the differences in output-per-person across countries; and growth in capital stocks accounts for little of output growth across countries. Moreover, while the ratio of investment to GDP is strongly and robustly associated with economic growth, there is little reason to believe that this constitutes evidence that increasing investment will cause faster growth. Indeed, recent results indicate the opposite: economic growth Granger-causes investment and savings, not the other-way-around.

We agree with Kaldor's (1960, p. 259) argument that capital accumulation is a feature of economic growth, not a fundamental cause:

... neither the proportion of income saved nor the rate of growth of productivity per man (nor, of course, the rate of increase in population) are independent variables with respect to the rate of increase in production...

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<sup>12</sup>In an earlier paper, we found that the predictable component of investment is not associated with economic growth. Specifically, in a pooled cross-section of about 80 countries with data averaged over the 1950s, 1960s, 1970s, and 1980s, we found, using instrumental variables, that investment entered insignificantly. This is consistent with the Carrol and Weil (1994) and Blomstrom, Lipsey, and Zejan (1993) findings who use pooled data averaged over five-year periods. See King and Levine (1993).

We hope that research into the economic, institutional, and legal determinants underlying innovation, human-capital accumulation, and physical-capital investment will improve our ability to design policies that promote sustained economic growth.

## References

Abramovitz, M., (1956). Resource and Output Trends in the United States since 1870. *American Economic Review, Papers and Proceedings*, **46**: 5-23.

Aghion, P. and Howitt, P., (1992). A Model of Growth through Creative Destruction. *Econometrica*, **60**: 323-51.

Barro, R.J. and Lee, J.W., (1993). International Comparisons of Educational Attainment. *Journal of Monetary Economics*, ~~forthcoming~~ **32**: 363-94. X

Baumol, W.J., Blackman, B., Anne, S., and Wolff, E.J., (1989). *Productivity and American Leadership: The Long View*. Cambridge: MIT Press.

Benhabib, J. and Jovanovic, B., (1991). Externalities and Growth Accounting. *American Economic Review*, **81**: 82-113.

Blomstrom, M., Lipsey, R.E., and Zejan, M., (1993). Is Fixed Investment the Key to Economic Growth? *NBER Working Paper* No. 4436.

Carroll, C.D. and Weil, D.N., (1994). Saving and Growth: A Reinterpretation. *Carnegie-Rochester Series on Public Policy*, **40**.

DeLong, J.B. and Summers, L.H., (1992). Macroeconomic Policy and Long-Run Growth. *Policies for Long-Run Economic Growth*. A Symposium sponsored by the Federal Reserve Bank of Kansas City, 93-128.

Denison, E.F., (1962). *Sources of Economic Growth in the United States and the Alternatives before Us*. New York: Committee for Economic Development.

Denison, E.F., (1967). *Why Growth Rates Differ*. Washington, D.C.: The Brookings Institution.

Domar, E., (1946). Capital Expansion, Rate of Growth and Employment. *Econometrica*, 137-47. X

Easterly, W., Kremer, M., Pritchett, L., and Summers, L., (1993). Good Policy or Good Luck? Country Growth Performance and Temporary Shocks. *Journal of Monetary Economics*, ~~forthcoming~~ **32**: 459-84. X

Elias, V.J., (1992). *Sources of Growth: A Study of Seven Latin American*

- Economies*. San Francisco, CA: International Center for Economic Growth.
- Fabricant, S., (1954). Economic Progress and Economic Change. *34th Annual Report of the National Bureau of Economic Research*, New York: NBER.
- Gillis, M., Perkins, D.H., Roemer, M., Snodgrass, D., (1992). *Economics of Development*, Third Edition. New York: W.W. Norton and Company.
- Griliches, Z., (1988). Productivity Puzzles and R&D: Another Nonexplanation. *Journal of Economic Perspectives*, **2**: 9-21.
- Grossman, G. and Helpman, E., (1991). Quality Ladders in the Theory of Economic Growth. *Review of Economic Studies*, **58**: 43-61.
- Harberger, A., (1978). Perspectives on Capital and Technology in Less Developed Countries, M.J. Artis and A.R. Nobay (eds.), *Contemporary Economic Analysis*. London: Croom Helm.
- Harrod, R.F., (1939). An Essay in Dynamic Theory. *Economic Journal*, March: 14-33.
- Jones, L. and Manuelli, R., (1990). A Convex Model of Equilibrium Growth. *Journal of Political Economy*, **98**(5): 1008-38.
- Jorgenson, D.W., (1973). The Economic Theory of Replacement and Depreciation. *Econometrics and Economic Theory, Essays in Honor of Jan Tinbergen*, (ed.) W. Sellekaerts. White Plains: International Arts and Science Press.
- Jorgenson, D.W., (1990). Productivity and Economic Growth. *NBER Studies in Income and Wealth: Fifty Years of Economic Measurement, The Jubilee of the Conference on Research in Income and Wealth*, **54**, (eds.) E.R. Brendt and J.E. Triplett. Chicago: Chicago University Press.
- Jorgenson, D.W. and Fraumeni, B.M., (1989). The Accumulation of Human and Nonhuman Capital, 1948-84. *The Measurement of Saving, Investment, and Wealth*, (eds.) R.E. Lipsey and H.S. Tice. Chicago: University of Chicago Press.
- Jorgenson, D.W. and Griliches, Z., (1967). The Explanation of Productivity Change. *Review of Economic Studies*, **34**: 249-83.

Jorgenson, D.W., Gallop, F. and Fraumeni, B., (1987). *Productivity and U.S. Economic Growth*. Cambridge: Harvard University Press.

Kaldor, N., (1960). *Essays on Economic Stability and Growth*, second edition. New York: Holmes and Meier Publishers, Inc.

Kaldor, N., (1961). Capital Accumulation and Economic Growth. F.A. Lutz and D.C. Hague (eds.), *The Theory of Capital*. New York: St. Martin's Press, 177-222.

King, R.G. and Levine, R., (1993). Finance and Growth: Schumpeter Might Be Right. World Bank: *Policy Research Working Paper*, No. 1083.

King, R.G. and Rebelo, S., (1993). Transitional Dynamics and Economic Growth in the Neoclassical Model. *American Economic Review*, **83**(4): 908-31.

Kuznets, S., (1966). *Modern Economic Growth: Rate, Structure, and Spread*. New Haven: Yale University Press.

Levine, R. and Renelt, D., (1992). A Sensitivity Analysis of Cross-Country Growth Regressions. *American Economic Review*, **82**(4): 942-63.

Lewis, W.A., (1954). Economic Development with Unlimited Supplies of Labour. *The Manchester School of Economic and Social Studies*, **22**(2), 139-91.

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

Maddison, A., (1982). *Phases of Capitalist Development*. Oxford: Oxford University Press.

Mankiw, N.G., Romer, D., and Weil, D.N., (1992). A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics*, **107**(2): 407-38.

Nehru, V. and Dhareshwar, A., (1993). A New Database on Physical Capital Stocks: Sources, Methodology, and Results. Mimeo, The World Bank.

Nehru, V., Swanson, E., and Dubey, A., (1993). A New Database on Human Capital Stock: Sources, Methodology, and Results. World Bank: Policy Re-



2 2 01

Solow, R., (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, **39**: 312-20.

Summers, R. and Heston, A., (1991). The Penn World Table (Mark 5): An Expanded Set of International Comparisons 1950-88. *Quarterly Journal of Economics*, **106(2)**: 327-68.

Yotopoulos, P. and Nugent, J., (1976). *Economics of Development: Empirical Investigations*, New York: Harper and Row.

Young, A., (1993). Lessons from the East Asian NICS: A Contrarian View. National Bureau of Economic Research: Working Paper, No. 4482.