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## Economic growth: A review essay

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### Abstract

The last decade has seen an explosion of research on economic growth. Based on a selective review of this literature and the recent book on *Economic Growth* by Robert Barro and Xavier Sala-i-Martin, we see four main challenges for future research. First, to more tightly link theory and evidence. We think a good way of achieving this would be to follow the methodology common in the business cycle literature of simulating models to compare their predictions to the data. Second, to develop new ways to empirically distinguish between competing theories of endogenous growth. Third, to develop more theories of international productivity differences. Finally, to collect detailed country data bearing on the process of technology diffusion. © 1997 Elsevier Science B.V. All rights reserved.

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### 1. Introduction

The last decade has witnessed an explosion of research on economic growth. Three related but conceptually distinct issues lie at the heart of this research: world growth, country growth, and dispersion in income levels. Theories of world growth attempt to explain the continuous growth in income per capita in the world economy over the last two hundred years. Most of the best-known models of endogenous growth (e.g. Lucas, 1988; Romer, 1990; Grossman and Helpman, 1991) belong to this group.

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Theories of country growth are motivated by the tremendous variation observed in country growth rates. This segment of the literature asks, for example, why some East Asian countries have grown so much faster than most other countries for over three decades. The essay on economic miracles by Lucas (1993) is concerned primarily with this issue.

Finally, many papers in the literature try to explain why, at any point in time, some countries are significantly richer than others. For instance, the human capital-augmented Solow–Swan model of Mankiw et al. (1992) models dispersion in income levels.

In their recent book on *Economic Growth*, Barro and Sala-i-Martin (1995a) exposit many of the models developed to explain the phenomena of world growth, country growth, and dispersion in income levels. They start with the Solow growth model and then modify it to incorporate endogenous savings, finite horizons, endogenous growth (through rising human capital, expanding product variety, and rising product quality, respectively), technology diffusion, and fertility. The authors then take advantage of the recent availability of large panel datasets, such as the cross-country dataset constructed by Summers and Heston (1991) and the regional datasets they have compiled in their own research, to present evidence bearing on the competing models.

As the book illustrates, recent research on economic growth has been inspired by theoretical questions (How does one model endogenous growth?) and fueled by newly-available datasets (e.g. Summers and Heston, 1991). Barro and Sala-i-Martin argue that the “combination of theory and empirical work is the most exciting aspect of the ongoing resurgence of work on economic growth”. In this selective review of the literature and the Barro and Sala-i-Martin book we offer a somewhat more negative assessment of the way data has been used to discriminate among theories of economic growth. We use the three central issues of growth economics to organize this paper. In Section 2 we discuss the (limited) work testing theories of long-run growth. In Section 3 we focus on methodological problems with many existing empirical analyses of country growth, and in Section 4 we discuss candidate explanations for dispersion in country income levels.

We conclude the paper with a wish-list for the direction of future growth research. First, we would like to see a much tighter link between theory and evidence. We think a good way of achieving this would be to follow the methodology common in the business cycle literature of simulating models to compare their predictions to the data. Second, we hope to see much more empirical work discriminating between competing theories of endogenous growth. Third, we see a need for more theories to explain international productivity differences. Fourth, we think that detailed country studies could help us better understand the process of technology transfer.

## 2. Explaining long-run world growth

Most of the theoretical work on economic growth has been aimed at understanding why growth in per capita income has been a persistent feature of the world economy in the past two centuries. Different strands of the literature use different forces to sustain growth, but all introduce some type of capital whose accumulation overcomes the diminishing returns to physical capital accumulation. One strand uses human capital accumulation to sustain growth (e.g. Lucas, 1988; Jones and Manuelli, 1990; Rebelo, 1991; Stokey, 1991). Another strand perpetuates growth through the accumulation of knowledge, either through learning by doing (Romer, 1986; Stokey, 1988; Young, 1991) or through R&D (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992).

Since these models often have different positive and normative predictions, it is important to distinguish between them empirically. In Rebelo (1991) the decentralized equilibrium is Pareto-optimal, so no-intervention is the best policy. Other models feature positive externalities to human capital or ideas, leading to too little growth in the absence of government subsidies. The activity deserving subsidy differs across the models, with some pointing to human capital investment and others to R&D. Moreover, as Romer (1993) emphasizes, the positive and normative implications of openness (e.g. to trade, foreign direct investment, and the flow of ideas) differ drastically across models. Some models imply that greater openness can slow down growth (e.g. Young, 1991; Stokey, 1991), while others imply that openness can speed up growth (Romer, 1990).

In our view there has been disappointingly little empirical work testing and discriminating between theories of endogenous growth. We reach this conclusion despite a large number of cross-country growth regression studies investigating what variables are correlated with growth rates. For example, Barro and Sala-i-Martin (1995a) (see Chapter 12) report results of panel regressions of the form

$$gy(i, t) = -b \cdot y(i, 0) + \text{control variables} + u(i, t), \quad (1)$$

where  $gy(i, t)$  is the growth rate of per capita GDP of country  $i$  from period 0 to period  $t$ ,  $y(i, 0)$  is the log of country  $i$ 's per capita GDP at time 0, and 'control variables' include (among others) initial school enrollment rates, the share of government consumption in GDP, the black market premium, and political instability. Barro and Sala-i-Martin motivate these regressions using the following approximation to the neoclassical growth model (see their p. 81):

$$gy(i, t) = \mu(i) + \beta \cdot [y_{ss}(i, 0) - y(i, 0)] + \varepsilon(i, t), \quad (2)$$

where  $y_{ss}$  represents the time 0 log level of income on the country's steady-state path. Now, it is not clear whether the control variables in Eq. (1) are proxying

for differences in country steady-state income levels ( $y_{ss}$ ) or for differences in country long-run growth rates ( $\mu$ ). In other words, the control variables could be picking up effects on the log-level of the country's steady-state income path rather than on the slope of that path.<sup>1</sup> If only level effects are involved, then significant coefficients on the control variables are consistent with a view of the world in which all countries grow at the same rate in steady state, with higher or lower than average growth being transitional phenomena; i.e. such coefficients may tell us nothing about the determinants of  $\mu$ . This issue (plus simultaneity problems that we discuss in the next section) make it hard to conclude much about endogenous growth theories from cross-country growth regressions.

Recent research more directly tests existing endogenous growth models. Jones (1995a) shows that post-war evidence for the OECD does not support the prediction of many R&D-based models that a higher scale of R&D input (e.g. the number of scientists and engineers devoted to R&D) increases the growth rate. Jones (1995b) tests the implication of AK models that permanent changes in the investment rate permanently affect the growth rate. He finds no support for this prediction in US time series. Kocherlakota and Yi (1997), however, estimate persistent growth effects of persistent changes in tax rates and public capital spending in US and UK time series. Kocherlakota and Yi (1996) test the related prediction of AK models that temporary increases in the investment rate permanently raise the level of output. Analyzing US time series, they estimate permanent GNP level effects of temporary changes in government nonmilitary capital spending.

We would like to see more tests of endogenous growth theories. This may require new data, but we think some existing evidence can be used for this. For instance, Barro and Sala-i-Martin (1995a) (see Chapters 11 and 12) present strong evidence of 'sigma convergence' – a declining standard deviation of per capita income – across US states from 1880 to 1980, across Japanese prefectures from 1955 to 1990, and across OECD countries since World War II. Such sigma convergence seems hard to reconcile with AK models which imply sigma divergence unless investment rates are negatively-correlated across time in a given location. For example, convergence of schooling enrollment and attainment across US states would only slow the rate of divergence; low income states would have to leapfrog the levels of high income states in order to close the income gap.<sup>2</sup>

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<sup>1</sup> Barro (1996) seems to interpret control variables as having long-run growth effects: "My estimate for studies of economic growth is that a 10% cut in the size of government – that is, in spending and taxes – would raise the *long-term* growth rate by 0.1% per year" (italics added).

<sup>2</sup> Tamura (1991) adds a positive externality to the human capital accumulation technology of an AK model precisely to avoid this prediction. Without knowing more about this externality, it is hard to conceptually distinguish it from technology diffusion and the flow of ideas, which we discuss later in this paper.

### 3. Explaining country growth

Why do growth rates differ across countries? Perhaps the easiest way to motivate this question is to look at the economic miracles of East Asia (Hong Kong, Singapore, South Korea and Taiwan) who have managed to grow at extraordinarily high rates for the last three decades. What lies behind these miracles?

One hypothesis is that country growth differences arise from transitions back to parallel long-run paths. An important model of country growth of this type is the Solow–Swan model. In this model high rates of growth occur when a country finds itself way below its steady-state path.<sup>3</sup> An alternative theory of this type views high growth as technological ‘catch-up’ and low growth as technological ‘falling behind’.<sup>4</sup>

Another hypothesis is that countries are very near their long-run growth paths, and that these growth paths are not parallel. One may then think of endogenous growth theories as applying to countries in isolation, so that differences in policies and institutions across countries lead to differences in rates of long-run economic growth. According to the AK endogenous growth theory, for instance, countries with low tax rates on capital grow faster in the long run than countries with high tax rates.

In terms of evidence, the literature on country growth rates consists of growth accounting and cross-country growth regressions. We will discuss growth accounting later in this section (Section 3.3). As for cross-country growth regressions, they produce estimated rates of conditional convergence which may bear on transitional theories of country growth.<sup>5</sup> In Section 3.1 we point out several problems with how the rate of conditional convergence is usually estimated. We then argue that theories of country growth based on endogenous growth models with no interdependencies among countries are not very promising (Section 3.2).

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<sup>3</sup> Of course, this gives rise to the questions of how the country got below its steady-state path. If there are persistent shocks that are pushing the country away, the convergence rate could be much slower than suggested by the Solow–Swan model. Indeed, it could even be negative (see Kocherlakota and Yi, 1995). As we discuss later, this underscores the need to be explicit about the process generating the data.

<sup>4</sup> Another theory views relative country growth as transitions between multiple steady-state income paths. If a country starts near the low steady-state path and a shock starts a transition to the high steady-state path, then the country experiences relatively high growth rates during the transition. (See Ciccone and Matsuyama, 1996).

<sup>5</sup> Conditional convergence is the idea that countries tend to grow faster the lower their income relative to (i.e. conditioning on) their steady-state income. The ‘rate of conditional convergence’ is estimated from the coefficient on initial income estimated from Eq. (1). Absolute convergence, in contrast, says simply that poorer countries tend to grow faster than richer ones. This would arise if differences in steady-state income paths are swamped by country transitions to their steady-state paths.

We close the section by discussing evidence relevant for discriminating between the neoclassical view of country growth, where high country growth is due to rapid accumulation of capital, and views that emphasize technology catch-up (Section 3.3).

### 3.1. *Conditional convergence and country growth*

One can try to discriminate among theories of country growth of the transitional type by comparing their implied rate of conditional convergence with the rate estimated in the data. Barro and Sala-i-Martin (1995a) usefully endeavor to do just this. Their approach is to present a model, linearize around its steady state, and choose reasonable values for parameters (such as the share of capital and the depreciation rate) to determine a numerical convergence speed implied by each model. This speed is then compared to the rate of conditional convergence estimated from the cross-country growth regressions presented in Chapters 11 and 12 of their book.

Specifically, the authors use the rate of conditional convergence estimated from cross-country growth regressions as evidence for or against the Cass–Koopmans model as well as versions of that model extended to include human capital accumulation (Mankiw et al., 1992; Barro et al., 1995; Lucas, 1988). They estimate a rate of conditional convergence of 3% per year (Chapter 12). This means that 3% of the gap between the actual and the steady-state income level tends to be eliminated each year. The authors show that this rate of convergence is significantly slower than the rate predicted by the Cass–Koopmans model, which is around 6% per year. As is well-known, the speed of convergence is decreasing in the share of capital. With this in mind the authors argue for adding human capital to the model to boost the share of capital from roughly 1/3 (the share of physical capital) to the level of 3/4 required to generate a 3% convergence rate.

We see two problems with these estimates of conditional convergence. First, the regressions typically include control variables that are associated with transition dynamics as well as with steady-state income, making it hard to say the magnitude of the coefficient on initial income picks up all transition dynamics. Second, the models do not point to observable control variables that will fully capture differences in steady states. Recent studies controlling for differences in steady states using country fixed effects in panel regressions find substantially higher convergence speeds. We now elaborate on the first point for several models, then summarize recent econometric studies pertaining to the second point. We end this subsection by suggesting a strategy for avoiding these problems in future research.

#### 3.1.1. *The Cass–Koopmans model*

Suppose all countries have the same steady-state income path, so differences in initial income represent different positions relative to the common

steady-state path. In the absence of shocks, this model says the lower the initial income, the faster the subsequent growth (i.e. absolute convergence). Because absolute convergence is not seen in the Summers and Heston (1991) panel (see Barro and Sala-i-Martin, 1995a, Chapter 12), one must entertain differences in steady-state income paths. Suppose these paths are parallel. Then differences in their levels arise from two sources: differences in productivity and differences in the steady-state investment rate in physical capital.<sup>6</sup>

Cross-country growth regressions typically include variables such as the initial investment rate, political instability, and the black-market premium to control for differences in steady-state income levels. We will shortly discuss what happens when these controls do not fully capture differences in steady-state income levels, but for now suppose they do. Is the initial investment rate in a country equal to its steady-state value? Yes only if parameter values are such that the investment rate is constant along the transition path. As Barro and Sala-i-Martin (1995a) (Chapter 2) show, this happens only when the steady-state investment rate is equal to the intertemporal elasticity of substitution in consumption. This condition is necessarily violated if individuals in different countries have the same preferences. So what happens when the initial investment rate is not the same as the steady-state investment rate? Suppose

$$gy(i, t) = \mu + \beta \cdot [y_{ss}(i, 0) - y(i, 0)] + \varepsilon(i, t),$$

$$\frac{I}{Y}(i, t) = -\theta \cdot [y(i, t) - y_{ss}(i, t)] + \lambda \cdot [y_{ss}(i, t) - y_{ss}(t)]$$

with  $y_{ss}(t)$  growing at the common trend  $\mu$ . The linear specification of  $I/Y$  is just to simplify the exposition. If one runs the cross-country growth regression

$$gy = b \cdot y(i, 0) + d \cdot \frac{I}{Y}(i, 0) + u,$$

then the true speed of convergence  $\beta$  relates to the estimated coefficients as follows

$$\beta = \hat{b} + \theta \cdot \hat{d}.$$

Now, a robust finding of Levine and Renelt (1992) is that  $\hat{d}$  is positive and significantly different from zero. As a result, the estimated convergence speed is biased because the investment rate varies with a country's income relative to steady-state ( $\theta \neq 0$ ). Intuitively, the initial investment rate contains some information about the distance from the steady-state rather than purely information about the steady-state. Its inclusion in the regression 'steals' from the

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<sup>6</sup> In this model the level of productivity does not affect the steady-state investment rate.

coefficient on initial income, leading to bias in the estimated speed of convergence. The direction of the bias depends on the sign of  $\theta$ . Barro and Sala-i-Martin, 1995a (p. 79), argue that the empirical evidence suggests rising investment rates during the transition ( $\theta < 0$ ), which would imply an upward bias. But regardless of the sign of  $\theta$ , our point is that including the investment rate – a variable which is endogenous to a country's position relative to steady-state – implies one cannot read the convergence rate from the coefficient on initial income in a cross-country growth regression.

### 3.1.2. *The Barro–Mankiw–Sala-i-Martin model (1995)*

The Barro–Mankiw–Sala-i-Martin (BMS) model is an extension of the Cass–Koopmans model to include human capital. It is a one-sector model in that new physical capital, new human capital, and consumer goods are all produced with the same technology. The setting is a small open economy that can borrow from the rest of the world up to the quantity of physical capital (human capital cannot serve as collateral). Barro and Sala-i-Martin (1995a) (Chapter 3) show that, with a share of physical capital of 30% and a share of human capital of 45%, the BMS model implies a convergence rate of 2.5%, a rate that “conforms well with empirical estimates of convergence coefficients” (p. 106).

To evaluate this statement, note that the coefficient on initial income implied by the BMS model depends on the variables used to control for differences in steady-state income paths. The regression examined in the book includes the initial stock of human capital (measured by average years of schooling in the working age population). But the human capital stock does not purely reflect the steady-state path. It also contains information about the deviation from that path. If steady-state income paths were the same the model would actually imply that a *lower* stock of human capital would lead to faster growth, because income convergence in this model is driven entirely by convergence in human capital.

A related problem is that including the initial stock of human capital in the regression is problematic because income and human capital are tightly linked in the BMS model (see Equation 3.13 on p. 104 in Barro and Sala-i-Martin, 1995a). More precisely, the log of income and the log of human capital are perfectly collinear in the BMS model. The results of the estimation procedure then depend on why these two variables are not perfectly collinear in the data. For instance, if the BMS model is right but the log of income and log of human capital are not perfectly correlated because of measurement error, then the size (but not the sign) of the coefficients on these two variables depend entirely on how accurately they are measured. This would have two implications. First, the coefficient of initial income cannot be interpreted as the rate of conditional convergence. Second, the coefficients on income and human capital should have the same sign (both negative), whereas in the cross-country growth regression presented in the book they have the opposite sign.



### 3.1.3. *The Lucas–Uzawa model*

The Lucas–Uzawa model is a two-sector model of endogenous growth. Because the combined share of physical and human capital is one, accumulation of capital does not run into diminishing returns, and positive growth can be maintained in the long run. For this model Barro and Sala-i-Martin (1995a) (Chapter 5) show that, if human capital production is relatively intensive in human capital, then the transitional growth rate of output (including output in the education sector) increases with the ratio of human capital to output. Their finding provides a rationale for including initial human capital along with initial income to estimate the rate of convergence to the steady-state path.<sup>7</sup>

But regressions estimating the coefficient on initial income (relative to the stock of human capital) often include initial enrollment rates (e.g. Barro and Sala-i-Martin, 1995a, Chapter 12). The initial enrollment rate contains further information about a country's transitional growth. Just as including investment rates is problematic in the Cass–Koopmans model, the inclusion of enrollment rates makes it hard to interpret the coefficient on initial income as picking up all of the transitional dynamics in the Lucas–Uzawa model.<sup>8</sup>

To summarize the preceding discussion, the coefficient on initial income may not accurately reflect the speed of conditional convergence because some of the control variables contain information about transition dynamics. A number of recent studies point out another problem, namely that cross-country growth regressions with imperfect proxies for steady-state income differences will lead to underestimation of the rate of convergence. This is because differences in country steady-state income paths – part of the error term if not fully captured by control variables – should be positively correlated with initial income, biasing the negative coefficient on initial income toward zero. Intuitively, countries would seem to be converging slowly to their apparently similar steady states when in fact they are close to their very different steady states.

Islam (1995), Canova and Marcet (1995), and Caselli et al. (1996) each use panel data techniques to address this problem. They find much faster rates of conditional convergence than the 3% estimated by Barro and Sala-i-Martin

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<sup>7</sup> Barro and Sala-i-Martin do not quantify the convergence rate implied by the Lucas–Uzawa model.

<sup>8</sup> Also, in the same way that the Cass–Koopmans model implies a low investment rate in physical capital along the transition, the Lucas–Uzawa model implies a low investment rate in human capital along the transition. Because fast growth countries in the Lucas–Uzawa model are those with high ratios of human capital to physical capital, they should have *low* enrollment rate (the high rate of return to physical capital provides strong incentives to devote most resources to the accumulation of physical capital, thus taking resources away from the accumulation of human capital). But just as for the investment rate in physical capital, Levine and Renelt (1992) find a positive coefficient on initial enrollment rates. In the context of these models, the positive coefficients suggest differences in steady-states swamp transitional dynamics.

(1995a) (Chapter 12). Using the Summers–Heston panel, Islam estimates a rate of convergence of 6% per year, Caselli et al. (1996) estimate 10%, and Canova and Marcet (1995) estimate 11%. These faster rates of convergence are consistent with smaller combined shares of physical and human capital than the 75% (30% physical capital, 45% human capital) calibrated to fit a 3% convergence rate. In fact, Caselli et al. report an implied capital share of only 10%, far below the reasonable 30% share for physical capital alone! This may imply that conditional convergence is coming from productivity, or technology catch-up, as well as from neoclassical-type input transition dynamics.

What we conclude from this discussion of conditional convergence is the need to specify full-blown stochastic models, simulate them, and compare their predictions to the data. We believe that this methodology, which has frequently been applied in the business cycle literature since the seminal paper by Kydland and Prescott (1982), could be enormously productive in growth research. As suggested by the examples above, it could prevent misspecification problems and ambiguity in interpreting conditional correlations. When the model is used as an artificial data generating mechanism, there can be no ambiguity about its implications for moments, conditional and unconditional (for a given set of parameter values).

Two studies working with versions of the neoclassical growth model help illustrate the advantages of this methodology. Mankiw et al. (1992) examine whether the magnitude of the correlations observed between investment rates and the level of output could reflect the impact of the former on the latter. Chari et al. (1996) endogenize investment rates and specify a stochastic process for distortions, then explicitly compare quantitative properties of the simulated data to those of the Summers–Heston panel (e.g. mobility matrices).

These examples show how this methodology requires one to be explicit about the distribution of country initial conditions for state variables, and the processes followed by policy and other forcing variables. Before one engages in empirical analysis one must address the following questions about the model under consideration: Do countries have the same long-run growth rates? If not, what causes these growth rates to differ? What is the distribution of the initial levels of country steady-state paths? What causes country steady-state paths to differ (inputs, productivity or some combination)? What is the distribution of the initial levels of country distances from their steady-state paths? What causes initial country distances from steady-state paths to differ (inputs, productivity, or some combination)? What policy and technology shock processes are hitting each country (tax rates, wars)? Without answers to these questions, cross-country growth regressions are like fishing with dynamite: you get lots of fish, but more than you know what to do with.

### 3.2. Country growth and endogenous growth theory

In this sub-section we argue that applying endogenous growth theory to each country in isolation is not very helpful for understanding country growth differences. We base this on three pieces of evidence. First, as documented in Parente and Prescott (1993), the standard deviation of log per capita income has not changed significantly over the last century (if anything, it has decreased) for 29 countries for which data is available. That is, we do not see sigma divergence. If we lived in a world of isolated economies whose long-run growth is determined by domestic policies and institutions we would expect to see sigma divergence since such policies are likely to be persistent.<sup>9</sup>

The second source of evidence against endogenous growth theory as explaining country growth comes from data from US, European and Japanese regions (see Barro and Sala-i-Martin, 1995a, Chapter 11). For these regions we see sigma convergence.

The third and final source of evidence comes from the Summers–Heston panel. It is not immediately obvious that this data rejects the view that long-run country growth can be explained by endogenous growth theory, since there actually is sigma divergence for the 1960–1985 period. Still, as pointed out by Parente and Prescott (1993), the five countries that started at the bottom of the distribution were able to grow just as fast as the five countries that started at the top of the distribution. By the same argument made above, an endogenous-growth view of country growth would predict that countries at the bottom of the distribution grow at a slower rate than those at the top.

Now, endogenous growth theory is (tautologically) the only way to explain world growth. But the preceding observations suggest it is not able to explain country growth differences without incorporating strong interdependencies among countries. Diffusion of technology – perhaps through some combination of trade, foreign direct investment, and migration of labor – seems an essential part of the story. A defensible view is that all countries grow at the same rate in the long run, with countries being at different points in the distribution at any point in time due to policies and institutions that affect how fully a country benefits from world frontier technology. In this kind of model, for example Parente and Prescott (1994), high country growth occurs as countries move up in the distribution. Faster-than-average growth could be explained as the result of adoption of better policies and an improvement of institutions that permit those countries to benefit more from frontier technology.

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<sup>9</sup> Easterly et al. (1993) find policies to be highly persistent over the 1960–1988 period. To prevent sigma divergence, policies would actually need to be *negatively* serially correlated.

### 3.3. Country growth: Neoclassical transition or technology catch-up?

The debate over whether fast rates of growth in some countries stem from accumulation of capital or from technology catch-up has been heavily influenced by the East Asian miracles. It was initially thought that these countries had very high total factor productivity (TFP) growth rates, pointing to technology catch-up as the heart of the story. Then came the careful work of Young (1995) showing that these countries grew mostly through input accumulation, and that their TFP growth rates were not extraordinarily high (Young, 1994). Singapore, for instance, was shown to have virtually no productivity growth over the last decades. As a result of this work, many people have concluded that the East Asian episodes illustrate the importance of neoclassical transition dynamics rather than technology catch-up.

We do not think this interpretation of Young's results is correct. First, the debate is over whether capital accumulation or technology catch-up explains growth in output *per worker*, not growth in output. Neither hypothesis tries to explain the growth rate of employment. Second, growth in physical capital induced by rising productivity should be causally attributed to productivity (Barro and Sala-i-Martin also make this point, p. 352). A higher level of productivity raises the marginal product of capital, thereby stimulating investment and capital accumulation that would not have occurred without the higher level of productivity.<sup>10</sup> The role of capital accumulation over and above that stimulated by productivity growth can be measured by the growth rate of the capital–output ratio. A few calculations from Young's (1995) tables illustrate the quantitative importance of these considerations. The annual growth rates of output and TFP, respectively, were 7.3% and 2.3% in Hong Kong, 8.7% and 0.2% in Singapore, 10.3% and 1.7% in South Korea, and 9.4% and 2.6% in Taiwan. So growth in output primarily came from input accumulation. But the growth rates of output per worker and 'adjusted TFP' – TFP raised to  $1/(1 - \text{capital's share})$  because of TFP's impact on capital accumulation – were as follows: 4.7% and 3.7% in Hong Kong, 4.2% and 0.3% in Singapore, 4.9% and 2.5% in South Korea, and 4.8% and 3.5% in Taiwan. So in three of the four East Asian miracles growth in output per worker came mostly from productivity gains.

In any case, the debate should not focus entirely on the miracle countries of East Asia. More generally, one wants to know how much variation in country growth rates is due to variation in TFP growth and how much to variation in human and physical capital accumulation. In another work (Klenow and Rodríguez-Clare, 1997) we have estimated that differences in TFP growth

<sup>10</sup> We are referring to models wherein disembodied technical change is a complement to physical capital, such as with  $Y = AK^{\alpha}N^{1-\alpha}$ .

explain about 90% of the variation in growth rates of output per worker across 98 countries over 1960–1985.<sup>11</sup> This evidence is consistent with a dominant role for technology catch-up.

Another piece of evidence favoring the technology catch-up view of country growth is sigma convergence of per capita income across US states, Japanese prefectures and OECD countries. Barro and Sala-i-Martin (1995a) (Chapter 9) conclude that neither migration of labor nor capital flows are important in these convergence episodes. They suggest that their findings are consistent with the Cass–Koopmans model as well as with models of technology diffusion. But it is hard to think of regions within countries as being isolated with respect to capital and labor flows. Thus the BMS model, an extension of the neoclassical model to allow for imperfect capital mobility, seems a better candidate from the family of neoclassical models to account for slow absolute convergence within a single country. This model implies, however, that both physical capital and skilled workers should flow to poor regions. Technology diffusion models appear more promising in that they imply the flow of all types of labor toward high income regions.

#### **4. International dispersion of income levels**

Taking the view that countries grow at the same rate in the long-run, one can think of dispersion in income levels as owing to some combination of different log-levels of parallel long-run growth paths and transitions towards or away from these paths. If a large part of the dispersion in per capita income can be explained by countries being away from their steady-state paths, then conditional convergence may tell us a lot about why some countries are rich and some poor. In fact, one can easily verify that this is not the case from the lack of absolute convergence in the data (see Barro and Sala-i-Martin, 1995a, Chapter 1). Initially poorer countries do not grow faster, suggesting persistent shocks and/or differences in steady-state paths as the dominant sources of income differences.<sup>12</sup>

In Section 4.1 we discuss whether the coefficients on the control variables in cross-country growth regressions (Chapter 12) shed light on the shocks and policies responsible for country income differences. After that we discuss the question of whether most differences in income stem from differences

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<sup>11</sup> Our human capital estimates are based on schooling and experience (own-years of schooling, own-years of experience, and teacher-years of schooling and experience).

<sup>12</sup> This stands in contrast to the within-country regional dispersion of income. Barro and Sala-i-Martin (1995a) (Chapter 11) report sigma convergence, consistent with a big role for transitional dynamics.

in productivity or from differences in physical and human capital intensity (Section 4.2).

#### 4.1. *Cross-country growth regressions and the determinants of income levels*

The most common interpretation of cross-country growth regressions is based on the neoclassical model with exogenous technological change. According to this model, a country's growth rate is the sum of two parts: a transitional term specific to each country and a long-run growth term common to all countries. If cross-country growth regressions are motivated by this model, then all of the variables besides the initial income level must be seen as controlling for differences in steady-state relative income levels.

Unfortunately, endogeneity of regressors makes it hard to conclude anything about causality from cross-country growth regressions.<sup>13,14</sup> Consider the investment rate in physical capital. In the neoclassical growth model the investment rate is endogenous to the expected rate of exogenous productivity growth. To try to capture the effect of investment rates on growth, Barro and Sala-i-Martin (1995a) use lagged investment rates as instruments, and are reassured by the fact that the regression residuals are serially uncorrelated.<sup>15</sup> But a forward-looking decision such as investment can be correlated with future growth even when growth is serially uncorrelated. Consider stock returns and output growth. Each may be serially uncorrelated yet the former can anticipate the latter. One should not interpret the coefficient from a regression of output growth on lagged stock returns as the causal impact of stock returns on future growth.

We are not suggesting just throwing in the towel because of endogeneity problems. Theory can provide some guidance. Consider human capital. Bils and Klenow (1996) find that, when they embed a Ben-Porath (1967) model of the schooling decision in an AK model, schooling responds positively to expected productivity growth. By calibrating the model to estimated returns to schooling in the labor market, they quantify how sensitive schooling should be to expected growth, versus how strong the effect of schooling should be on growth in an AK model. The results suggest the coefficients estimated by Barro and Sala-i-Martin (1995a) – e.g. that 0.68 more years of male secondary schooling produces 1.1%

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<sup>13</sup> Distressingly, Barro and Sala-i-Martin (1995a) often use language implying causality, such as writing that an increase in a control variable (with a positive coefficient) 'raises' the growth rate. (See also footnote 1 above.)

<sup>14</sup> Mankiw (1995) discusses further problems of multicollinearity and limited degrees of freedom.

<sup>15</sup> In Chapter 12 the authors break the 1965–1985 Summers–Heston sample into 1965–1975 and 1975–1985 and run regressions on the resulting panel. They can therefore check the correlation between country growth residuals for 1975–1985 and those for 1965–1975.

faster annual growth, and 0.091 more years of male higher schooling produces 0.5% faster annual growth (see p. 431) – are much too big to reflect the effect of schooling on growth, but could plausibly reflect the effect of expected growth on schooling.

#### *4.2. A versus K*

Recent studies finding that the rate of conditional convergence is large suggest that countries are near their steady state relative income levels. This is also suggested by the fact that there is no absolute convergence. Thus, to explain differences in income levels it is necessary to explain differences in steady-state income levels. In an influential paper Mankiw et al. (1992) argue that the Solow model (augmented to include human capital but preserving diminishing returns to capital and keeping productivity the same across countries) can explain 80% of cross-country differences in income levels. Something left out of MRW's analysis, namely an explanation for country differences in investment rates, has since been offered by CKM (Chari, Kehoe and McGrattan, 1996). CKM argue that distortions like tax rates, bribes, risk of expropriation, and corruption contribute to an effective tax rate which, if it varies in the right way across countries, can explain the levels of income observed in the Summers–Heston panel.

In our view, MRW, CKM, and the interpretation widely given to the findings of Young (1995) collectively constitute a neoclassical revival. MRW and CKM take the position that the level of productivity is essentially the same across countries, so that differences in income levels owe largely to differences in levels of physical and human capital. Romer (1993), in contrast, argues that such 'object gaps' are not as important as 'idea gaps'. In terms of a simple production function  $Y = A \cdot K$ , this debate can be crudely summarized as being over the relative importance of  $A$  and  $K$  differences.

This debate matters because the  $A$  view has positive and normative implications not shared by the  $K$  view. Suppose productivity differences reflect differences in technology used. Unlike the neoclassical growth model, technology-based models generically have scale effects because of the nonrival nature of innovation, imitation, adoption and adaptation. Technology-based models also suggest a prominent role for openness (access to higher quality or more specialized goods through imports or access to better technology through joint ventures or technology licensing). And whereas the normative implications of the neoclassical model center on tax rates, those of technology-based models extend to trade policy, foreign investment policy, research policy, and intellectual property protection.

We now discuss three types of evidence pointing to large dispersion in productivity across countries: levels accounting, the pattern of international trade, and the entry wages of immigrants in the US. In another work (Klenow

and Rodríguez-Clare, 1997) we find that variations in physical and human capital explain less than half of the variation in output per worker across 98 countries in 1985. Our findings diverge from MRW's because our measure of human capital varies much less across countries. Our measure is based on enrollment rates in primary, secondary, and post-secondary schooling, whereas they consider only secondary schooling. Moreover, we incorporate a production technology for human capital that is more intensive in labor and human capital, consistent with the evidence.

Next consider the pattern of international trade. As is well known, the Heckscher–Ohlin–Vanek (HOV) model does not do very well in explaining the factor-content of trade across countries (see Bowen et al., 1987). Treffer (1995) shows that one of the main reasons for this is the standard HOV assumption that all countries have access to the same technology. Treffer allows productivity to differ across countries and estimates productivity levels for the countries in his sample in order to maximize the predictive power (i.e., the likelihood) of the HOV model. The estimates of productivity are close to each country's income relative to the United States, suggesting that differences in TFP explain most differences in per capita income. And the goodness-of-fit of the HOV model (as measured by its success in predicting the sign of trade in factor services and by the correlation between the actual and the model's predicted factor content of trade) improves significantly when country TFP levels are allowed to differ.

Finally, consider the entry wages earned by immigrants to the US from poorer versus richer countries.<sup>16</sup> Using 1970 and 1980 Census data on the US earnings of immigrants from 41 countries, Borjas (1987) finds that immigrants with 1% higher per capita income in their country of origin earn a 0.12% higher entry wage.<sup>17</sup> This regression controls for the immigrant's age and quantity of schooling, so the 0.12% gain may come from more teacherhuman capital in the country of origin. Suppose this is the case, and that teacherhuman capital and student time input are equally important in human capital accumulation (consistent with the evidence in Kendrick, 1976). Then human capital differences explain 24% of country differences in per capita income. This leaves 76% of

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<sup>16</sup> The enormous pressures for migration from poor to rich countries are themselves consistent with substantial differences in productivity, but could alternatively be explained by higher physical–human capital ratios and/or nonpecuniary advantages to living in richer countries.

<sup>17</sup> Immigrants may be more able than the average person in their country of origin. Borjas' regression controls for observable differences in immigrants' ability such as age, years of schooling, and English proficiency. In terms of unobservables, our calculation would be biased against human capital if positive selection (in Borjas' terminology) was greater the poorer the country of origin. As Borjas notes, the opposite may be true since income inequality tends to be greater in poorer countries.



income differences to be explained by differences in physical capital–output ratios and productivity. Given that the typical finding is that physical capital explains 20% of country differences (see the results of Mankiw et al. (1992) with a one-third share), productivity differences are left to explain 56% of country income differences.

The conclusion we draw from all of this evidence is that differences in productivity are the primary cause of the large international dispersion in income per capita. Thus, although models of development that focus on physical and human capital accumulation are clearly important, we think more effort needs to be devoted to studying the causes of productivity differences across countries.

We think a useful framework for thinking about productivity differences across countries is in terms of a technology frontier and a distribution of distances from that frontier, as in Parente and Prescott (1994). Evidence consistent with the hypothesis that technology does not diffuse instantaneously or fully includes studies of international patenting by Eaton and Kortum (1995a,b) and studies of the correlation between country TFP and imports from R&D-doing countries by Coe and Helpman (1995) and Coe et al. (1995).

Yet skeptics argue that technology cannot differ across countries other than through differences in knowledge embodied in people, i.e. human capital. Lucas (1988) (p. 15) takes this view, and Mankiw (1995) (pp. 300–301) echoes it in arguing that “Knowledge, as opposed to capital, travels around the world fairly quickly”. But the transfer of knowledge may often be costly. Many countries pay fees to license individual foreign technologies. Benefiting from the knowledge embodied in imported capital and intermediate goods may entail setting up distribution channels. (Consistent with the existence of such fixed costs of importing, in Klenow and Rodríguez-Clare (1996) we find a larger variety of imports in larger markets.) Foreign technology may have to be adapted to local conditions. (For instance, hybrid corn diffused slowly across the US, mainly because of the cost of adapting it to specific regions (Griliches, 1957).) Tariffs, taxes, property rights, and corruption may affect the costs of technology transfer, leading to differences in country productivity levels.

Moreover, as stressed by Jovanovic (1996), when there are different types of human and physical capital the average levels of investment may contribute to differences in country productivity levels. For instance, models with technology embodied in equipment imply that the investment rate endogenously affects the average quality of capital in use. In both Jovanovic and Rob (1996) and Rodríguez-Clare (1996), for example, a lower domestic price of investment goods leads to a higher real investment rate and therefore more frequent upgrading of equipment quality (the fixed costs of technology adoption being paid more frequently at the firm level in Jovanovic and Rob’s model and at the market level in Rodríguez-Clare’s). Similarly, models where using new technology

requires technology-specific human capital imply that productivity can be higher where the human capital investment rate is higher. For example, in Ciccone (1994) more firms can profitably pay the fixed costs of importing specialized capital goods the higher the domestic levels of complementary technology-specific human capital.

## 5. Conclusion

To summarize, we see four main challenges for future growth research:

- (i) to simulate models and formally compare their predictions to the data;
- (ii) to empirically distinguish between theories of endogenous growth;
- (iii) to develop theories of international differences in productivity;
- (iv) to innovate in terms of data.

The most fully-developed version of (i) we have seen is Chari et al. (1996). We think this is the way to go to avoid mis-specification in empirical work and to fully exploit the quantitative implications of candidate models. As for (ii), we would like to see more work along the lines of Jones (1995a,b) and Kocherlakota and Yi (1996, 1997) that tests existing endogenous growth theories.

Important work has already been done under (iii). Recent papers show that inefficiencies may arise because of powerful groups that prevent the economy from using new technologies (Holmes and Schmitz, 1995; Parente and Prescott, 1996), because of inefficient government production (Schmitz, 1996a, b), because of government corruption that leads to rent seeking (Shleifer and Vishny, 1993), and because of trade barriers that reduce the variety of inputs imported (Romer, 1994). Other work develops models in which policies slow down technology diffusion, as in Parente and Prescott (1994), Barro and Sala-i-Martin (1995b) and Rodríguez-Clare (1996).

As for (iv), we think the insights gleaned from cross-country regressions have run into sharply diminishing returns. We would like to see more detailed country analysis *a la* Young (1995). Particularly useful would be evidence relevant to technology transfer. When fast-growing countries climb the product quality ladder, how important are trade, foreign direct investment, and reverse migration of specialized labor? Do individual firms, or managers, or production workers or some combination climb the product quality ladder? Or do new, better-educated entrants into the labor market start on a higher rung than previous cohorts, as suggested by Kim and Topel's (1992) study of South Korea? Data on these topics would help guide future theorizing and help refine and winnow existing theories.

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