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The Growth of Nations

AVERAGE INCOMES in the world's richest countries are more than ten times as high as in the world's poorest countries. It is apparent to anyone who travels the world that these large differences in income lead to large differences in the quality of life. Less apparent are the reasons for these differences. What is it about the United States, Japan, and Germany that makes these countries so much richer than India, Indonesia, and Nigeria? How can the rich countries be sure to maintain their high standard of living? What can the poor countries do to join the club?

After many years of neglect, these questions are again at the center of macroeconomic research and teaching. Long-run growth is now widely viewed to be at least as important as short-run fluctuations. Moreover, growth is not just important. It is also a topic about which macroeconomists, with their crude aggregate models, have something useful to say.

My goal here is to assess what we now know about economic growth. The scope of this paper is selective and, to some extent, idiosyncratic. The study of growth has itself grown so rapidly in recent years that it would take an entire book to discuss the field thoroughly.[1] In this paper, I do not try to lay out the many different views in the large literature on economic growth. Instead, I try to present my own views, as cogently as I can, on what we know about the growth of nations.

Textbook Neoclassical Theory

Most students of economics begin their study of long-run growth with the neoclassical model of capital accumulation. When discussing what we know about growth, this model is the natural place to start.

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1. Indeed, Barro and Sala-i-Martin (1995) have just finished such a book.

Overview

Robert Solow provided the most basic version of the neoclassical theory of growth.[2] The centerpiece of the model is the production function

$$(1) \qquad Y = F(K, AL),$$

where Y is output, K is capital, L is labor, and A is a measure of the level of technology. AL can be seen as the labor force measured in *efficiency units*, which incorporates both the amount of labor and the productivity of labor as determined by the available technology. If we assume that the production function has constant returns to scale, we can write the production function as

$$(2) \qquad y = f(k),$$

where $y = Y/AL$, $k = K/AL$, and $f(k) = F(k,1)$. This production function relates output per efficiency unit of labor to the amount of capital per efficiency unit of labor.

The neoclassical model emphasizes how growth arises from the accumulation of capital. The capital stock per efficiency unit, k, evolves according to

$$(3) \qquad \dot{k} = sf(k) - (n + g + \delta)k,$$

where s is the rate of saving, n is the rate of population growth, g is the rate of growth in technology, δ is the rate at which capital depreciates, and a dot over a variable denotes change per unit of time. The model takes s, n, g, and δ as exogenous.

As long as the production function is well behaved, the economy approaches a steady state over time. The steady state is defined by

$$(4) \qquad \dot{k} = 0,$$

or, using a star to denote a steady-state value,

$$(5) \qquad sf(k^*) = (n + g + \delta)k^*.$$

In the steady state, income per efficiency unit, $y^* = f(k^*)$, is constant. Income per person grows at rate g, and total income grows at rate $(n + g)$.

2. Solow (1956).

Predictions

One strength of Solow's version of the neoclassical growth model is that, despite its simplicity, it has many predictions. Since these predictions are so well-known, I will not formally derive them here. But, in evaluating the usefulness of the model in explaining growth experiences, it is worth stating some of these predictions once again:

1. In the long run, the economy approaches a steady state that is independent of initial conditions.
2. The steady-state level of income depends on the rates of saving and population growth. The higher the rate of saving, the higher the steady-state level of income per person. The higher the rate of population growth, the lower the steady-state level of income per person.
3. The steady-state rate of growth of income per person depends only on the rate of technological progress; it does not depend on the rates of saving and population growth.
4. In the steady state, the capital stock grows at the same rate as income, so the capital-to-income ratio is constant.
5. In the steady state, the marginal product of capital is constant, whereas the marginal product of labor grows at the rate of technological progress.

These predictions are broadly consistent with experience. If factors of production earn their marginal product, then the last prediction can be tested with data on factor prices. As a first approximation, in the U.S. economy the real wage grows at about the same rate as income per person, and the profit rate exhibits little trend. These facts are consistent with prediction 5. Similarly, the capital-to-income ratio exhibits little trend, which is consistent with prediction 4.

The dependence of steady-state income on saving and population growth rates (prediction 2) also appears to be consistent with experience. In cross-country data income per person is positively correlated with saving rates and negatively correlated with population growth rates. Moreover, these correlations are quite strong: a regression of income per person on these two variables alone, using a sample of ninety-eight countries, yields an adjusted R^2 of 59 percent.[3] It is possible that

3. Mankiw, Romer, and Weil (1992, p. 414).

reverse causality is part of the story here; but at the very least, these correlations do not give any reason to doubt the model.

The other two predictions are less easily evaluated. The inability of saving to affect steady-state growth (prediction 3) might appear inconsistent with the strong correlation between growth and saving across countries. But this correlation could reflect the transitional dynamics that arise as economies approach their steady states. The independence of the steady state from initial conditions (prediction 1) is closely related to the debate over convergence, which I discuss below.

The simplicity of the neoclassical model, together with its ability to yield substantive and seemingly reasonable predictions, has given it a prominent place in the macroeconomist's toolbox. Whenever practical macroeconomists have to answer questions about long-run growth, they usually begin with a simple neoclassical growth model. For example, when the 1994 *Economic Report of the President* discusses the benefits of higher national saving, it does so by offering numerical simulations from a standard growth model of the sort Solow presented almost forty years earlier.[4]

Household Behavior

So far I have followed Solow's rendition of the neoclassical model in treating the saving rate as an exogenous parameter. This approach is extraordinarily useful. It allows us to abstract from household behavior in order to highlight the roles of capital accumulation, population growth, and technological progress. In other words, by sweeping the saving decision under the rug, we can concentrate our attention on the production side of the model.

If we want to add an explicit analysis of household behavior, we can choose from two basic approaches. We can follow Paul Samuelson and Peter Diamond and model the economy as composed of a series of overlapping generations, each with a finite lifetime.[5] Or we can follow Frank Ramsey, David Cass, and Tjalling Koopmans and model the economy with a single, infinitely lived representative consumer.[6] Both of these

4. *Economic Report of the President*, 1994, pp. 85–87.
5. See Samuelson (1958) and Diamond (1965).
6. See Ramsey (1928), Cass (1965), and Koopmans (1965).

approaches parsimoniously turn the Solow model into a rigorous general-equilibrium model.

These two models of household behavior differ in some important respects. For example, in the overlapping-generations model, the economy can accumulate too much capital. In particular, the economy can reach a steady state with the capital stock greater than what Edmund Phelps called the Golden Rule level.[7] This outcome is not possible in the representative-consumer model, for the representative consumer would never choose an allocation of resources that is dynamically inefficient.[8] To give another example, in the overlapping-generations model, government debt can alter the saving rate and the capital stock. In the representative-consumer model, Ricardian equivalence holds, and so government debt does not crowd out capital.

For most of the issues addressed by neoclassical growth theory, however, the two approaches to household behavior yield similar results. In both the overlapping-generations and representative-consumer models, the economy reaches a steady state with a constant saving rate. The steady-state saving rate is higher when consumer preferences exhibit more patience. In both models, a constant saving rate can arise even out of steady state for specific functional forms and parameter values. The steady states in these models are much the same as the steady states in the Solow model. In particular, the five predictions listed above continue to hold.

In my view, neither of these standard approaches to modeling household behavior is fully satisfactory, for neither holds up under empirical scrutiny. The overlapping-generations model assumes that all saving is for life-cycle purposes; yet bequests are a large part of wealth accumulation.[9] The representative-consumer model assumes that all consumers look into the infinite future when deciding how much to save; yet many people leave no bequests and, therefore, are not economically linked to future generations. Both models of household behavior are based on the premise that people smooth consumption over their own lifetimes; yet, in the world, consumption smoothing is far from perfect.[10]

7. Phelps (1961).

8. Although important as a matter of theory, excessive capital accumulation is not a practical concern for policymakers. Actual economies appear to have less capital than the Golden Rule level. See Abel and others (1989).

9. Kotlikoff and Summers (1981).

10. Campell and Mankiw (1989).

For the purposes of this paper, these issues regarding household behavior are tangential. Little would be added (and much generality would be lost) by tying the analysis to either the overlapping-generations model or the representative-consumer model. Therefore, like Solow, I will abstract from household behavior and take the saving rate as given.

I do not mean this choice to suggest that explaining saving is uninteresting or unimportant. Indeed, as I hope to make clear, the saving rate is a crucial variable to understand. Yet the models of saving routinely employed in the growth literature do not take us very far toward this goal. Until better models of household behavior are developed, the most we can do is discuss some general lessons about economic growth that apply regardless of what determines national saving.

Theoretical Objections

Is the neoclassical model a good theory of economic growth? Although this question is largely empirical, one might also answer it along theoretical lines. Before turning to the data, therefore, let us consider some possible theoretical objections one might lodge against the neoclassical growth model.

One might object to the model on the grounds that it does not, in the end, shed light on economic growth. In the steady state of the neoclassical model, all growth is due to advances in technology, but technological progress is taken as exogenous. It might seem that the model unravels the mystery of economic growth simply by assuming that there is economic growth. Indeed, this critique helped to motivate the recent theories of endogenous growth, which I discuss later.

The persuasiveness of this objection to the neoclassical model depends on the purpose of growth theory. If the goal is to explain why standards of living are higher today than a century ago, then the neoclassical model is not very illuminating. In my view, however, the goal is not to explain the *existence* of economic growth. That task is too easy: it is obvious that living standards rise over time largely because knowledge expands and production functions improve.

A more challenging goal is to explain the *variation* in economic growth that we observe in different countries and in different times. For this purpose, the neoclassical model's assumption of constant, exogenous technological change need not be a problem. Even with this assumption, the model predicts that different countries will reach different steady-state levels of income per person, depending on their rates of saving and population growth. And it predicts that countries will have different rates of growth, depending on each country's initial deviation from its own steady state. Thus, the assumption of constant, exogenous technological change does not preclude addressing many of the central issues of growth theory.

To use the neoclassical model to explain international variation in growth requires the assumption that different countries use roughly the same production function at a given point in time. To some writers, this assumption is preposterous.[11] In poor countries, workers dig ditches with shovels. In rich countries, they use bulldozers. Common sense seems to suggest that we abandon the premise of a common production function.

In my view, this objection to the neoclassical model is also not persuasive. The production function should not be viewed literally as a description of a specific production process, but as a mapping from quantities of inputs into a quantity of output. To say that different countries have the same production function is merely to say that if they had the same inputs, they would produce the same output. Different countries with different levels of inputs need not rely on exactly the same processes for producing goods and services. When an economy doubles its capital stock, it does not give each worker twice as many shovels. Instead, it replaces shovels with bulldozers. For the purposes of modeling economic growth, this change should be viewed as a movement along the same production function, rather than as a shift to a completely new production function.

In summary, various theoretical objections can be advanced against the neoclassical growth model. Yet none is compelling. More important is the empirical question: Can the model help to explain the wide variation in economic experiences observed throughout the world?

Three Problems for Neoclassical Growth Theory

The neoclassical model has come under attack in recent years as providing an empirically inadequate theory of growth. I now turn to some

11. See, for example, Grossman and Helpman (1994).

of the problems that arise when this model is brought to the data. In particular, I consider three reasons to doubt the validity of the neoclassical model, at least as it has been traditionally interpreted.

The approach I take here is one of calibration rather than estimation. The problems that I highlight do not hinge on subtle issues of theory or econometrics. They are, I hope to show, robust implications of the neoclassical model that are evaluated fairly easily. The issue at hand is not whether the neoclassical model is exactly true. The issue is whether the model can even come close to making sense of international experience.

Problem 1: The Magnitude of International Differences

Suppose, for the moment, that all economies were in their steady states. The neoclassical model predicts that different countries should have different levels of income per person, depending on the various parameters that determine the steady state. To see these predictions, consider the two steady-state conditions:

$$sy^* = (n + g + \delta)k^*, \tag{6}$$

and

$$y^* = f(k^*). \tag{7}$$

Equation 6 says the saving must equal break-even investment (the amount of investment required to keep k constant). Equation 7 is the production function.

To see the predicted variation in income per person, differentiate this system and solve for dy^* to obtain

$$dy^*/y^* = [\alpha/(1 - \alpha)][ds/s - d(n + g + \delta)/(n + g + \delta)], \tag{8}$$

where $\alpha = f'(k^*)k^*/f(k^*)$. If the factors of production earn their marginal product, then α is the steady-state capital share. Notice that this equation does not require that the production function be Cobb-Douglas. If it is Cobb-Douglas, then α is a constant production function parameter.

Equation 8 is easily calibrated with data from the national income accounts. A standard estimate of the capital share is one-third, so $\alpha/(1 - \alpha)$ is one-half. The equation now shows the magnitude of income differences that the neoclassical model can explain. In particular, it says that differences in rates of saving will lead to differences in income that are proportionately half as large. If one country's saving rate is four times that of another country, its steady-state income will be about twice as large.

The equation also has numerical implications for the impact of population growth. For example, suppose that $(g + \delta)$ is 5 percent per year. (As I discuss later, this figure is about right.) Then, a decrease in population growth from 3 to 1 percent per year reduces $(n + g + \delta)$ from 8 to 6 percent. If $\alpha/(1 - \alpha)$ is one-half, then steady-state income moves proportionately half as much as $(n + g + \delta)$. Hence, a country with 1 percent population growth will have steady-state income 1.15 $[(8/6)^{1/2}]$ times the steady-state income of a country with 3 percent population growth.

These calculations show the first defect of the neoclassical model: it does not predict the large differences in income observed in the real world. A comparison of rich and poor countries finds saving rates that differ by about a multiple of four and population growth rates that vary by about 2 percentage points.[12] The above calculations, therefore, indicate that the model can explain incomes that vary by a multiple of slightly more than two. Yet income per person varies by a multiple of more than ten. There is much more disparity in international living standards than the neoclassical model predicts.

These findings might once again call into question the assumption that all countries operate with the same production function. Perhaps poor countries have not only low saving and high population growth, but also poor production technologies. But it should be clear that the magnitude of the unexplained differences makes this explanation unsatisfactory. My calculations above indicate that the neoclassical model leaves a multiple of five in income per person unexplained. If differences in the production function are the reason, then poor countries must be using a technology that is vastly inferior to that of rich countries. That is, poor countries could be producing much more output without increasing the quantities of their capital or their labor. If this were the case, the incentive to imitate technology used by rich countries would be tremendous.[13]

Of course, imitating technology is not necessarily so easy. To adopt

12. See Mankiw, Romer, and Weil (1992, data appendix).

13. It may be helpful to state this point in units of time. If technological change enhances productivity by 2 percent per year, and if rich countries are five times as productive as poor countries, then poor countries must be using a production function that is about eighty years out of date.

the best available technology, an economy may need a skilled labor force. In this case, however, it would not be enough simply to assert that there are international differences in production functions without further analysis. Instead, one is naturally led to think about the role of human capital in economic growth. I take up this issue later.

Problem 2: The Rate of Convergence

Much of the recent debate over economic growth has centered on the issue of *convergence*. Convergence has usually been defined as a tendency of poor economies to grow more rapidly than rich economies. Convergence in this sense might more properly be called mean reversion.

Whether convergence is found in the data depends on the sample being examined. Samples that include relatively homogeneous economies, such as the countries of the OECD or the states of the United States, typically yield evidence of convergence.[14] Yet more diverse samples give the opposite result. In large samples of countries, such as the data set compiled by Robert Summers and Alan Heston, a country's initial level of income per person is not correlated with its subsequent growth rate.[15]

As I have described the neoclassical model, it does not necessarily predict convergence. If countries are in different steady states, then rich countries remain rich, and poor countries remain poor. On the other hand, if all countries have the same steady state and differ only in initial conditions, then the model does predict convergence. Those who reject the neoclassical model on the grounds that it predicts convergence, which does not occur in large samples of countries, appear to be assuming this very special case of identical steady states.

More generally, the neoclassical model predicts that each economy converges to its own steady state, which in turn is determined by its saving and population growth rates. This prediction has been called conditional convergence. To test for conditional convergence, various authors have run regressions of growth rates on initial income, including variables to control for determinants of the steady state.[16] Most studies

14. See, for example, Dowrick and Nguyen (1989), and Barro and Sala-i-Martin (1991).

15. Summers and Heston (1991); Romer (1987).

16. See, for example, Barro (1991), Mankiw, Romer, and Weil (1992), and Levine and Renelt (1992).

have found evidence of conditional convergence at a rate of about 2 percent per year. That is, each country moves 2 percent closer to its own steady state each year and, by implication, moves halfway toward its steady state in thirty-five years. This rate of conditional convergence is fairly robust to the sample being examined.

Although conditional convergence is qualitatively consistent with the neoclassical model, the model begins to have problems once again when we turn to its quantitative predictions. According to the model, income converges to its steady-state level as follows:

$$\dot{y} = -\lambda(y - y^*), \tag{9}$$

where

$$\lambda = (1 - \alpha)(n + g + \delta). \tag{10}$$

These equations are derived in the appendix. For the purposes at hand, the key parameter is the rate of convergence, λ. This parameter measures how quickly a deviation from steady state dissipates over time. If n, g, and δ are measured as percent per year, then λ indicates the percentage of the deviation from steady state that is eliminated each year.[17]

This formula is easily calibrated. In the United States, for example, the capital share, α, is about one-third, and the rate of population growth, n, is about 1 percent per year. The average rate of growth of income per person is about 2 percent per year, which gives us a value for g. If we take the capital consumption allowance and divide it by the capital stock, we obtain an estimate of the depreciation rate, δ, of 3 percent per year. Together with the equation above, these estimates give a predicted rate of convergence, λ, of 4 percent per year. At this rate, an economy would go halfway toward its steady state in seventeen and one-half years.

Hence, although the model does predict the conditional convergence found in the empirical literature on economic growth, it does not predict the rate of convergence that these studies estimate. In particular, the model predicts convergence at about twice the rate that actually occurs. In practice, economies do regress toward their conditional mean, but

17. The rate of convergence depends on the steady-state capital share, α, but not on the specific form of the production function. If the production function happens to be Cobb-Douglas, then α is a production function parameter. If it is not Cobb-Douglas, then α will depend on the saving rate as well as production function parameters.

only slowly. An economy's initial condition matters for much longer than the model says it should.

Problem 3: Rates of Return

A third critique of the neoclassical model emphasizes the predicted differences in rates of return. If poor countries are poor because they have small capital stocks, then the marginal product of capital should be high. We should, therefore, observe higher profit rates and higher real interest rates in poor countries. Moreover, capital should be eager to flow from rich to poor countries.

There is some evidence for return differentials of this sort. Because the profit rate is capital income divided by the capital stock, it also equals the capital share of income divided by the capital-income ratio. If one accumulates data on investment to obtain data on capital stocks, one finds that capital-income ratios are more than twice as large in rich as in poor countries.[18] Unless rich countries have capital shares that are also more than twice as large (which appears not to be the case), they must have lower profit rates. This seems qualitatively consistent with the neoclassical model.

Persistent return differentials are not necessarily puzzling, even in the presence of capital mobility, if the differentials are modest. Investment abroad, particularly in poor countries, involves greater information costs and greater risk of expropriation. Many American investors are only beginning to see the virtues of international diversification, even in other developed economies. Investment in the so-called emerging markets is still rare. Those investors who are now entering these markets, often through mutual funds, do expect to earn higher returns.

The neoclassical model runs into trouble when we turn from qualitative to quantitative predictions about rates of return. To see the magnitude of the predicted return differentials, consider the following equations (which hold both in and out of steady state):

$$y = f(k) \tag{2}$$

$$R = f'(k). \tag{11}$$

The first equation is the production function. The second equation says that the gross return to capital, R, is the marginal product of capital,

18. See, for example, Mankiw, Romer, and Weil (1992, p. 431).

which equals the first derivative of the production function. Differentiating these equations, with some manipulation, yields

$$dR/R = [ff''/(f')^2]\, dy/y. \tag{12}$$

Additional algebra allows substitution for f, f', and f'' in order to obtain a more easily interpreted expression:

$$dR/R = -[(1 - \alpha)/(\alpha\sigma)]dy/y, \tag{13}$$

where α is the capital share and σ is the elasticity of substitution between capital and labor.[19] This equation shows how the return to capital varies with the level of income.

As equation 13 illustrates, it is impossible to establish a quantitative prediction about return differentials without saying something about the elasticity of substitution between capital and labor. A common approach is to assume that the production function is Cobb-Douglas, so that $\sigma = 1$.[20] Imposing also the standard value for α of one-third gives

$$(1 - \alpha)/(\alpha\sigma) = 2. \tag{14}$$

That is, the return to capital moves proportionately twice as much (in the opposite direction) as the level of income. Because poor countries have about one-tenth the income of rich countries, they should have returns to capital that are about one hundred times as large. In particular, since the profit rate is about 10 percent per year in rich countries, it should be about 1,000 percent per year in poor countries. Detailed data are not necessary to reject this prediction. Moreover, the return differential is so large that the failure of capital to move toward poor countries cannot be explained by invoking information costs or political risk.

This prediction, however, relies crucially on the assumption of a Cobb-Douglas production function. The size of the predicted return differentials can be reduced by assuming a larger elasticity of substitution between capital and labor. If the elasticity is four, for example, the return to capital in a poor country should be only 3.2 [$10^{1/2}$] times as large as in a rich country, in contrast to the previous multiple of 100. Although this figure is still large, it is empirically much more plausible.[21]

19. Straightforward algebra establishes that $\alpha = f'k/f$ and $\sigma = [(f')^2/(f''f)][1 - f/(f'k)]$.

20. See, for example, Lucas (1990).

21. The calculations in this paragraph are indicative of how the elasticity of substitution matters, but they should not be taken too literally. These calculations rely on a log-linear approximation that is exact if σ equals one, but becomes less accurate as σ departs from one, for α is no longer a constant in this case.

A large elasticity of substitution is not as outlandish as it might first appear. Cobb-Douglas is often considered a reasonable assumption because factor shares in U.S. data are roughly constant over time. Yet, in the neoclassical model, factor shares are constant in the steady state for any production function. Factor shares may be roughly constant in U.S. data merely because the U.S. economy has not recently been far from its steady state. The approximate constancy of the capital-to-income ratio over time suggests that the U.S. economy has indeed been in a steady state.

In judging the plausibility of a large elasticity of substitution, keep in mind that an economy's elasticity depends not only on each industry's technology, but also on the ability to move resources among industries. For example, a large elasticity of substitution might arise because of international trade. In traditional Heckscher-Ohlin trade theory, international trade in goods equalizes factor prices in countries with different factor endowments. The implication of this factor-price-equalization theorem for growth theory is that trade increases an economy's ability to substitute capital and labor.[22] When a country's endowment of capital increases, it can increase exports of capital-intensive goods and increase imports of labor-intensive goods without altering the returns to either capital or labor. Each country has a production function that is, in effect, linear in capital and labor. In other words, as international trade works to equalize factor prices around the world, it drives the effective elasticity of substitution in each economy toward infinity.

There are, however, limits to how high the elasticity of substitution can plausibly be set when trying to explain the return to capital. This can be seen by considering the return to the other factor of production—labor. In the neoclassical model, the real wage, W, is

$$W = f(k) - f'(k)k. \tag{15}$$

This equation, together with the production function, $y = f(k)$, implies

$$dW/W = (1/\sigma)dy/y. \tag{16}$$

The wage is positively related to income per person. In contrast to capital, labor should be eager to migrate from poor to rich countries, since larger capital stocks raise labor productivity and real wages. Of course, these predictions about wages and migration are consistent with experi-

22. See Ventura (1994).

ence. The magnitude of the predicted effects, however, diminishes as the elasticity of substitution rises. Although the elasticity of substitution may be greater than its traditional Cobb-Douglas value of one, international experience on factor returns cannot be explained merely by positing that this elasticity is very large.

In summary, the neoclassical growth model can be evaluated by examining how the return to capital differs across countries. The size of the predicted differentials, however, depends on the production function. The larger the elasticity of substitution between capital and labor, the smaller the return differentials. For the traditional Cobb-Douglas production function, the return differentials predicted by the neoclassical model are vastly larger than are observed in the world.

A New View of Capital

The neoclassical growth model emphasizes the accumulation of capital over time. To use the model to shed light on international experience, one must have some interpretation of the term *capital* and some way of measuring the *return to capital*. Traditionally, capital is thought to be tangible—it includes the economy's stock of equipment and structures. The return to capital is the profit received by the owners of equipment and structures.

Over the past decade, a new view of capital has emerged. According to this view, the return to capital is a much larger fraction of national income than has been traditionally believed. This new view alters the interpretation of the neoclassical growth model and, by doing so, greatly expands its scope and applicability.

The Key Role of the Capital Share

The previous section discussed three problems that arise when the neoclassical growth model is used to understand international experience. First, the model predicts less variation in income than is observed across countries. Second, the model predicts a faster rate of convergence to the steady state than most studies estimate. Third, the model predicts greater variation in rates of return across countries than is empirically plausible.

Recall that these conclusions were derived from the following equations:

$$dy^*/y^* = [\alpha/(1 - \alpha)][ds/s - d(n + g + \delta)/(n + g + \delta)],$$

$$\lambda = (1 - \alpha)(n + g + \delta),$$

$$dR/R = -[(1 - \alpha)/(\alpha\sigma)]dy/y.$$

Looking at these equations for a minute yields an important insight: *The capital share, α, plays a key role in each of the three problems*. The reason is that the capital share determines the shape of the production function. To be precise, one can show that the elasticity of the average product of capital, $f(k)/k$, with respect to amount of capital, k, is $(\alpha - 1)$. The larger the capital share, the less rapidly the average product declines. Thus, a larger value of α implies that changes in saving have greater effects on steady-state income, that the transition to the steady state is slower, and that the return to capital varies less with income.

In my earlier calculations, I used a conventional estimate for the capital share of one-third. This estimate comes from the national income accounts. In the U.S. economy, capital receives about one-third of gross income, and labor receives about two-thirds. Approximately the same is true in the other developed economies for which good data on factor income are available.

Suppose, however, that the capital share were two-thirds rather than one-third. (For now, do not ask how this could be true. I will turn to that question in a moment.) Let us see how this increase in the capital share would affect each of the problems with neoclassical growth theory.

Consider first the predicted differences in steady-state income. An increase in the capital share, α, from one-third to two-thirds raises $\alpha/(1 - \alpha)$ in the first equation from one-half to two. Income now moves proportionately twice as much as the rate of saving, rather than half as much. If one country has four times the saving rate as another, it would have sixteen times as much income per person, rather than only two times as much. Thus, the model can now explain variation in income of the magnitude observed.

This increase in the capital share also raises the predicted impact of population growth, n, on steady-state income. Suppose that $(g + \delta)$ is 5 percent per year, and we are comparing one country with population growth of 1 percent per year and another with population growth of 3 percent per year. In this case, $(n + g + \delta)$ is 6 percent in the first country and 8 percent in the second. If $\alpha/(1 - \alpha)$ is one-half, then income in the country with low population growth is 1.15 $[(8/6)^{1/2}]$ times income in the country with high population growth. Yet if $\alpha/(1 - \alpha)$ is two, the predicted multiple is 1.78 $[(8/6)^2]$. Thus, with a larger capital share, differences in population growth are predicted to lead to much larger differences in income.

Next, consider the predicted rate of convergence. If the capital share, α, is two-thirds rather than one-third, the implied convergence parameter, λ, is half as large. For the other parameter values used earlier, $(n + g + \delta) = 0.06$, and $\lambda = 0.02$. Thus, the model now predicts the rate of convergence estimated in the empirical literature.

Finally, consider the implied differences in the return to capital between a rich country and a poor country with incomes that differ by a multiple of 10. For concreteness, suppose that the elasticity of substitution, σ, is one. The last equation says that the return moves proportionately twice as much as income if the capital share is one-third. Yet the return moves proportionately half as much as income if the capital share is two-thirds. Thus, the predicted return differential falls from a multiple of 100 $[10^2]$ to a multiple of 3.16 $[10^{1/2}]$. And if the capital share is larger than two-thirds, the predicted return differential is smaller still.

Once again, the elasticity of substitution, σ, is significant. If this elasticity is four rather than one, then the last equation (with $\alpha = 2/3$) says that the return to capital moves proportionately one-eighth as much as income. In this case, the return in a poor country is predicted to be only 1.33 $[10^{1/8}]$ times the return in a rich country. That is, if the return to capital is 10 percent per year in rich countries, then it should be 13 percent per year in poor ones.

The predicted return differentials now appear unobjectionable. It is not at all implausible to think that the emerging economies offer returns of 3 percentage points per year higher than is available in developed economies. Keep in mind that, for the purpose of these comparisons, the relevant return is gross of taxes and political risks. Foreign investors in emerging economies might require compensation of several percent per year just to compensate them for the risk of expropriation.[23]

Hence, each of the three problems with the neoclassical model of

23. The night this paragraph was written, the television show "60 Minutes" ran a segment on Nigerians posing as government officials to defraud American businessmen, and the Nigerian government's failure to prosecute the con men. Viewers of this show were left in no doubt as to why capital does not flow from rich to poor countries.

growth would disappear if the capital share were much higher than is conventionally understood. As a theoretical matter, this resolution is attractive for its parsimony: it solves three serious problems by changing the value of one parameter. The question is, why should one believe that the capital share is actually so high?

Capital with Externalities

One way to raise the capital share above one-third is to argue that there are positive externalities to capital. That is, some of the benefits to capital accumulation may accrue not to the owners of capital, but to others in society. If new ideas arise as capital is built, for example, and if these ideas enter the general pool of knowledge, then even if capital receives only one-third of income, in some sense it deserves credit for more.

One of the recent advances in growth theory, due largely to Paul Romer, has been the ability to formalize this idea.[24] Suppose that each individual firm, i, in an economy has the production function

$$y_i = \theta k_i^a, \tag{17}$$

where θ is a parameter that each firm takes as given. Also suppose that, because of externalities to capital, the technology available to each firm is determined by the average firm's level of capital, k, so that

$$\theta = k^b. \tag{18}$$

Then the production function for the economy is

$$y = k^{a+b}. \tag{19}$$

In this case, the parameter a measures the role of capital in each firm's production function; it determines the fraction of income paid to the owners of capital. Yet the role of capital in the economy's production function is measured by $(a + b)$. For the purposes of calibrating the neoclassical growth model, the capital share, α, should be set equal to $(a + b)$.

For the economy's capital share, α, to be much larger than the share of income received by the owners of capital, the externalities to capital must be large. To raise the capital share from one-third to two-thirds,

24. Romer (1986, 1987).

the externality (as measured by the parameter b) must be about as large as the direct benefit (as measured by the parameter a). That is, the owners of capital must be paid only half of the social return from their investments.

In evaluating the plausibility of such an externality, it is important to note that the externality must be geographically limited if it is to help explain differences across countries. One commonly cited external benefit to capital accumulation is the creation of ideas. Yet since many ideas, like public goods, are neither rival nor excludable, they flow freely around the world. If externalities to capital are to make the neoclassical model conform to experience, the parameter b should be taken to measure the benefits to capital that are external to the firm and yet stop at the border.

It is hard to know how large such externalities could be. The idea that capital conveys positive externalities is plausible. It is easier to be skeptical whether capital conveys local externalities of the magnitude necessary to save the neoclassical model from the three problems discussed above.

Human Capital

A second argument for a larger capital share posits that capital is a much broader concept than is suggested by the national income accounts. In the national income accounts, capital income includes only the return to *physical capital*, such as plant and equipment. More generally, however, we accumulate capital whenever we forgo consumption today in order to produce more income tomorrow. In this sense, one of the most important forms of capital accumulation is the acquisition of skills. Such *human capital* includes both schooling and on-the-job training.

When applying the neoclassical model to understand international experience, it seems best to interpret the variable k as including all kinds of capital. Thus, the capital share, α, should include the return to both physical and human capital. Yet, the return to human capital is not part of capital income in the national income accounts. Instead, it is part of labor income. Therefore, if we use the national income accounts to calibrate the neoclassical model, we are likely to substantially underestimate the capital share.

To gauge the true capital share, it is necessary to decide how much of labor income should be credited to human capital. To do this, we might look at the minimum wage, which is roughly the return to labor with minimal human capital. In the United States the minimum wage today is about one-third of the average wage. This fact suggests that the return to human capital is about two-thirds of labor income, or almost one-half of national income.

Another way to estimate the human capital share of income is to look at the return to schooling. A large literature in labor economics finds that each year of schooling raises a worker's wage by at least 8 percent. Moreover, the average American has about thirteen years of schooling.[25] Together these facts imply that the average worker earns almost three times as much as he would without any human capital. Again, this suggests that about two-thirds of the average worker's earnings is the return to his education, and that human capital earns almost one-half of national income.

Adding this estimate of the human capital share to the physical capital share of one-third, we find that the income from all forms of capital is about 80 percent of national income. Hence, when calibrating the neoclassical model, the capital share, α, should be set at about 0.8. For reasons already discussed, a parameter value of this magnitude makes the neoclassical model conform much more closely to international experience.

Reinterpreting capital to include human capital, however, creates a new problem: Data from the national income accounts correspond less well to the variables in the model. Most of the accumulation in human capital takes the form of forgone wages of students in school or workers in training. The national income accounts do not include this expenditure on human capital in either measured investment or measured GDP. Moreover, most direct expenditures on human capital, such as on teachers and books, enter the national income accounts as consumption rather than investment.

Focusing on human capital does help to resolve an earlier problem: the international comparison of rates of return. There is a large literature estimating the returns to schooling around the world. George Psacharopoulos summarizes results from over 60 countries.[26] The findings are

25. Psacharopoulos (1985, table 3) and *Statistical Abstract of the United States, 1993*, table 230.

26. Psacharapoulos (1985).

consistent with the neoclassical model and its prediction of diminishing marginal product. The measured return to schooling is consistently larger in poor countries than in rich countries.

Acknowledging the role of human capital can also help explain why capital does not flow from rich to poor countries. Because human capital does not serve well as collateral, borrowing to finance human capital investment is often difficult, even in rich countries with developed financial institutions. It is not surprising that resources do not flow into poor countries to help them finance investment in human capital. Moreover, once we acknowledge this capital market imperfection, the failure of physical capital to flow is less puzzling. Because human and physical capital are complementary inputs in production, imperfections in the financing of human capital impede the international movement of physical capital as well.[27]

Incorporating human capital investment into the neoclassical model also raises the proportion of international variation that the model can explain. As mentioned earlier, a cross-country regression of income per person on saving and population growth rates yields an R^2 of 59 percent. If a measure of saving in the form of human capital is added to this regression, the R^2 rises to 78 percent.[28] Put simply, most international differences in living standards can be explained by differences in accumulation of both human and physical capital.

Hence, broadening the meaning of capital to include human as well as physical capital can help make the neoclassical growth model consistent with international experience. In this case, one can argue for a large capital share without invoking externalities of any sort. Of course, externalities to capital, either physical or human, could still exist. If so, the implied capital share is higher still. But externalities are not necessary for the capital share to be large. Either with or without externalities, the role of capital in economic growth appears much greater than traditionally has been assumed.

Theories of Endogenous Growth

So far, my attention has centered on the neoclassical growth model. I have taken the conservative position that we should begin with this stan-

27. Barro, Mankiw, and Sala-i-Martin (1995).
28. Mankiw, Romer, and Weil (1992, p. 420).

dard model, see what problems arise when we go to the data, and then try to make the minimal changes necessary to make the model work. If we are willing to give the capital share a value much larger than traditionally has been assumed, the major problems with this model disappear, and the model becomes a useful framework for understanding international differences in economic growth.

Yet much of the recent literature on economic growth has taken a more radical approach. The neoclassical model, even with capital interpreted broadly, implies that growth in income per person eventually approaches g, the exogenous rate of technological progress. Although the model can explain international differences in growth rates as the result of convergence to different steady states, it cannot explain the persistence of economic growth throughout most of the world. Persistent growth is built into the neoclassical model in a way that is simple but not terribly illuminating. The goal of much recent work in growth theory, therefore, has been to develop models of persistent growth that avoid the assumption of exogenous advances in technology. Hence, this work goes by the name *endogenous growth theory*.

The Basic Model

The idea behind endogenous growth theory can be seen most easily by considering the production function, $Y = AK$. This production function has the property of constant returns to the accumulated factor. If we double the amount of capital, we double the amount of output. To see what this implies for economic growth, consider the accumulation equation:

$$\dot{K} = sY - \delta K. \tag{20}$$

This equation, together with the $Y = AK$ production function, implies

$$\dot{Y}/Y = \dot{K}/K = sA - \delta. \tag{21}$$

As long as $sA > \delta$, income grows forever, even without the assumption of exogenous technological progress.

Thus, a simple change in the production function can dramatically alter the predictions about economic growth. In the neoclassical model, saving leads to growth temporarily, but eventually the economy approaches a steady state in which growth is independent of the saving rate. By contrast, in this endogenous growth model, saving leads to growth forever.

The endogenous growth model can be viewed as a limiting case of the neoclassical model. As I showed above, the rate of convergence to the steady state in the neoclassical model depends on the capital share. As the capital share, α, goes to one, the rate of convergence, λ, goes to zero. The basic endogenous growth model is, in essence, the limiting case of the neoclassical model in which convergence is so slow as to be nonexistent. In the endogenous growth model, the transitional dynamics of the neoclassical model last forever.

This limiting case has two notable properties. First, differences in saving rates across countries lead to increasingly large differences in income over time. Second, large differences in income are not associated with differences in the return to capital. Thus, the world can contain great disparities in income without any incentive for capital to move from rich to poor countries.

In some sense, the endogenous growth model is not really novel. Solow himself pointed out in his original article that if the production function were not well behaved, his model might not have a steady state.[29] Solow noted that, in this case, capital accumulation can lead to perpetual growth. The innovation in endogenous growth theory is to make this case canonical.

The question is, how do we interpret the variable K in the production function, $Y = AK$? If K is seen as including only the economy's stock of plant and equipment, then it is natural to assume diminishing returns. That is probably why Solow chose not to emphasize the possibility of endogenous growth in his model. Yet if we interpret K more broadly, then the assumption of constant returns to capital is more palatable. Thus, the literature on endogenous growth has often relied on capital with externalities and human capital when making the case for constant returns.

The most appealing way of interpreting the endogenous growth model is to view knowledge as a type of capital. It is clear that scientific discoveries build on previous scientific discoveries. Knowledge is used to produce knowledge. Compared to other forms of capital, the production of knowledge seems less likely to exhibit diminishing returns. Indeed, as Paul Romer and, more recently, Michael Kremer have emphasized, if

29. Solow (1956, p. 77).

we look over very long spans of history it appears that growth has accelerated somewhat over time.[30] The production of knowledge might even exhibit increasing returns.

It is worthwhile to distinguish here between *knowledge* and *human capital*. Although the two terms are sometimes treated as synonyms, there is an important difference. Knowledge refers to society's understanding about how the world works. Human capital refers to the resources expended transmitting this understanding to the labor force. Put crudely, knowledge is the quality of society's textbooks; human capital is the amount of time that has been spent reading them. Even if the accumulation of knowledge does not encounter diminishing returns, it seems likely that the accumulation of human capital does. The best case for endogenous growth, therefore, relies on knowledge rather than human capital as the source of perpetual growth.

Bells and Whistles

The $Y = AK$ model is the simplest example of endogenous growth, but it does not do justice to the large literature on endogenous growth theory. The literature has moved two steps further. The first step was to develop models with more than one sector of production; for instance, one sector might produce goods and services while another sector produces innovations in technology. The second step was to develop models that incorporate the microeconomic decisions behind the research process. Both are steps in the direction of offering a more explicit description of how economic growth arises from the accumulation of knowledge.

To see what can be learned from models with more than one sector, consider the following example of endogenous growth based on the work of Hirofumi Uzawa, Robert Lucas, and Casey Mulligan and Xavier Sala-i-Martin.[31] The economy has two sectors: manufacturing firms and research universities. Firms produce goods and services, which are used for consumption and capital accumulation. Universities produce a factor of production called knowledge, which is then freely used in both sectors. The economy is described by the production function for firms,

30. See Romer (1986) and Kremer (1993).

31. See Uzawa (1965), Lucas (1988), and Mulligan and Sala-i-Martin (1993).

the production function for universities, and the capital accumulation equation:

(22) $$Y = F[K,(1 - u)HL],$$

(23) $$\dot{H} = g(u)H,$$

(24) $$\dot{K} = sY - \delta K,$$

where u is the fraction of the labor force in universities, H is the stock of knowledge, and $g' \geq 0$. The rest of the notation is standard. As before, the production function for the manufacturing firms is assumed to be homogeneous of degree one in its two arguments.

This model is a cousin of the $Y = AK$ model. In particular, this economy exhibits constant returns to scale in the accumulated factors of production. If we double the inputs of capital and knowledge, we double the output of both sectors. Like the $Y = AK$ model, this model can generate perpetual growth without the assumption of exogenous shifts in the production function.

This model is also a cousin of the neoclassical growth model. For any constant u, knowledge, H, grows at the constant rate g, and the model is exactly the one Solow analyzed in 1956. Thus this model has the transitional dynamics of the neoclassical model. When the stock of capital is low relative to the stock of knowledge (that is, when K/HL is below its steady-state value), the economy's production of goods and services grows more quickly. In contrast to the $Y = AK$ model, this endogenous growth model can explain conditional convergence.

There are two key decision variables in this model. As in the neoclassical model, the fraction of output used for saving and investment determines the stock of capital. In addition, the fraction of labor used in universities determines the stock of knowledge. Both s and u affect the level of income, although only u affects the long-run growth rate. Thus, this model of endogenous growth takes a small step toward showing which societal decisions determine the rate of technological change.[32]

Yet even this endogenous growth model tells only a rudimentary story about the creation of knowledge. If one thinks about research for even a

32. For a discussion of decisionmaking and dynamics in this kind of endogenous growth model, see Barro and Sala-i-Martin (1995, chap. 5).

moment, three facts become apparent. First, even though knowledge is largely a public good, much research is done in firms that are driven by the profit motive. Second, research is profitable because innovations give firms temporary monopolies, either because of the patent system or because there is an advantage to being first. Third, when one firm innovates, other firms build on that innovation in order to produce the next generation of innovations. These (essentially microeconomic) facts are not easily connected with the (essentially macroeconomic) growth models discussed so far.

Some recent work on endogenous growth is aimed at incorporating these facts about research and development by melding the theory of monopolistic competition into the theory of growth.[33] One virtue of this class of endogenous growth models is that it offers a detailed description of the process of innovation. In linking technological change and market power, these models harken back to themes that Joseph Schumpeter emphasized many years ago.[34] The recent formalization is valuable both for clarifying these old ideas and for providing a framework in which to examine the welfare properties of equilibria.

Whither Endogenous Growth?

Like many theories, the theory of endogenous growth has its place but has been oversold by its advocates. Its value is twofold. First, it helps explain the existence of worldwide technological progress, which the neoclassical growth model takes as given. Second, it offers a more realistic description of research and development.

Yet for practical macroeconomists trying to understand international differences, the payoff from endogenous growth theory is not clear. Models that emphasize unmeasurable variables such as knowledge are hard to bring to the data. It is not surprising, therefore, that these models have appealed to more theoretically inclined economists, and that there have been few attempts to evaluate these models empirically.

Even though knowledge is undeniably important for economic growth, theories of the creation of knowledge may be of little help in explaining international differences in growth rates. Knowledge, as op-

33. For example, see Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992).

34. Schumpeter (1942).

posed to capital, travels around the world fairly quickly. State-of-the-art textbooks are available in the poorest countries. Even when a firm has some monopoly power over an innovation, this lasts only a short time, after which the innovation becomes a worldwide public good. For understanding international experience, the best assumption may be that all countries have access to the same pool of knowledge, but differ by the degree to which they take advantage of this knowledge by investing in physical and human capital.

It is ultimately an empirical issue whether capital or knowledge is more important in explaining international differences in economic growth. In a recent paper, Alwyn Young sheds light on this question by examining in detail the spectacular growth of Hong Kong, Singapore, South Korea, and Taiwan.[35] From 1966 to 1990 income per person grew by more than 7 percent per year in each of these countries. Young shows that this exceptional growth can be traced to large increases in measured factor inputs: labor-force participation, educational attainment, and the capital stock. Growth in total factor productivity—which measures the rate of improvement over time in the production function—was not unusually high. For understanding these growth miracles, endogenous growth theory appears unnecessary.

Empirical Studies of Economic Growth

One hallmark of recent work on economic growth, in contrast to the work of the 1950s and 1960s, is its empirical emphasis. Largely because of the important work of Summers and Heston, international data suitable for cross-sectional analysis are now available for most countries.[36] These data have allowed systematic examination of the differences between economies that have experienced rapid growth and those that have not.

Some Findings

The typical empirical paper on economic growth chooses a sample of countries and then runs a cross-sectional regression. On the left-hand

35. Young (1995).
36. See Summers and Heston (1991).

side is each country's average growth rate over a long period. On the right-hand side is a set of variables expected to determine that growth rate. The variables change from study to study, and the interpretations of the results differ, but the basic setup is usually pretty much the same.[37]

Although it is impossible to summarize this vast literature, some of the findings are worth noting:

—A low initial level of income is associated with a high subsequent growth rate when other variables are held constant. This is the finding of conditional convergence, discussed earlier.

—The share of output allocated to investment is positively associated with growth.

—Various measures of human capital, such as enrollment rates in primary and secondary schools, are positively associated with growth.

—Population growth (or fertility) is negatively associated with growth in income per person.

—Political instability, as measured by the frequency of revolutions, coups, or wars, is negatively associated with growth.

—Countries with more distorted markets, as measured by the black market premium on foreign exchange or other impediments to trade, tend to have lower growth rates.

—Countries with better developed financial markets, as measured, for instance, by the size of liquid assets relative to income, tend to have higher growth rates.

Each of these findings has been confirmed independently in several studies. Most of them depend to some extent on which other variables are included in the regression. This sensitivity to specification is not surprising in light of the serious multicollinearity problem (which I discuss below).

It is easy to reconcile these results with existing theories of growth. In terms of the neoclassical model, these regressions show a tendency for convergence toward a steady state that is determined by the control variables. And, as discussed above, endogenous growth models with

37. For a sampling from the huge literature estimating cross-country growth regressions, see Kormendi and Meguire (1985), Dowrick and Nguyen (1989), Barro (1991), De Long and Summers (1991, 1992a, 1992b, 1993), Murphy, Shleifer, and Vishny (1991), Fischer (1991, 1993), Mankiw, Romer, and Weil (1992), Levine and Renelt (1992), and King and Levine (1993a, 1993b).

more than one sector are consistent with a similar interpretation. Even the signs on the control variables make sense. What economist doubts that growth is fostered by high investment, widespread education, low population growth, political stability, free markets, and well-developed financial institutions?

Yet despite their success in uncovering some interesting and interpretable regularities, cross-country growth regressions are not unassailable as a tool for learning about the determinants of growth. Three problems in particular affect this entire literature.

The Simultaneity Problem

The most obvious problem with cross-country growth regressions is *simultaneity*—the fact that the right-hand-side variables are not exogenous, but are jointly determined with the growth rate. For example, there is a strong, positive correlation between investment and growth. But does this imply that high investment causes high growth, that high growth causes high investment, or that some third variable causes both high investment and high growth? The same question can be posed for population growth, human capital, political stability, and all the other variables commonly used in growth regressions.

The standard econometric solution to simultaneity is to follow the advice of the Cowles Commission: find exogenous variables to use as instruments. The problem is that there are few, if any, such variables in cross-country data sets.

When looking for instruments, it is easy to fall prey to temptation. Some economists are tempted to treat political variables, such as the number of revolutions and coups, as if they were exogenous. But political scientists are tempted to call economic growth exogenous and put political instability on the left-hand side. Some economists are tempted to treat lagged variables as exogenous. But a variable is not necessarily exogenous just because it is predetermined.[38] For empirical work on economic growth, the advice of the Cowles Commission does not seem feasible.

38. Anyone who thinks that predetermined variables are naturally good instruments should ponder the following problem: A person regresses the quantity of apples on the price of apples, instrumenting with yesterday's price of apples. Has he identified the supply curve or the demand curve for apples? (The answer, in most cases, is neither.)

Where does this conclusion leave us? Very simply, with a bunch of correlations among important endogenous variables. The cross-country data can never establish, for instance, the direction of causality between investment and growth. Yet the correlation between investment and growth is an interesting and useful fact. It says that any explanation of international experience must be consistent with these two variables moving strongly together. In other words, correlations among endogenous variables can rule out theories that fail to produce the correlations, and they can thereby raise our confidence in theories that do produce them, but these correlations can never establish causality beyond a reasonable doubt.

The Multicollinearity Problem

Another problem with interpreting cross-country regressions is *multicollinearity*—the strong correlation among all the right-hand-side variables. In some ways, multicollinearity is more a pernicious problem than simultaneity, for its effects are less obvious.

There is no doubt that multicollinearity is severe in cross-country regressions. High-growth countries have higher rates of investment, higher enrollment in primary schools, higher enrollment in secondary schools, higher rates of literacy, lower rates of population growth, more developed financial markets, and fewer revolutions and coups than low-growth economies. As a rough approximation, those countries that do things right do most things right, and those countries that do things wrong do most things wrong.

At first, multicollinearity might not seem like a problem, for multiple regression is supposed to deal with it automatically. Under standard econometric assumptions, multicollinearity reduces the precision with which coefficients are estimated, but it does not bias the coefficients or standard errors. Thus, it might appear that multicollinearity does not contaminate the inferences drawn from cross-country regressions.

Yet there are two reasons to doubt that multiple regression does in fact deal well with multicollinearity. The first reason is that multiple regression treats each country as if it were an independent observation. For the reported standard errors to be correct, the residual for Canada must be uncorrelated with the residual for the United States. If country residuals are in fact correlated, as is plausible, then the data most likely contain less information than the reported standard errors indicate. That is, statistical significance is overstated. The reported standard errors, therefore, cannot be relied upon to warn us about the problem of multicollinearity.[39]

The second reason to doubt that multiple regression deals well with multicollinearity is the prevalence of measurement error in international data sets. Everyone who uses cross-country data admits that many variables are crude proxies at best. Yet the implications of this fact are rarely acknowledged. It is a standard econometric result that measurement error tends to bias downward the coefficient on the variable measured with error. At the same time, it can bias upward the coefficients on variables correlated with the variable measured with error, for these other variables stand in for the error-prone variable. Hence, when growth rates are regressed on a group of crude proxy variables that exhibit substantial multicollinearity, the set of coefficients largely reflects the differing measurement errors in the right-hand-side variables.

Let us consider a specific example. In a series of provocative papers, Bradford De Long and Lawrence Summers argue that the social return to equipment investment is very high.[40] This finding is based largely on cross-country growth regressions with equipment investment among the control variables. From a large coefficient on equipment investment, they conclude that equipment investment yields substantial externalities, and that government policy should target this form of capital accumulation.

De Long and Summers also find in their sample that secondary school enrollment has an insignificant negative coefficient, but they choose not to emphasize this result. They note that secondary school enrollment is "not a very good proxy" for investment in human capital. They go on to explain that "it is premature to conclude that education is not important: education almost surely is important. Instead, the lack of significance of our human capital investment proxies in our cross-national regressions should most likely be attributed to the large divergence between measured schooling and actual skills learned."[41]

This interpretation makes sense. But do the implications of measure-

39. De Long and Summers (1991) tried to address the possibility of spatial correlation between the residuals in cross-country growth regressions and were surprised that they found little evidence of it. More recently, Elliot (1993) has found such evidence. He reports that standard errors corrected for spatial correlation are substantially larger than the uncorrected standard errors usually used.

40. De Long and Summers (1991, 1992a, 1992b, 1993).

41. De Long and Summers (1992b, pp. 116–17).

ment error stop at the schooling coefficient? Almost certainly not. If investment in human capital is important but hard to measure, then it is possible that equipment investment is also serving as a proxy for investment in human capital. Because equipment requires workers to operate it, economies with highly skilled workers may attract more equipment investment than economies with less skilled workers. Thus, it is hard to know whether the coefficient on equipment investment reflects a truly large rate of return, or merely the combination of measurement error and multicollinearity.

I am not picking on De Long and Summers because their work is particularly egregious. Quite the opposite is true. These authors are keenly aware of the pitfalls in interpreting cross-country growth regressions and they do more than most to try to avoid them. But they, like others running these regressions, are limited by the available data.

The Degrees-of-Freedom Problem

One goal of empirical work on economic growth is to establish the conditions that are associated with rapid growth. Is the key to growth a high rate of equipment investment? Political stability? Well-developed financial institutions? Stable money growth? Low inflation? More engineers than lawyers? Or some variable yet to be investigated?[42]

There is no limit to the possibilities—and that itself raises one more problem. There are only about one hundred countries on which to run cross-country growth regressions. As a matter of econometric logic, one hundred observations can estimate only one hundred coefficients (and far fewer than that with any degree of accuracy). There are too few degrees of freedom to answer all the questions being asked.

Of course, no individual study ever includes one hundred variables on the right-hand side of a cross-country growth regression. Yet including only a subset of variables does not help matters much. It just means that the results of the study are contingent upon what variables the study chooses to exclude.

There is no easy solution to this degrees-of-freedom problem. In the end, there appears to be little choice but to admit the limitations of cross-

42. See, respectively, De Long and Summers (1991, 1992a, 1992b, 1993), Barro (1991), King and Levine (1993a, 1993b), Kormendi and Meguire (1985), Fischer (1991, 1993), and Murphy, Shleifer, and Vishny (1991).

country growth regressions. It is not that we have to stop asking so many questions about economic growth. We just have to stop expecting the international data to give us all the answers.[43]

The Future of Growth Empirics

Although I applaud the empirical emphasis in recent work on economic growth, I am not sanguine about the future of this work. There are two problems working in concert: the subtlety of the theories and the limitations of the data.

When the field of economic growth was revived about a decade ago, some people argued that the international data offered a way of rejecting some theories in favor of others. The neoclassical model predicts convergence, whereas the $Y = AK$ endogenous growth model does not. Since large samples of countries exhibit little evidence of convergence, the data seemed to favor the endogenous growth model.

In actuality, things are not so simple. If different countries are allowed to have different steady states, then the neoclassical model predicts conditional convergence, which is found in the data. Conditional convergence, however, is also consistent with more sophisticated endogenous growth models that exhibit some form of transitional dynamics. Once we admit that growth theories have subtle implications, we are forced to conclude that cross-country regressions cannot easily distinguish among them.

Using these regressions to decide how to foster growth is also most likely a hopeless task. Simultaneity, multicollinearity, and limited degrees of freedom are important practical problems for anyone trying to draw inferences from international data. Policymakers who want to promote growth would not go far wrong ignoring most of the vast literature

43. One approach to the degrees-of-freedom problem is to move from cross-sectional to panel data. See, for example, Islam (1995) and Barro and Sala-i-Martin (1995, chap. 12). Including more frequent observations on each country increases the number of degrees of freedom. Yet the amount of information being added is not obvious, for the new observations are not independent of the old ones. Moreover, this information comes at the cost of introducing another problem: the business cycle. Distinguishing growth effects from business-cycle effects is difficult, for many of the determinants of long-run growth (such as investment) fluctuate strongly over the business cycle. Given the traditional view that short-run fluctuations and long-run growth are fundamentally different phenomena, it is not at all apparent that the benefit of panel data is worth the cost.

reporting growth regressions. Basic theory, shrewd observation, and common sense are surely more reliable guides for policy.

Where Do We Stand?

The purpose of economic theory is to take a complicated world, abstract from many details, and express the key economic relationships in a way that enhances understanding. From this standpoint, the neoclassical model is still the most useful theory of growth we have. It will continue to be the first growth model taught to students and the first growth model used by policy analysts.

The modern interpretation of this model, however, differs from that of twenty years ago. There is an increasing consensus that the role of capital in economic growth should be interpreted more broadly. Either because capital accumulation conveys positive externalities, or because labor income is largely the return to human capital, or for both reasons, the capital share is likely much greater than the traditional estimate of one-third derived from the national income accounts. If the neoclassical model is to explain the international experience, a capital share of at least two-thirds seems necessary.

Recent work in endogenous growth has shown how to model technological progress, which is exogenous in the neoclassical growth model. Although endogenous growth models are often presented as alternatives to the neoclassical model, they can also be viewed as complements. Endogenous growth models provide a plausible description of worldwide advances in knowledge. The neoclassical growth model takes worldwide technological advances as given and provides a plausible description of international differences.

If one accepts the neoclassical conclusion that the accumulation of capital (broadly interpreted) is the key to international differences in economic growth, one is naturally led to ask why some countries save and invest so much more than others. Little progress has been made in answering this important question. Recent work on economic growth has emphasized innovations in the production side of the model, appending standard theories of the household to explain the saving decision. Much of the growth literature continues to rely on the most basic representative-consumer model to explain saving, even though the consumption literature has rejected this model of household behavior. At this point, advances in the study of consumption and saving may do more to further understanding of economic growth than advances in growth theory as conventionally practiced.

The implications of recent work on economic growth for policymakers are far from clear. Obviously, if capital accumulation is the key to growth, then accumulating capital more rapidly will raise the growth rate. Just as obviously, political stability will raise growth by encouraging investment both by domestic residents and from abroad. Yet some recent work on economic growth suggests that a more activist government could be beneficial. If certain types of capital yield large positive externalities, then policymakers should try to direct resources in this direction. The problem is that economists have not produced a persuasive way of measuring the magnitude of these externalities. Relying on estimates from cross-country regressions (or on the judgments of the political process) will likely lead to haphazard policy, which is surely worse than no policy at all. Without a solution to this measurement problem, modern growth theory does not offer any clear policy prescriptions. In my view, policymakers who want to foster economic growth would do well to heed the first rule for physicians: do no harm. This may seem like a modest conclusion from an ambitious literature. But sometimes modesty is all that economists have a right to offer.

APPENDIX

The Rate of Convergence to the Steady State

THIS APPENDIX derives the rate of convergence to the steady state in the Solow version of the neoclassical growth model. Begin with the capital accumulation equation:

$$dk/dt = sf(k) - (n + g + \delta)k. \tag{A1}$$

Now take the first-order Taylor expansion of the right-hand side of this equation around the steady-state capital stock, k^*. This yields

$$dk/dt = [sf'(k^*) - (n + g + \delta)](k - k^*). \tag{A2}$$

Substitute for s using the steady-state condition $sf(k^*) = (n + g + \delta)k^*$ This gives

(A3) $$dk/dt = \{[f'(k^*)k^*/f(k^*)] - 1\}(n + g + \delta)(k - k^*).$$

If capital earns its marginal product, then $f'(k^*)k^*/f(k^*)$ is the steady-state capital share, α. Therefore,

(A4) $$dk/dt = -\lambda(k - k^*),$$

where

$$\lambda = (1 - \alpha)(n + g + \delta).$$

To show that income converges to its steady-state level at the same rate as capital, note that $y = f(k)$. Therefore, the following first-order approximations hold:

(A5) $$dy/dt = f'(k^*)dk/dt,$$

(A6) $$y - y^* = f'(k^*)(k - k^*).$$

By substitution,

(A7) $$dy/dt = -\lambda(y - y^*).$$

Thus, income converges to its steady state at rate λ. Notice that this result does not depend on any specific functional form for the production function, $f(k)$.

In interpreting the neoclassical growth model, some authors have asserted that convergence follows from the property of diminishing marginal product. This interpretation is not correct, at least for this most basic version of the model. The second derivative of the production function, f'', measures the extent of diminishing marginal product; this plays no role in determining the rate of convergence, λ. It is more accurate to say that convergence arises here from the property of diminishing *average* product. As the capital stock rises, depreciation rises proportionately, but income and investment rise less than proportionately; thus, a higher level of capital leads to a lower growth rate of capital.

Comments and Discussion

Edmund S. Phelps: This paper gives some noteworthy support to the wisdom that the phenomenon of poor countries in the world can be explained by the importance of human capital. Having little human capital, they invest little in tangible capital. If virtually all income is attributable to this capital, human and nonhuman, a dearth of human capital has a devastating effect on national potential output. Moreover, the importance of human capital (on top of the already measured importance of nonhuman capital) in the production function is a serious drag on the speed with which a low-income economy can climb to its steady-state income level; and it adds mightily to the sensitivity of the steady-state income level to a country's saving-to-income ratio.

Becoming very bold, Mankiw adds that not much of the difference in income from country to country is to be accounted for by disparities in technological knowledge. Textbooks, blueprints, and chemical formulas travel fast over the world, evidently at low transmission costs. So in the author's view, it is ultimately human capital that holds back a country—though he agrees with the recent econometric studies finding that a country can boost its growth path with "political stability, free markets, and well-developed financial [intermediaries]."

For me this paper is a model of exposition and is destined to have a long life. Yet I see places in which Mankiw's analysis badly needs to be corrected or supplemented. One of these is his apparent conception of the function of human capital, defined as the resource cost incurred in teaching and learning the world's stock of knowledge. He appears to see it entirely as a factor of production, analogous to the stocks of tangible capital. Thus he posits an elasticity of true national income with respect to that human stock, to be measured by labor's share of true income, that is entirely analogous to the capital elasticity of output. This is a very static and deterministic view.

The alternative view is that all or most persons in the labor force could forget everything they had learned beyond the ninth grade, say, without putting much of a dent in today's output. First of all, most schooling is learning how to learn—which fosters the ability to understand a description of an innovative technique, such as a new tool or a new chemical, or understand legislation setting out regulations or prohibitions affecting some industrial activity. Thus education facilitates the adoption and dissemination of technical advances and, more generally, the exploitation of market opportunities. This theme is developed in a paper by Richard Nelson and myself.[1] Second, much of our learning is precautionary, and seemingly redundant, because we do not know when we are young, and our opportunity costs are low, what job or sequence of jobs will be most in demand over our working life. The best econometric evidence for this view so far is the finding that the stock of human capital contributes negatively to a country's productivity level but positively to the rate of improvement in its productivity.[2] Certainly in communist Eastern Europe, where the demand for innovation was weak, having massive human capital did not appear to help much at all. There is also microeconomic evidence in longitudinal studies finding that entrepreneurs show outside returns from additional education.[3]

One consequence of this alternative model concerns the importance of human capital. The disadvantage posed by having low human capital, this model says, is that it impedes the ability to implement promptly and widely the successive advances in the best-practice technology. The country is always behind the curve. Thus we may assume that a country is farther behind the best-practice frontier, the lower is its human capital and the faster that the frontier is advancing. If only technological progress would stop, the returns on much of the human capital would drop, and the countries disadvantaged in human capital could then converge to the frontier (perhaps very nearly at Mankiw's original 4 percent rate).

The alternative view also has implications for the demand for human capital. Why is it that several countries have, in only a few short decades, experienced a rapid accumulation of human capital—the Asian

1. Nelson and Phelps (1966).
2. Benhabib and Spiegel (1994).
3. Evans and Leighton (1989).

miracle economies—while other countries at about the same place in the poverty ranking have not? Surely the answer is the emergence of entrepreneurship, encouraged and sanctioned by the government. To an important degree, I suggest, a dearth of human capital is found in those countries where there is a low demand for it, its reward being meager because the entrepreneurs who might introduce best-practice techniques and enter new markets are not permitted or emboldened to do so by the government and the prevailing economic philosophy.

This observation leads to another area where I feel the paper falls a bit short. A student in Budapest or Moscow could come away from this paper with the impression that, although noninterference with exchange rates and other niceties of liberal economic policy may be rather important for a government to observe, whether ownership and control of industry is primarily capitalist or socialist should not be a vital consideration in a country's strategy for a high rate of growth. The *c*-word barely appears in the paper. Unless I missed it, the postwar experience of the socialist countries in Eastern Europe, Africa, and Asia is not considered significant.

If the new wave of research on economic growth is to graduate to a really useful endeavor, it has to introduce the factors that have become prominent in discussions of the road back to capitalism in eastern Europe: tax rates on enterprise profits and payrolls, the size of the public enterprise sector, red tape and corruption in the government's licenses and contracts to the private sector, impediments to shareowners' exercise of enterprise control, and various other property rights.

This gap in the paper is frustrating. We Western economists should be sending messages to countries where corporate ownership and control are now crucial issues. Yet if this paper is a guide, present-day mainstream research on economic growth is cut off from the searching analysis of the crucial contributions of key capitalist institutions for economic growth that has been touched off by the events in eastern Europe in the 1990s. However, it is not too late to start filling this gap.

Paul M. Romer: Greg Mankiw and I agree on many issues concerning growth, but it will be more useful if I focus here on the areas in which we disagree. Our most obvious disagreement is apparently over a statement of fact. Mankiw argues that technology is a public good that is available everywhere in the world. I argue that there is ample evidence that this assertion is wrong. But our disagreement here is not really about the facts. Mankiw's position is not that his claim is literally true, but that it is close enough for macroeconomics. What constitutes close enough depends on what one is trying to accomplish—getting the answers right or catering to a target audience.

Our differing positions on the nature of technology are derived from a more basic disagreement about strategies for constructing macroeconomic models of growth. Mankiw believes that the neoclassical model built on the foundation of the public-good assumption is so useful in the classroom and in policy debates that the burden of proof should rest on those who support a richer model. Even in the face of strong evidence against the public-good model, he would apparently be reluctant to consider an extension. I believe that an unnecessary reliance on this neoclassical model has hampered clear thinking about growth, particularly among macroeconomists and the students and policymakers who listen to them. Even in the absence of strong evidence against this model, we must explore an extended model that forces us to think more carefully about the economics of technology and knowledge.

The differences between our modeling strategies may themselves be the result of different beliefs about the ultimate objectives that economists should pursue. I believe that our fundamental goals are, first, to uncover important truths, and then, to communicate them to outsiders. The order in this two-step process is important. We should start by using observation and logic to decide what those truths are, without thinking ahead to the reception that awaits our findings. Once our results are in hand, we should communicate them to the relevant outsiders, without catering or condescending to them.

From this point of view, it follows almost immediately that we should work with an extended theoretical framework that lets us take technology seriously. It costs little to adopt an extended model because these kinds of models have a mathematical structure that is only slightly more complicated than that of the public-good model. On the benefit side, technological change is an extremely important force in modern economic life, one that we would surely like to understand better. The extended model forces us to be precise in our reasoning about intangible inputs like technology, and it encourages us to adopt a broader perspective when we look at the evidence concerning growth. Because the public-good model of technology can be nested as a special case of this extended model, working with the extension keeps all of our intellectual options open.

There is, however, another set of beliefs about what it is that economists should do. According to this view, we *should* think ahead to the reaction of our audience when we engage in research. I am frequently warned that the models I use, and the results I describe, could be used to justify bad government policies. The implication is that economists should filter their results, keeping in mind how they might be used in the political process. From this point of view, a model that takes technology seriously poses risks that are not present in the public-good model. The public-good model used by Mankiw implies that the optimal government policy (at least for a small developing country) is laissez faire. As a result it is unlikely to provide support for the wrong kinds of policies.

A similar strategic calculation could presumably apply to the reaction that a more sophisticated treatment of technology would provoke among students. Precisely because it does not try to capture any of the subtle issues that arise when we treat technology and knowledge as economic goods, the public-good model is familiar and unthreatening to the median student. If we plan with this student's reaction in mind, the intellectual power of a broader perspective is a disadvantage rather than an advantage. It raises new issues, some of which are not yet resolved. Any discussion of these issues will inevitably leave many loose ends. If our strategy in doing research is to cater to the demands of a textbook market that values simplicity, familiarity, and decisive answers over all else, a model that treats technology seriously may indeed be something to avoid.

It is within this context that the balance of my comments must be placed. I will point to empirical failures of the public-good model of technology. Many of the points I raise are not new. Jan Fagerberg provides a useful discussion of the history of objections to this approach to modeling growth.[1] As the persistence of this debate suggests, a discussion of the evidence by itself is unlikely to resolve the differences of opinion on what is a good model of growth. Whether the problems noted below are minor issues that a theory of growth can skip over or whether they are

1. Fagerberg (1994).

decisive evidence against the public-good model may depend entirely on one's views about what the goal of growth theory, or economics more generally, should be.

The recent history of the public-good model of cross-country differences in wages and income is a story of strategic retreat. This kind of model gets the signs right for many questions about growth, but careful examination eventually shows that it fails to explain the magnitudes observed in the data. As Mankiw explains in this paper, and as I have argued elsewhere, the first stage in this retreat came with the recognition that a model of the form $Y_j = AK_j^{\alpha}L_j^{1-\alpha}$ cannot explain the cross-country data for values of the parameter α that are close to capital's share in total income.[2]

This finding provoked two different responses. The first was to allow for the possibility that the technology parameter, A, could vary across countries. Early versions of the endogenous growth models let A vary because of spillover effects from investment in physical capital or human capital. More recent models have proposed more complicated mechanisms for producing variation in A, such as research and development, or trade in intermediate inputs in production. But whatever the cause of the differences in technology, these models attribute an important part of the cross-country variation in wages and incomes to variation in the technology used in different countries.

The other response was to leave A the same in all countries and to add an additional input, H_j (for human capital), that covaries with K_j. The message of Mankiw's paper with David Romer and David Weil is that this, by itself, is enough.[3] There is no need to consider the possibility that the technology might also vary across countries. As they show, a model of the form $Y_j = AK_j^{1/3}H_j^{1/3}L_j^{1/3}$ can be made to fit the cross-country data. But as Mankiw recognizes in subsequent work and reiterates in this paper, there are important quantitative problems with this model as well, when one looks beyond the national income accounts data used in the cross-country regressions.[4] If H and K covary across countries, the rate of return to physical capital will be much higher in poor countries than in rich countries.

The next retreat from the neoclassical strategy of treating each nation

2. See Romer (1994).
3. Mankiw, Romer, and Weil (1992).
4. See Barro, Mankiw, and Sala-i-Martin (1994).

as a closed economy with the same public-good technology is therefore to allow the rate of return on physical capital to be equalized across countries through a process of international borrowing and lending. The relative scarcity of H can then be used to explain why total income and wages for unskilled workers are both lower in poor countries.

As Mankiw observes, this amended version of the Mankiw, Romer, and Weil model gets the signs right. The rate of return to investments in human capital does seem to be higher in poor countries, just as this approach predicts. What he fails to note is that the implied magnitudes are wildly inconsistent with the available evidence. Using the baseline model with exponents of one-third on the three main inputs, and allowing for free mobility of physical capital, an easy calculation leads to the following simple result. In the poorest countries, where the wage for unskilled labor is one-tenth the wage for unskilled labor in the United States, the wage for skilled labor will be ten times larger than the wage for skilled labor in the United States. Thus if the ratio of the skilled wage to the unskilled wage in the United States is two, the ratio of the skilled wage to the unskilled wage in the poor country will be two hundred! Because the cost of education is the forgone unskilled wage, and the return to education is the differential between the skilled and the unskilled wage, the implied rate of return to education in poor countries should be larger than the return in the United States by a factor of one hundred, rather than by the factor of two or three that is found in the data.[5] Moreover, as Robert Lucas has emphasized, we can also use evidence about migration to test our models of growth.[6] Here the public-good model that Mankiw proposes does not even get the signs right. The net flow of skilled workers is from poor countries to rich countries, rather than from rich to poor.

The new fallback position for the neoclassical model that Mankiw introduces in this paper is to suggest that the elasticity of substitution between capital and labor could be four or ten, instead of the value of one implied by a Cobb-Douglas specification. He raises this possibility only in the context of a model with two factors of production and leaves the exploration of the model with three factors of production for future research. I will interpret his suggestion by treating one of the two inputs in

5. See Psacharopoulos (1985) for a description of the empirical results on rates of return.

6. Lucas (1988).

a CES production function as unskilled labor and letting the other input be a composite of physical capital and human capital. In this setting a higher elasticity of substitution helps the model fit the data along some dimensions, but it hurts in others. As Mankiw emphasizes, a higher elasticity of substitution can lead to large differences in income per capita without inducing large differences in rates of return to physical and human capital. This reduces the amount by which the wage for the scarce skilled workers in poor countries exceeds the wage for the abundant skilled workers in rich countries. But this change also leads to reductions in the predicted difference between the wages for unskilled workers in rich and poor countries.

To get an order of magnitude estimate of the effect that this change in the elasticity of substitution can have on wages for the unskilled workers, let us accept the rough estimate that the share of total income accruing to physical capital and human capital in the United States is about 0.8. Then we can calibrate a CES production function with an elasticity of substitution of four between unskilled labor and the composite of human and physical capital. This implies that the wage for unskilled workers in a country that has *zero* human and *zero* physical capital is about 60 percent of the wage for unskilled workers in the United States. This fraction is far too high to be consistent with the evidence on cross-country variation in wages for low-skilled workers.

This kind of result should come as no surprise. Mankiw justifies his high elasticity of substitution by invoking the arguments that lead to factor price equalization. In the limit, where the elasticity of substitution is infinite, wages for unskilled workers will be the same all over the world, regardless of the local stock of human and physical capital. The point for the purpose of this discussion is that an elasticity of four goes a long way toward infinity.

The basic conclusion that emerges from this account is simple. The neoclassical assumption that the aggregate level of technology is the same in all countries is inconsistent even with the macroeconomic data on growth and development. Fitting the public-good model of technology to the these data is like squeezing a balloon. You can make it smaller in one place, but problems always pop out somewhere else.

The case against the public-good model becomes much stronger when one looks at the microeconomic evidence. Formal comparisons of productivity levels routinely uncover wide variation among firms in the same manufacturing industry. Even in a service industry such as retailing, firms such as K-Mart and Wal-Mart use very different technologies to provide their service, with very different outcomes in terms of profitability and returns on equity. These persistent differences are difficult to explain if the technology that each uses is a public good.

Furthermore, even a cursory look at the details of the development experience suggest that the process of technology transfer by foreign firms has been important in many countries. This process of transfer is also responsive to the incentives created by the host government. For example, when Mauritius pursued the traditional policy of erecting high tariff barriers to encourage import-substituting local manufacturing, its only exports were in agriculture. Once it had created an export processing zone that let foreign firms earn profits by making use of local labor, garment assembly firms from Hong Kong located production there, and exports of garments from Mauritius to the United States and Europe grew dramatically. The garment assembly industry did not exist prior to the creation of the export processing zone in 1970. By 1990 almost one-third of all employment on the island was in this industry.

The impediment to the development of a garment assembly industry on Mauritius before 1970 was not a level of savings that was too low to finance the purchase of sewing machines. Nor was it a level of education too low for workers to be able to operate such machines. The problem was that the relevant technology was not a freely available public good. Until the foreign entrepreneurs arrived, no one in Mauritius knew enough about the garment business to begin production there. This knowledge did not leak in from Hong Kong. It was brought in when entrepreneurs were presented with an economic environment that let them earn a profit on the knowledge that they possessed.[7] If the public-good model does not apply to an industry as basic as garment assembly, where could it apply?

We have overwhelming evidence that technology is not a public good. We also have formal models of growth that let us take account of this fact. The puzzle for me is why many economists still resist doing so in their teaching and in their research. The only conjecture that I can offer is the one outlined above. These economists may be paying too much attention to how a particular model will be received and used by out-

7. See Romer (1993) for more details concerning this case.

siders, and too little attention to what they think is true. Mankiw may be right that the neoclassical model "will continue to be the first growth model taught to students and the first growth model used by policy analysts." Nevertheless, as economists, we should not settle for this. Our goal should be to make them have second thoughts about a question that is as interesting and as important as the one addressed here: What causes growth and development?

General Discussion

There was a lively discussion of the relative importance to growth of conventional inputs, like physical capital, human capital, and labor, and intangible factors such as knowledge. Several participants criticized the paper's assumption that knowledge is identical across countries. James Duesenberry argued that the process by which modern techniques are mastered is more complicated than simply sending people to school and handing them blueprints when they graduate. It typically involves many kinds of learning, including experience and interaction with foreigners. Robert Gordon emphasized the importance of organizational capital, citing Paul Romer's example of Mauritius. If organizational capital were not important, the management consultant industry would not exist. And Nordhaus noted that technologies differ in their rates of diffusion across space and time; he felt that we do not know very much about the process. Barry Bosworth and John Haltiwanger noted that the variability of total factor productivity (TFP) supports these observations. Even after human capital is accounted for, there is tremendous variation in TFP across countries. In fact within narrowly defined industries in the United States itself there are large productivity differences across plants. Moreover, these differentials are persistent; the most productive plants in 1995 were generally the most productive in 1985, and often also in 1975. William Brainard added that productivity differentials exist even within plants; different assembly lines are often of different vintages, for example.

Several participants thought that the paper gave short shrift to institutions and government policy. Duesenberry and William Branson found it curious that the study of "growth" emphasized theoretical models, national production functions, and cross-country regressions but failed to embrace the study of "development," which emphasizes the development of product, labor, and financial markets and the many ways in which the government can affect efficiency; for example, overvalued exchange rates, parallel markets, subsidies, rationing, state enterprises, corruption, volatile inflation, interest rate regulation, and capital allocation. Several members of the panel presented evidence on the importance of government policy. Nordhaus suggested that the narrow concentration on factor inputs as the source of growth was rejected by what he called the socialist experiment. Although Eastern European countries were relatively well endowed with physical and human capital after World War II, this just seemed to help them go downhill. According to research by Fred Bergsten, in the U.S.S.R., Hungary, Poland, and Yugoslavia output per worker in 1975 was 30 percent lower than in the Western countries, after accounting for differences in capital and land per worker and adjusting for labor quality. Bosworth noted that, while socialist economies clearly underperformed capitalist economies, it has been more difficult to demonstrate the benefits of liberalizing measures in economies that have pursued a middle road. For instance, he interpreted the evidence as indicating that trade promotion has been a better strategy than trade liberalization.

Jeffrey Frankel thought that government policy toward trade and openness was worthy of special comment. Although human and physical capital explain much of the variation in GDP, trade explains a significant portion of the residual. The positive correlation between growth and openness is a robust finding of cross-country studies, and is confirmed in the paper by Sachs and Warner in this volume. Frankel also argued that causation has convincingly been shown to run from trade to growth, as there now exist relatively good instrumental variables for trade. One of the channels through which trade aids growth is by facilitating the transfer of technology.

Haltiwanger noted that an important component of productivity growth is the reallocation of resources to the more productive plants, implying that policies interfering with resource mobility can have significant effects. Bosworth pointed out that some countries have had negative TFP growth for periods lasting many years, a fact that the neoclassical model cannot account for. In addition to government policy and technological diffusion, Bosworth emphasized the importance of macroeconomic stability, reminding the Panel of Arthur Okun's dictum that "one recession can wipe out a thousand Harberger triangles." He noted that a number of countries show negative TFP growth over certain periods. These data points, which represent the loss of precious ground gained, can be attributed largely to economic crises. One secret of success of the Asian economies has been their ability to avoid periods of declining output.

While agreeing that institutions and technological diffusion cannot be ignored as sources of growth, and that the neoclassical model sheds no light on the effects of science policy, trade policy, the socialist experiment, and the like, Mankiw asserted that doing so was not its purpose. He defended the model as being good at what it is supposed to do—explain differences in standards of living across countries and time. A regression with per capita income levels on the left and saving rates, population growth rates, and human capital variables on the right has an R^2 around 0.78. He noted that the neoclassical model seems to work well in explaining the experience of the newly industrializing countries (NICs) in Asia. Alwyn Young's research indicates that the NICs grew mainly through the accumulation of physical and human capital, rather than increases in TFP.

Gordon echoed Romer's comments about wage differentials. He wondered how it is that an individual migrating to the United States with the same human capital as in his home country can work with about the same physical capital as in his home country and raise his standard of living by a factor of ten. He reasoned that to explain this, one needs to allow for complementarity among factors of production. Mankiw suggested that the model's difficulty in explaining facts like these reflects an oversimplified production function. He believed that human capital is fundamentally different from physical capital, implying the need for a production function that explicitly included both.

Benjamin Friedman noted that the correlation between saving rates and income per capita is poor. Many high-income countries have low saving rates, and vice versa; a notable comparison is the low-saving United States with the high-saving China. But he was less pessimistic than Mankiw about the accuracy of the neoclassical growth model in predicting rates of convergence. The estimated rate is about 0.02, while the predicted rate is 0.04; given the usual downward bias in regression coefficient estimates, and the inherent difficulty of fitting models to facts, Friedman thought the model actually gets pretty close.

There was debate about whether human capital helps to explain much of the variation in economic growth. Frankel and Bosworth both noted that adding human capital to growth regressions significantly improves their explanatory power. Branson mentioned research by Krueger in the

1960s that estimated that close to 60 percent of the difference between developed and less developed countries is attributable to human capital. However, Nordhaus said that, using Denison's technique to measure the impact of education on productivity growth and income growth, one finds that it explains very little of the differences across countries. He preferred Denison's approach for its "internal consistency." Richard Cooper suggested that comparison of national capital-to-output ratios provides evidence on this point. The rank correlation between per capita income and capital stock per unit of output is nearly perfect. The only outlier whose capital-to-output ratio is lower than expected is the United States, suggesting more efficient use of capital. He dismissed human capital as a full explanation because, in that case, American human capital per worker would need to be way out of line with that of other rich OECD countries, including Germany, the United Kingdom, France, and Japan.

Gordon expressed skepticism about the importance of investment externalities in some models of endogenous growth. In particular, he questioned the plausibility of the De Long and Summers thesis that equipment investment plays a special role. In the United States from 1936 to the present, the ratio of equipment to structures has increased steadily from 1/1 to 3/1. There has been little correlation between this ratio and growth, as the increasing importance of equipment has continued unabated during both fast and slow periods. Nordhaus stated that although the evidence is clear on externalities to R&D, he knew of no evidence for the existence of returns to physical capital that are not captured by the firm.

Some discussants offered suggestions for future empirical research. Duesenberry thought that researchers working with cross-country data should pay more attention to important events at the microeconomic level. By using microeconomic data, he thought it possible to avoid some of the identification problems that plague macroeconomic studies. Nordhaus cautioned that researchers defining human capital as an input need to account for it on the output side also; they need to take care to count production of human capital not as consumption, but as investment. He thought most empirical studies get the accounting of human capital wrong, with Dale Jorgenson's recent work a noteworthy exception. Friedman suggested that it was important to be explicit in empirical research about whether economies are to be treated as if they are at their steady states.

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