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 pub-

lic-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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