

The Search for Growth

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The idea that capital investment is essential to the long-run rate of growth of a nation is a common, if somewhat vague, axiom of most policy discussions of economic growth and development. Yet for the better part of a generation the preeminent theory of economic growth developed by the Nobel Prize winning economist Robert Solow and the data summarized by the important contributions of Edward Denison, John Kendrick, Solow, and others provided us with virtually no basis for making such claims. Perhaps even more striking was the fact that the theory seemed unable to explain the extreme and persistent differences in living standards or growth rates across countries. Finally, the theory and evidence offered little scope for policymakers to influence the long-run rate of growth of an economy. For these reasons, many economists interested in positive economic theories came to view growth theory as a rather sterile, and uninteresting branch of economics through most of the 1960s and 1970s. Understanding business cycles and monetary economics became much more popular pursuits among academic economists.¹

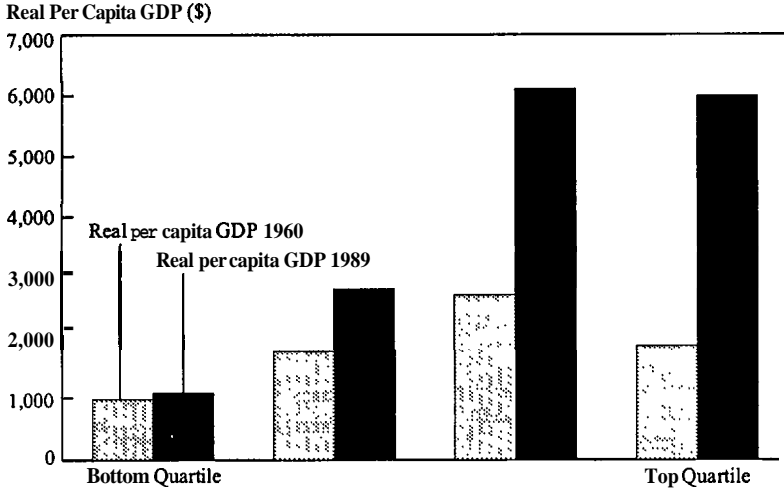
The importance of understanding the sources of long-term economic growth and the public policies that influence it should be self-evident, but let's try to attach some numbers to the concept that may help put the discussion in some perspective. By almost any measure, the range of living standards across countries is enormous. By some measures, real income per capita in such countries as Bangladesh, Ethiopia, Haiti, and Bolivia was less than 5 percent of U.S. per capita income in 1989.

Perhaps more important than the existence of these very poor countries is the fact that not all countries that start out poor remain poor—while others seem unable to raise their standard of living above mere subsistence levels. Countries such as Botswana and Korea had per capita incomes of less than 10 percent of that in the United States in 1960 and by any metric would be classified as very poor. Yet by 1989, Botswana had increased its per capita income by almost eight-fold, growing at a compounded annual rate of about 7 percent. Korea grew at an annual rate of about 6 percent, resulting in an almost sixfold increase in per capita income over the three decades. The United States, on the other hand, grew at an annual rate of about 2 percent resulting in an increase of only about 75 percent over the same time interval. Other countries that were not as poor as Botswana and Korea but that experienced significant growth over this 30-year interval include Cyprus at an annual rate of 4.7 percent, Greece at 4.3 percent, Hong Kong at 6 percent, Japan at 5.6 percent, Malta at 6 percent, Portugal at 4.1 percent, and Singapore at 6.4 percent. At a growth rate of 4 percent per year rate, real per capita income doubles every 17 years; at a 5 percent rate, it doubles every 14 years.

While these countries obviously made great strides in improving their living standards over the last generation, other countries were not so fortunate. Indeed, most countries that were poor in 1960 remain among the poorest in 1989.² All the more reason why it is important to ask why Botswana grew at a 7 percent rate while Bangladesh and Ethiopia grew at only about 0.5 percent per year. Why did Korea grow at 6 percent while Bolivia grew at only 0.5 percent? And why did Singapore grow in excess of 6 percent annually while New Zealand and the Philippines grew at less than 1.5 percent per year? Was there something about the national economic policies followed by these countries that led to either rapid growth or stagnation?

The differences in welfare levels produced by these differential growth rates is staggering. For example, Chart 1 shows the magnitude of the consequences of a country's being among the fast growers versus the slow growers. The countries in the top quartile of growth over the 1960-89 period grew at an average annual rate of about 4.1 percent and their per capita incomes increased from just under \$2,000 per year to more than \$6,000 per year. Those countries in the bottom

Chart 1
Average Real Per Capita GDP in 1960 and 1989



quartile of growth over the period grew at a rate that was indistinguishable from 0.0 percent. For the United States, an extra two percentage points added to the average growth rate would add about 22 percent or \$3,500 to real per capita gross domestic product (GDP) over the next decade and more than 80 percent or \$1 2,800 per capita over 30 years! By contrast, the gain from eliminating fluctuations in per capita incomes through stabilization policies is relatively small.³ The ability of any economy to raise living standards from one generation to the next depends on its ability to sustain economic growth.

During the last half dozen years, many academic economists have turned their attentions to the challenges of understanding economic growth. Building on the work of Solow (1956), Cass (1965), and Koopmans (1965), these economists are seeking to remedy the shortcomings of the earlier attempts to model the growth process and in doing so are exploring new and potentially important sources of economic growth and the avenues for policies to influence the long-term welfare of a nation.

The traditional view of economic growth

Modern work on economic growth can trace its intellectual roots to the work of Robert Solow. The basic neoclassical model of economic growth developed by Solow is, first and foremost, a model of capital accumulation. Its influence on the profession and its thinking about aggregative economics is based on a combination of its simplicity and its contribution to the quantification of various factors influencing economic growth. The model's foundation rests on the concept of an aggregate production function that combines labor and physical capital to produce a composite good that is associated with the output of the economy. The level of output is also influenced by the level of "technology" or "productivity" of the factors of production. The model is silent, however, on the factors influencing the evolution of technology.

The characteristics of the production function are central for the model's predictions about growth. The essential features are: (1) constant returns to scale (for example, doubling of all inputs leads to a doubling of output); and (2) diminishing marginal returns to both capital and labor (for example, increasing capital by a factor of two and holding labor input fixed raises output by less than a factor of two). Diminishing returns to physical capital limits the ability of the Solow framework to deliver a very satisfactory explanation of cross-country differences in income per capita or rates of growth. As we will see below, it is the key feature that distinguishes the traditional view of economic growth from the new or endogenous theories of growth.

The technology of the sort just described is frequently expressed in the form of a Cobb-Douglas production function which is written

$$Y = AK^{1-\alpha}L^\alpha, \text{ and } 0 < \alpha < 1$$

where total output, Y , is produced from physical capital, K , and labor, L . The level of technology is captured by A , which grows at some predetermined rate. This formulation exhibits both constant returns to scale and diminishing marginal returns to each input. The degree of diminishing returns to capital is measured by $(1-\alpha)$. The smaller this value (that is, the larger is α) the smaller are the rewards to increasing

the capital stock. The capital stock accumulates over time through net investment such that $K_{t+1} - K_t = I_t - \delta K_t$, where δ is the depreciation rate of physical capital. It is often easier to express this framework in per capita terms so that production is written as $Y/L = y = A[K/L]^{1-\alpha} = Ak^{1-\alpha}$ and the accumulation of capital becomes $k_{t+1} - k_t = \dot{k} - \delta k_t$.⁴

An economy that produces output according to this neoclassical technology exhibits some striking and important characteristics. For the moment assume that the rate of population growth is constant and that there is no growth in productivity or technology. The first important feature is that given a savings/investment rate, and therefore, a rate of accumulation of physical capital, the per capita output of the country will reach a steady state or constant value. Similarly, the per capita amount of capital also reaches a constant level. The reason is that as the per capita capital stock grows, the return to capital falls and, because of the constant investment rate, the amount of new investment per capita increases but at a diminishing rate. Eventually the amount of new investment per capita will just equal the depreciation on the larger capital stock and then growth of the per capita capital stock will stop. Thus the level of income and the level of capital will grow at the same rate as the population; per capita values will not exhibit growth.⁵ If we allow for technological progress or productivity growth, then per capita income and capital stocks would grow at a rate that is proportional to the rate of technological change.

The second important implication of the Solow framework is that the savings/investment rate is a fundamental determinant of the long-run standard of living. Countries with higher savings/investment rates will have higher per capita incomes in the steady state. The intuition behind this result is simply that a higher investment or savings rate results in more accumulated capital per worker which, in turn, increases the per capita output of the economy, but at a decreasing rate. Thus the Solow model suggests that sustained or long-run differences in the level of per capita income across nations is associated with differences in savings rates. Thriftiness, however, while impacting the long-term wealth of a society, does not cause it to grow faster. In steady state, the growth rate of per capita income is independent of the savings rate. In other words, in the long run, societies that save more will not grow faster than those that save less.⁶

Although exogenous technological progress is the only source of long-term or steady state growth in per capita incomes and consumption, the **Solow** framework does predict per capita growth during the transitions from one steady-state level to another. Suppose that through some impulse, a society became more savings oriented, perhaps as the result of a change in tax policy that encouraged savings. In the long run, the new higher rate of investment will enable workers to use more capital and thus operate at a higher **capital/labor** ratio and produce more output per worker. In order to get to the higher standard of living, the economy must, for some period of time, grow faster than the growth rate of technology. However, once the new higher steady state is achieved, per capita income growth will return to a rate proportional to the rate of technological change. The rate at which the gap is closed between the initial income level and the new steady state critically depends on the degree of diminishing returns.

The last important implication of the traditional view of growth is that countries that have access to similar production technologies and have similar **savings/investment** rates should converge to similar steady-state levels of per capita income. This convergence property means that the poor country, which starts with a lower **capital/labor** ratio, will grow faster during the transition as it catches up to the rich country, but both countries will ultimately arrive at the same standard of living. The case for convergence assumes that both countries are closed economies so that there is no trade between them. If the economies were open so that international borrowing and lending were feasible, then the economies are likely to converge more quickly. Since the poor country has less capital per worker, the returns to capital investment will be higher than in the rich country. The poor country will be attractive to foreign investors and the capital stock is likely to grow even more quickly, thereby speeding up the process of convergence. Of course, countries with different savings rates will have different steady states so just because one is poor and one is rich does not imply that convergence will occur or that one will grow faster than the other.

At this purely qualitative level, the **Solow** model makes an important distinction between factors that influence the level of per capita income and those that influence the growth rate. The commonly held

view that changes in tax structures that make savings and investment more attractive activities that can result in sustained increases in an economy's rate of growth, is simply not an implication of the traditional Solow analysis of economic growth. Sustained growth in living standards comes about from productivity or technological growth. Unfortunately, the theory has nothing to say about how this productivity growth is determined or how policy might influence it.

Quantifying the basic neoclassical model of growth

One of the attractive features of the classical framework is that it permits the decomposition of economic growth into that portion due to the growth of inputs (physical capital and labor) and due to the growth of technology or productivity. This practice of growth accounting involves computing the shares of national income devoted to the compensation of both physical capital and labor. Assuming the inputs to production are paid their marginal products, then the labor's share corresponds to the exponent α in the Cobb-Douglas production function. Table 1, derived from Maddison (1987), presents estimates of factor shares for a variety of industrialized countries. These estimates put capital's share ($1-\alpha$) at about 0.3 and labor's share at about 0.7. The similarity of factor shares across countries and across time is one of the stylized facts of economic growth that any theory must confront.

Table 1
Estimates of Factor Shares in GDP¹
 (average for 1973-82)

	Total capital share	Total labor share
France	.31	.70
Germany	.30	.70
Japan	.29	.71
Netherlands	.30	.70
United Kingdom	.26	.74
United States	.27	.73
Average	.29	.71

¹ Source: Maddison (1987)

If capital's share is about 0.3 then the production technology exhibits sharply diminishing returns to capital formation. Other researchers have put capital's share above 0.4 for some countries and some time periods, but in much of the literature it is frequently assumed that capital's share in GDP is about one-third and labor's share is about two-thirds (that is, $\alpha = 2/3$). Sharply diminishing returns to capital formation places limits on the Solow model's ability to account for cross-country differences in per capita incomes and growth rates. For example, it says that a doubling of the capital stock per capita increases steady state income per capita by only about 26 percent $[(2^{1/3} - 1)100]$. Thus for capital accumulation to account for the fact that the United States has 20 times the income per capita of Kenya, the capital stock per capita in the United States would have to be about 8,000 times the capital stock in Kenya! According to Summers and Heston (1991) U.S. capital per worker is only about 26 times that of Kenya. Even for countries more similar to the United States than Kenya, diminishing returns limits the explanatory power of the Solow model. Summers and Heston report that the capital stock per worker in the United States is approximately 22 percent higher than in Sweden while per capita income is more than 40 percent higher. The difference in physical capital can account for only about a 7 percent differential in per capita incomes if the share of fiscal capital in output is just one-third. Thus the Solow model with such sharply diminishing returns accounts for very little cross-country variation in per capita incomes.⁷

Neither can the model offer much help explaining differences in growth rates by appealing to the transitional dynamics. Imagine that a country could increase its rate of net investment by 50 percent. The model predicts that the growth rate would immediately increase, but would gradually decline over time until the new higher steady-state capital stock per capita was reached. The new steady-state income per capita would rise by about 22 percent.⁸ If the country completed the transition to this higher steady state in exactly 30 years, then the increase in the average annual growth rate would only be about 0.7 percent per year.⁹ Thus large increases in investment rates have little ability in the theory to explain growth rate differentials.

The above observations can be summarized by looking at the growth rates of productivity. If capital accumulation does not account for

much of the observed per capita growth, then the **Solow** model must rely on exogenous growth in technology or productivity. Since productivity growth is measured as the residual after accounting for factor accumulation, it is often referred to as the “**Solow residual**.” As can be seen from Table 2, productivity growth accounts for a substantial portion of economic growth in many countries and across many time periods. For example, the growth acceleration during the period 1950-73 from the previous 40 years and the slowdown since 1973 is, to a large degree, accounted for by variations in productivity growth, not variations in factors.

Table 2
Real GDP Growth and productivity¹

	1913-50		1950-73		1973-84	
	GDP growth	Productivity	GDP Growth	Productivity	GDP Growth	Productivity
France	1.20	1.42	5.10	4.02	2.20	1.84
Germany	1.30	.86	5.90	4.32	1.70	1.55
Japan	2.20	1.10	9.40	5.79	3.80	1.21
Netherlands	2.40	1.25	4.70	3.35	1.60	.81
U.K.	1.30	1.15	3.00	2.14	1.10	1.22
U.S.	2.80	1.99	3.70	1.85	2.30	.52
Average	1.87	1.30	5.30	3.58	2.12	1.19

¹ Source: Maddison (1987).

Implications for tax policy

The implications of the **Solow** model of economic growth should be fairly clear from the preceding discussion. Nevertheless, it is useful to explicitly consider a quantitative example that can serve as a benchmark for later discussions. King and Rebelo (1991) have simulated the quantitative impact of changes in the income tax in the **Solow** model. They calibrate the model by selecting the conventional value of $\alpha = 2/3$ for labor's share, a depreciation rate of 10 percent ($\delta = .1$) and a growth rate of technology of 2 percent. Because of the technological progress, this economy grows at 2 percent per year in the steady state.

The tax experiment explored by King and Rebelo is an increase in the average income tax rate from 20 percent to 30 percent. The steady-state growth rate is determined by the rate of technological progress so the long-run growth rate is unaffected by this policy. However, the tax increase does result in a lower steady-state capital stock and thus a lower steady-state level of output. King and Rebelo calculate that the capital stock declines by 18.2 percent in the long run. This translates into about a 6.5 percent decline in the level of income from what it otherwise would have been. During the transition to this lower capital stock the economy grows at less than its steady-state rate of 2 percent. If the new steady state is reached in 30 years, then the average annual growth rate is reduced by a mere 0.2 percent by this 50 percent increase in average tax rates. Thus high tax rates would not appear to cause much damage to this economy.¹⁰ By like token, lower taxes would not reap many benefits.

The search for new mechanisms for growth

The basic weakness of the traditional view of economic growth stems from two related factors. First, physical capital exhibits sharply diminishing returns in the production process, making it difficult for the model to be reconciled with cross-country variations in either living standards or growth rates. The second, related factor, is that the model does not provide any explanation for steady-state growth. Long-term growth is independent of savings and investment and is determined by the exogenously specified rate of technological progress. Since technology or productivity is not determined by the model, the theory provides no framework for understanding the economic forces and policies that influence the most important source of growth. While it may turn out to be true that there are severe limits on the ability of public policy to influence the long-run growth rate, it is important that we arrive at that conclusion some way other than by relying on models that simply beg the question.

The new growth theories attempt to address these deficiencies by constructing models where steady-state growth arises endogenously. The literature in this area is expanding at an exponential rate and it is impossible, nor is it my intent, to survey the scores of papers and theoretical perturbations they explore. What I will try to do is to

summarize what I consider to be two major strands to this increasingly technical literature in fairly simple terms. I apologize, in advance, to all those authors whose work I am summarizing but whom I fail to individually reference.

All of the models of endogenous growth must break the constraint of diminishing returns to accumulation imposed in the basic Solow or neoclassical model. The way this is done varies, but for my purposes it is convenient to divide the approaches into two broad strategies. The general set of implications of the new theories of endogenous growth is that societies that save and invest more will generally grow faster in the long run and therefore policies that affect the savings rate will have more important and sustained consequences for economic welfare.

The first group of models focuses on a broad measure of reproducible capital that includes not only physical capital, as stressed in the Solow framework, but other types of capital as well, especially human capital. The key to obtaining positive growth in the long run in these models is that there must be some subset of these capital goods whose production does not require the use of nonreproducible inputs. These models are the closest in spirit to the traditional framework of Solow, but the production technology is such that the role of investment and capital accumulation becomes a much more important channel for influencing growth. In these models, tax policy is more important for the long-run growth rate to the extent that it influences the long-run rate of accumulation of either physical or human capital.

The second strategy for generating endogenous growth captures a wide variety of approaches under one heading. These approaches must also break the link between capital, somehow measured, and diminishing returns, but they do so because there is some kind of spillover, externality or public good feature to the model. That is, private returns may be diminishing, while social returns are not because of the spillovers or externalities. What distinguishes these models from the previous ones is that external effects frequently result in competitive equilibrium being sub-optimal. If so, then there may be some scope for government policy to bring about a welfare improving outcome. In some ways it may be useful to think of these as attempts to model

technology as a reproducible factor of production.

Models with reproducible factors of production

One way to break the link between diminishing returns and capital accumulation is to think of all inputs to the production process as some form of reproducible capital, either physical or human. The idea is that what matters for production is not raw labor measured in terms of persons or hours worked, but the quality or efficiency of the labor as indexed by the knowledge or acquired skills of the worker. This broad measure of capital may also include other types of capital such as the state of knowledge.¹¹

The simplest form of this sort of process is one developed by Rebelo (1991) where output is expressed as a linear function of a broadly defined concept of capital. It is frequently referred to as the “AK” technology since the production function is written $Y = AK$.¹² This production function retains the property of constant returns to scale, but it no longer exhibits diminishing returns to capital accumulation. It is a special case of the production function in (1) with $\alpha = 0$.

This simple technology generates the most basic of all endogenous growth models. Since the production of output no longer faces diminishing returns as in the Solow framework, it can exhibit perpetual growth in per capita values. The reason is that since there are no diminishing returns to capital accumulation, a constant rate of investment can result in an ever growing capital stock per capita and thus steady-state growth.¹³ Thus to raise the long-run growth rate of an economy, it is sufficient that the savings rate rise.

In the Solow framework with diminishing returns to capital accumulation, the long-run growth rate is independent of the rate of savings or investment. Instead, steady-state growth is determined by an exogenously given rate of technological progress. In this class of endogenous growth models, the long-run growth rate is fundamentally determined by the saving and investment decisions of the citizens of the economy. This suggests that anything that influences the incentives of people to save and invest is potentially an important factor for influencing long-run growth prospects. Tax policies are obviously one

important factor influencing investment decisions. Since capital and financial markets are central to the efficient allocation of investment, regulation and development of the financial sector may be important for sustained economic growth.¹⁴ The importance of investment in these endogenous growth models for the long-run prospects of a nation stands in stark contrast to the Solow framework where raising the investment rate causes transitional growth, but has no impact on steady-state or long-term growth.

This simple endogenous growth model exhibits the essential features of almost all the models of this class. Nevertheless, it is instructive to add more structure to the framework. Rebelo (1991) explores the implications of various extensions of this simple linear model that treat the production of consumption, physical capital, and human capital as separate goods with distinct production functions. He demonstrates that in order to generate endogenous steady-state growth, it is only necessary that a "core" of capital goods be produced without the use of nonreproducible factors and according to a constant returns-to-scale technology. For example, the production of the consumption or physical capital good may involve nonreproducible factors or exhaustible resources, but as long as the production of human capital is constant returns to scale in human capital, then sustained growth is possible.

Quantifying the impact of taxes

King and Rebelo (1990) have calibrated both a one- and two- sector endogenous growth model of the sort described by Rebelo. The one sector model is essentially the linear technology model described above. The parameters are the same as in the Solow type model except that $a = 0$ so capital's share is one so that K must be interpreted as a broad measure of capital including human capital.

The tax experiment is again an increase in the income tax rate from 20 percent to 30 percent. Since the increase in taxes has an immediate effect on the investment rate by lowering the after-tax return to all forms of capital accumulation, the economy's long-run growth rate drops. Under the parameter values chosen, the economic growth rate drops by 1.63 percent, from 2 percent per year to 0.37 percent per year.

The consequences are large. After 30 years, an economy growing at 2 percent per year increases per capita income by 81 percent while an economy growing at 0.37 percent increases per capita income by just 12 percent.¹⁵ Even after just 10 years, the economy growing at 2 percent increases by 21 percent while one growing at 0.37 percent increases by just 3.8 percent.

King and Rebelo also explore the consequences of taxation in a two-sector model where one sector produces a familiar **consumption/physical** capital good and the other sector produces a core capital good labeled human capital. The basic results are similar. However, the two-sector model **permits** the ability to distinguish between taxes levied on physical goods and capital and human capital. Since income taxation amounts to taxing consumption and investment at the same rate, an increase in the tax rate reduces the long-run growth rate of the economy. It brings this about by reducing the **capital/labor** ratio in the economy. On the other hand, a consumption tax acts like a **nondistortionary** lump-sum tax and will have no impact on the long-run growth rate. As long as physical capital is used in the production of human capital, then even if human capital is not taxed directly, a tax on income in general impacts growth but the magnitude depends on the importance of physical capital in the production of human capital.

The lessons learned from these exercises is that investment in a broad concept of capital that includes human capital, can have quantitatively large effects on a nation's growth rate and thus the welfare of its citizens. From a public policy perspective, this means that policies intended to influence investment may be quantitatively more important than suggested by the traditional **Solow** view of capital accumulation. Specifically, investment in human capital plays a more prominent role and thus should not be ignored simply because it is harder to measure than physical capital.

Growth with externalities and spillovers

The models I group under this category are similar to the ones just described in that to generate sustained growth they must exhibit constant returns to scale in reproducible factors for some set of capital goods. They differ because they exhibit external effects. Nevertheless,

it is important to keep in mind that it is not the external effects that generate sustained growth, but it is constant returns to scale in all inputs that can be accumulated.

The work of Robert Lucas (1988), for example, emphasizes that human capital accumulation has external effects on the productivity of the economy. He postulates that an individual worker is more productive, regardless of his skill level, if other workers have more human capital. The important implication of the external effect is that under a purely competitive equilibrium its presence leads to an under-investment in human capital because private agents do not take into account the external benefits of human capital accumulation. Since the equilibrium growth rate in this model depends on the rate of investment in both physical and human capital for all the reasons discussed previously, the externality implies that growth would be higher with more investment in human capital. This framework suggests the possibility that a government subsidy to human capital formation or schooling could potentially result in a substantial improvement in economic growth and welfare.

Another example of the role played by external effects has been proposed by Paul Romer (1986) in one of the seminal contributions to the new work on growth. Building on the work of Kenneth Arrow (1962) and others, Romer's framework is conceptually similar to Lucas' model just described except that the source of the externality is the stock of knowledge. Knowledge is produced by individuals, but since newly produced knowledge can, at best, be only partially kept secret, the production of goods and services depends not only on private knowledge, but on the aggregate stock of knowledge as well. Firms or individuals only partially reap the rewards to the production of knowledge and so a market equilibrium results in an under-investment in knowledge accumulation. Knowledge in this framework is closely related to the level of technology so that Romer is explicitly attempting to make technological progress something that is determined by the model rather than imposed externally. Some of Romer's more recent work (for example, Romer [1990]) continues to stress the importance of invention and the development of new technologies as the engines of economic growth. In these newer models, firms cannot appropriate all the rewards to knowledge production so that the social

rate of return exceeds the private rate of return to certain forms of capital accumulation. Since knowledge and invention are developed by private profit maximizing firms, the economy may under-invest in these forms of capital. Consequently, public policies regarding tax incentives for research and development, patents and property rights, and regulatory issues may be critical to raising the growth rate and economic welfare in these economies.

Barro (1990) has explored a framework that includes tax-financed government services. In Barro's framework, government provides two types of services. First, government provides consumption-related services directly to households. These could be anything from food-stamps to art work. Second, the government sector supplies productive goods that can be considered public capital and serve as an input to private production. Services from infrastructure such as roads and bridges as well as courts and police services which may enhance property rights are candidates for public provided capital. Both types of services are assumed to be financed by a flat rate income tax. The production function must, as stressed before, exhibit constant returns to scale in factors that can be accumulated, in this case private and public capital. Otherwise, the long-run growth rate is once again determined by the rate of technological progress.¹⁶

The two types of government services impact long-run growth in different ways. First, government consumption services have no productive impact in this model economy, yet they are financed by an income tax that lowers the return to the accumulation of capital. Consequently, increases in government supplied consumption services reduces the long-run growth rate of the economy. Second, government supplied capital induces two offsetting effects. An increase in public capital raises the returns to private capital accumulation and thus raises the long-run growth rate. The increase in the income tax rate necessary to provide the capital acts to reduce the long-run growth rate. To balance these two effects and thus maximize growth, the government must supply public capital at the same level as would be provided by the private sector. Supplying more or less capital lowers the long-run growth rate. Thus a shift from productive to nonproductive spending by government would lower the long-run growth rate. Barro also argues that looking across countries, one should expect to see that the higher the ratio

of productive spending to output, the lower long-run growth rates will be.¹⁷

Industrial policies and endogenous growth

To some, these models with externalities are attractive because they appear to provide a rationale for government intervention and may have been seen as justifying a type of "industrial policy." Unfortunately, the leap from theory to practice in this case is a particularly large one. In the first place, welfare improving subsidies of specific activities are usually assumed to be offset by a nondistorting lump-sum tax elsewhere in the economy. In reality, tax and subsidy schemes are never so clear-cut. Subsidies are often financed by distortionary taxes and thus the benefits may be partially or totally offset. Second, the models generally say that it may be beneficial to reduce the tax on, say, research and development or on investment in those technologies that have the greatest external benefits. Such prescriptions are not easily translated into a method of "picking winners." The policymaker still does not know which investments will have the biggest external benefits nor is he likely to know in advance which industries will make the greatest contributions to the state of knowledge or human capital. Perhaps the best way to interpret these models is to recognize that reducing the taxation on investment in human capital and the production of knowledge will generally result in increases in sustained growth rates and to the extent such investments generate external benefits to the economy, the rewards are enhanced.

Economic growth in a cross-section of countries

Table 3 summarizes some of the facts surrounding the growth experiences for a broad cross-section of countries for the period 1960-89. The variables are ones that are frequently found in empirical studies of economic growth. The 97 countries had an average growth rate over the period of just over 2 percent. Of the 97 countries I have arbitrarily classified, the 23 that grew on average less than 0.5 percent per year as slow growth countries and they grew at an average annual rate of about -0.3 percent. The 14 countries that grew faster than 3.5 percent are classified as fast growth countries.¹⁸

Table 3
Growth Characteristics of a Cross-Section of Countries
1960-1989

	Overall average n=97	Slow growth <.5% n=23	Fast growth >3.5% n=14	Correlation with GDP growth rate
Real per capita GDP growth 1960-89	2.03%	-.26%	4.88%	1.00
Investment share of GDP	.21	.17	.26	.61
Government consumption share of GDP	.15	.15	.14	.10
Inflation rate	23.00%	42.11%	7.90%	-.17
Standard deviation of inflation rate	52.38	137.19	5.68	-.16
Exports as a share of GDP	.28	.24	.35	.30
Imports as a share of GDP	.33	.30	.40	.31
Secondary school enrollment rates 1960	.21	.06	.34	.41
Primary school enrollment rates 1960	.74	.44	.98	.54
Population growth	2.06%	2.55%	1.26%	-.36
Revolutions and coups per year	.20	.35	.12	-.37
Real per capita GDP in 1960	\$1840	\$889	\$1968	.20

There are several interesting aspects to these data. First, countries that grow faster typically devote a larger share of GDP to investment. They have sharply lower inflation rates and thus resort to inflation as a source of tax revenue to a lesser degree than the countries that grow slowly. Fast-growing countries also are engaged in trade with other countries to a greater degree than slow-growing countries. Moreover, it is not just export trade that is associated with fast-growing countries, but imports also constitute a larger share of GDP. Both secondary and primary school enrollments rates are higher in faster growing economies. These enrollment rates have been used by Barro (1991) and others as proxies for investment in human capital. Population growth in the slow-growth countries is 1.3 percent higher than in the faster growing economies. The average number of revolutions or coups is a variable intended to capture the political (in)stability of a country and is clearly larger for the sample of slow growth economies.

Barro (1991) and others have presented evidence that government consumption to GDP is negatively related to growth in some samples. The measure used in Table 3 indicates that slow growing economies have more government consumption to GDP than fast growing countries, but the correlation is weak. The measure used in Table 3 does not correspond to the nonproductive government spending emphasized in Barro's model. For a smaller sample of countries, Barro constructs a measure of government consumption that omits spending on education and national defense. He argues that these expenditures are more like public investment than consumption. He finds that measured appropriately, government consumption has significantly negative association with average growth rates. He also finds that public investment is largely unrelated to economic growth.

I have also reported the simple correlation of each variable with the real per capita growth rate. These correlations point to investment, trade, and school enrollments as the most correlated activities with growth. The school enrollment rates are of particular interest since they are as strongly correlated with real income growth as investment.

Finally, many authors have noted that in broad samples of countries initial income levels are not correlated with subsequent economic growth. If the Solow model is interpreted literally, the transitional dynamics of the model would suggest that poor countries should grow faster than rich ones so the correlation should be negative. In this sample the correlation is positive rather than negative. Charts 2-5 visually depict several of these associations summarized in the table. In Chart 2 the 97 countries are divided into quartiles based on their income per capita in 1960. The average growth rate of the countries in each quartile for the subsequent 29 year is then plotted. In this sample, this simple chart shows that richer countries on average grew faster during the period than poor countries.

Charts 3-5 divide the countries according to their growth rate rather than income. Chart 3 shows the positive association between investment shares and growth. This is one of the most robust correlations in the table. Chart 4 highlights the association between school enrollment rates in 1960 and growth. The more rapid growing countries appear to have been investing more in human capital. This result is particularly

Chart 2 Real Per Capita Growth and Real Income

Real Per Capita GDP Growth 1960-1989

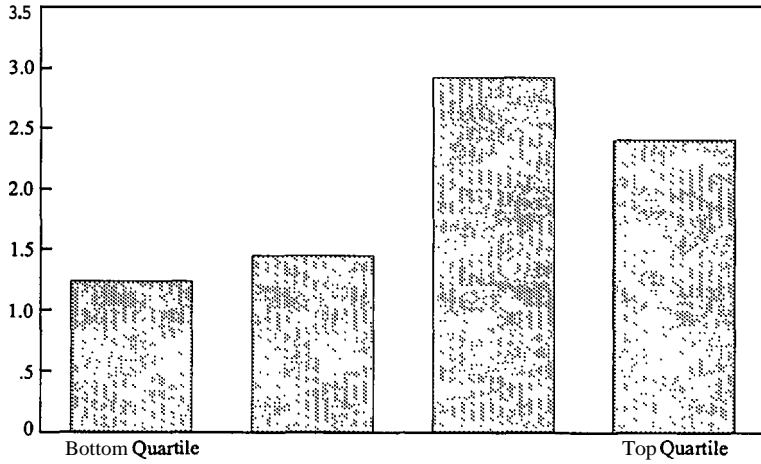


Chart 3 Investment Shares and Real Per Capita Growth

Investment Share of GDP

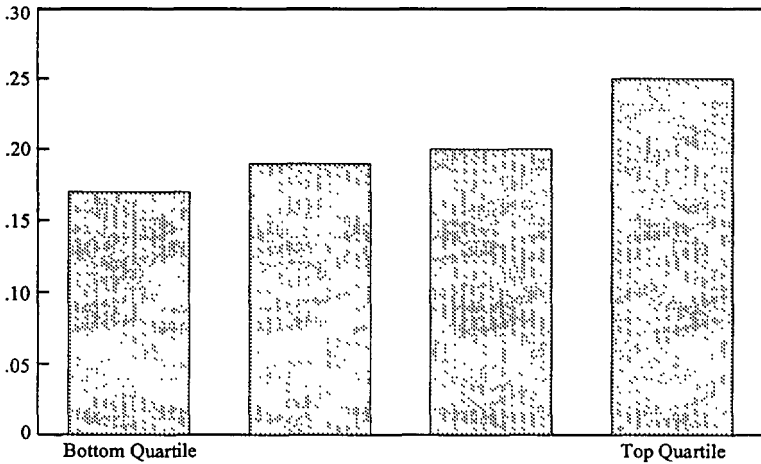


Chart 4 School Enrollment Rates and Real Per Capita Growth

Secondary School Enrollment Rates in 1960

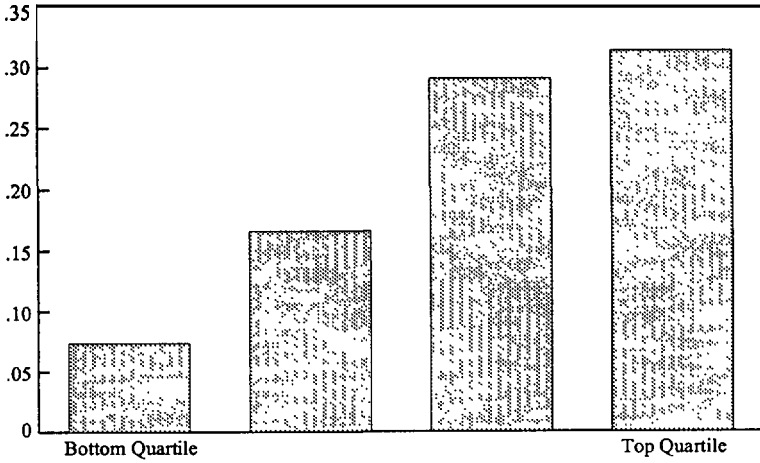
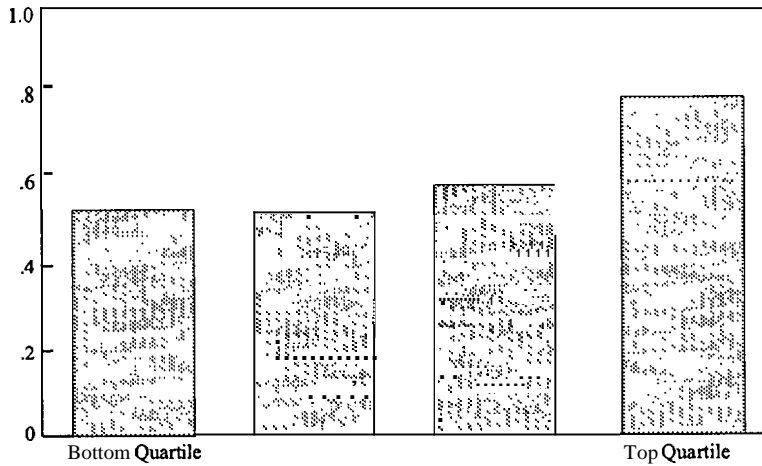


Chart 5 Trade Share of GDP and Real Per Capita Growth

Trade Share of GDP



important given the significant role played by human capital accumulation in the new models of long-term growth. Finally, Chart 5 breaks down the relation between the volume of trade and growth. The fastest growing countries engaged in more trade in relation to the size of the economy than slower growing nations.

While these comparisons are interesting and instructive, the sample contains a very wide variety of countries whose experiences, endowments, and forms of government are quite different. It is helpful to break out a subsample of countries that are potentially more similar to see if the relations observed previously are robust. Table 4 replicates the previous table for 24 countries of the Organization for Economic Cooperation and Development (OECD). Compared to the larger sample this is a fairly homogenous group of countries which were generally among the richest nations in 1960, if not always the fastest growing.

It is instructive to note the features that are associated with slower economic growth and compare them to the broader sample. First, the association between growth and investment remains strong. In this sample a negative correlation between growth and government spending is more pronounced. There is also a negative association between the initial level of income and growth. Finally, Table 4 includes a variable that measures the average tax rate on income and profits in each country. In the endogenous growth models such a tax would act to discourage investment in both physical and human capital and thus lower the growth rate. The correlation is indeed negative as seen in the table. Chart 6 displays this negative association between tax rates and growth.

It would be wrong to take these simple correlations as evidence of causation running from the variable of interest in Tables 3 or 4 to real economic growth. Many of them, such as investment rates, are endogenous variables. That is, investment may cause more rapid economic growth, but rapid economic growth may also increase the demand for investment goods. Other variables might be spuriously correlated with growth simply because they may be correlated with a third more important variable. In fact, many of these variables are correlated with each other so determining the marginal impact on growth of any one

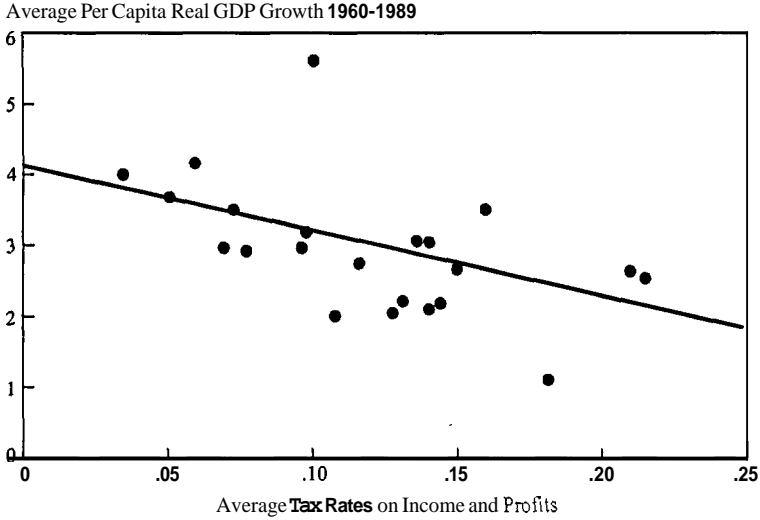
of them may prove difficult. On the other hand, this sort of information is suggestive and important for understanding various factors related to long-run growth.

The empirical strategy followed in most of the literature is to estimate various cross-country regressions in search of a set of stable relations among the various variables suggested by the theories. One of the major difficulties is that the data necessary to adequately test the predictions of both the old and new models of growth are not available. In some cases the quality of the data is suspect and is likely to be heavily influenced by measurement error.¹⁹

Table 4
Growth Characteristics for OECD Countries 1960-1989

	Overall average n=24	Slow growth <3.0% n=13	Fast growth >3.0% n=11	Correlation with GDP growth rate
Real per capita GDP growth 1960-89	3.00%	2.40%	3.71%	1.00
Investment share of GDP	.23	.21	.25	.61
Government consump- tion share of GDP	.17	.19	.16	-.45
Income & profit taxes share of GDP	.12	.14	.10	-.52
Inflation rate	9.03%	8.33%	9.84%	.13
Standard deviation of inflation rate	5.61	5.38	5.87	.13
Exports as a share of GDP	.29	.31	.27	-.17
Imports as a share of GDP	.30	.31	.29	-.11
Secondary school enrollment rates	.50	.51	.50	-.15
Primary school enrollment rates	1.10	1.10	1.09	.03
Population growth	.78%	.88%	.67%	-.14
Real per capita GDP in 1960	\$4333	\$4990	\$3534	-.68

Chart 6 Real Economic Growth and Tax Rates in OECD Countries



Levine and Renelt (1992) have examined these cross-country regressions in great detail attempting to identify those relations that appear robust. The following findings are summarized from their conclusions:

Investment rates (for both physical and human capital) display a robust positive correlation with average growth rates across a wide variety of samples and specifications.

Trade as a share of GDP is positively correlated with investment. Moreover, import shares work as well as export shares so growth appears to be closely associated with trade not just exports as is sometimes asserted.

Poor countries seem to grow faster than rich countries if the initial level of human capital is held fixed as measured by school enrollment rates. This conditional convergence property appears significant over the 1960-89 period but does not appear to hold over the 1974-89 period.

Trade policy variables appear closely related to investment and so their separate impact on growth cannot be determined independently of investment.

The correlation of some fiscal policy variables with growth is dependent on what other factors or policies are held fixed.

In some ways it is not surprising that policy variables are not robustly correlated to growth, especially when investment is held fixed. After all, if there is a channel for policy it is through its impact on the incentives to save and invest. Moreover, policies are complex and varied ranging from monetary and fiscal policies to regulatory and trade restrictions. Finally, policies within a country are frequently highly correlated. For example, countries that have strong and large central governments frequently adopt a wide range of potentially slow growth policies including higher taxes, more restrictive trade policies, more regulation of financial intermediaries, and so on. So if we are clever, we may find a way of summarizing an entire package of government policies employed by a country but it may prove very difficult or impossible to disentangle empirically the separate effects of one aspect of policy from another.

Solow revisited

The work on endogenous growth models and their emphasis on broader concepts of capital has prompted a number of authors to ask if the original Solow framework with diminishing returns can be made more consistent with data by broadening the concept of capital. Barro (1991), Barro and Sala-i-Martin (1992) and Mankiw, Romer, and Weil (1992), for example, find evidence that after controlling for potential differences in steady states, and in particular differences in investment in human capital, poor countries grow faster than rich countries. Conditional convergence of this sort is usually interpreted as supporting the Solow framework and its dependency on diminishing returns and as inconsistent with endogenous growth models.

The logic of the Solow model with diminishing returns is that countries will converge to a steady-state level of income per capita, but not necessarily the same steady state. Thus without accounting for

the potential differences in the steady-state income levels there would be no reason to expect to see poor countries growing faster than rich ones and, indeed, Chart 2 and Table 3 make it clear that they don't. However, convergence would be anticipated in the Solow framework after conditioning on the determinants of the steady-state level of income.

Mankiw, Romer, and Weil (1992) find evidence of such conditional convergence but find that reasonable estimates are produced only after broadening the concept of capital to include human capital. As a result, the version of the Solow model constructed by these authors exhibits a capital share that is at least 0.67 rather than the value of 0.33 that is commonly associated with physical capital. Barro and Sala-i-Martin (1992), through a similar analysis, arrive at an estimate of capital's share of 0.8. Both of these results point to a much more important role for capital accumulation and human capital accumulation because their implied models are much less influenced by the sharply diminishing returns of the standard neoclassical framework. Nevertheless, these analyses remain silent on the sources of sustained economic growth since technological progress or productivity improvements remain the sole source of growth in the steady state.

It was noted earlier that in the Solow framework with capital's share set at 0.33, the convergence to a new steady state should have a half-life of six to 10 years. With capital's share increased to 0.67, the half-life increases to something on the order of 30 years; One implication of this slower transition is that the impact of policies that alter the steady-state growth rate is spread out over much longer periods so that impact on growth rates of the transitional dynamics in these models is even less. For example, if a policy increases the steady-state level of income by 25 percent, but it takes 60 years instead of 30 years to fully close the gap, then, during the transition, growth rates would on average only be 0.4 percent per year higher compared to 0.8 percent higher for the model with a shorter transition period. Thus, using the Solow model, even with a much higher capital share, does not really offer much additional explanation for growth.

It is worth noting at this point that conditional convergence of the type uncovered by these authors is not necessarily inconsistent with

the new theories of endogenous growth. In some settings where there are multiple sectors, the new theories do predict transition paths from one steady-state path to another. Thus it is very likely that some form of convergence will be found in these models as well. What the empirical literature has found may simply be evidence for the existence of transitional dynamics not a discriminating test of old vs. new theories of growth.

An assessment and prospects for the future

The new theories of economic growth seek explanations for sustained economic growth and persisting disparities across countries in income levels and growth rates. The traditional view based on the work of Robert Solow appeared to leave too much of such explanations to unobserved exogenous forces like technological progress. Indeed, economic policies intended to influence the rate of physical investment could not affect steady-state growth in this traditional framework. Such policies could influence the level of steady-state output and thus the transition to new long-run equilibrium. However, diminishing returns to capital accumulation make it virtually impossible for the traditional model of growth to explain much of the very large variations in income levels or growth rates.

The new growth theories are extensions of the basic neoclassical framework developed by Solow. The feature that distinguishes these models from the neoclassical framework is that they entertain the possibility that the returns to capital accumulation are no longer bound by diminishing marginal productivity. In order to generate sustained economic growth, these models focus on the existence of a "core" set of capital goods that are constant returns to scale in reproducible factors of production. Breaking the dependence on diminishing returns is frequently achieved by considering broad forms of capital in the production process and especial focusing on the role of human capital. Another closely related strategy is to consider endogenous technological progress where private investment in the acquisition of knowledge or technology has external benefits that offer an escape from the limitations of diminishing returns.

The implication of these models is that capital accumulation in all

forms is quantitatively more important than in the traditional framework. Consequently, they provide an interesting and rich laboratory for investigating the impact of policy on economic growth. The sorts of public policies that impact the incentives of millions of individuals to save and invest in both physical and human capital as well as invest in the development of new technologies turn out to be central to the long-run rate of growth.

It is too early to measure how successful these attempts will be to explain growth and understand how policies are likely to interact with a nation's growth rate. As yet these models have simply not confronted the data in ways that will deliver answers to such important questions. Understanding the role and significance of human capital or the accumulation of knowledge and technology are difficult but the payoffs are large.

Endnotes

¹whether economists have been any more successful at these endeavors remains an open question.

²Of the 24 countries, out of a sample of 97, whose per capita incomes were in the bottom quartile in 1960, 18 were in the bottom quartile in 1989, and 23 remained among the bottom 50 percent.

³Lucas (1987) argues that eliminating variability in consumption of the magnitude experienced in the United States over the postwar period would be equivalent in utility terms to an increase in average real consumption of somewhere between 0.1 percent and maybe as much as 0.75 percent. On the other hand, raising the long-term growth rate by two percentage points would be equivalent in utility to an increase of 31 percent in real consumption.

⁴I am assuming that the population and the labor force are the same. For purposes of this discussion, nothing of importance is sacrificed with this simplification. It should be apparent that this production technology exhibits diminishing returns to the capital/labor ratio K/L .

⁵In technical terms, the growth rate of the per capitacapital stock can be written as $(k_{t+1}-k)/k_t = g_{kt}$ so that dividing the capital accumulation equation through by k yields $g_k = i/k - \delta = sAk^{-\alpha} - \delta$, where s is the investment rate i/y . As the capital stock per capita grows, the first term, $sAk^{-\alpha}$, declines until it reaches δ .

⁶The discussion in the text will typically proceed as if the savings rate is predetermined since this makes certain aspects of the framework more intuitive. However, it is important to keep in mind that savings rates are chosen by agents and so are endogenously determined. In order to affect changes in the savings rate, the incentives to savings/investment must be altered.

⁷Mankiw, Romer, and Weil (1992) find that if capital's share is set at one-third, they can only explain 28 percent of the cross-country variation in long-run average income levels using a sample of 75 countries. The model explains even less of the variation among OECD countries.

⁸The investment to output ratio is proportional to the capital and output ratio in the steady state and given the Cobb-Douglas technology is $Y/L = A[K/Y]^{1-\alpha}/\alpha$ or $y = A[k/y]^{1-\alpha}/\alpha$.

⁹How fast an economy converges to a new steady state is a matter of considerable debate. Estimates apparently depend on the sample and other characteristics that are held fixed. Barro and Sala-i-Martin (1990) and Mankiw, Romer, and Weil (1992) estimate that one-half the gap is closed anywhere between 25 years and 110 years depending on the sample considered. The Solow model with $\alpha = 2/3$ predicts that the gap should close much more rapidly and depends on several parameters. King, Rebelo, and Plosser (1988) compute the half-life of the transition as ranging from five to 10 years under a reasonable range of parameter assumptions.

¹⁰King and Rebelo measure the welfare loss to this economy of the increase in taxes as equivalent to a permanent 1.6 percent drop in real consumption.

¹¹See Uzawa (1965) and Lucas (1988) for early work on incorporating the accumulation of human capital into a model of economic growth.

¹²In per capita terms, this production function is $Y/L = y = AK/L = Ak$.

¹³For this model with a constant Investment rates, the growth in the per capita capital stock can be expressed as $g_k = sA - \delta$. Thus anything that raises the rate of investment, s , or the level of technology, A , will also raise the growth rate.

¹⁴The role of financial intermediaries and their ability to allocate investment is explored by King and Levine (1991, 1992) and by Roubini and Sala-i-Martin (1991).

¹⁵The welfare consequences are equally large. King and Rebelo estimate the loss due to the tax increase is equivalent to a drop of 65 percent in real consumption.

¹⁶The potential for a sub-optimal competitive equilibrium arises in this framework if, for example, tax rates are fixed so that an increase in private capital results in an increase in public capital because output and therefore, public spending rises. If the increase in public capital is not recognized as part of the return to private capital accumulation then the resulting competitive equilibrium will produce too little growth since the social rate of return exceeds the private rate of return.

¹⁷The reasoning behind this point is somewhat subtle. If governments are optimizing, then the reason why different countries exhibit different spending ratios is that the relative productivity of public vs. private capital differs across countries. Countries with higher spending ratios and higher taxes are likely to experience lower growth rates because public capital must be financed through a distortionary tax.

¹⁸The standard deviation of the average growth rates for the 97 countries is 1.78 percent so the slow and fast growth countries are those that are slightly less than one standard deviation from the mean.

¹⁹Summers and Heston (1991) grade the quality of their extensive cross-country data set and many of the countries rate a C- or D, especially in Asia, Africa, and South America. Yet a large fraction of the cross-country variability in growth rates arises from countries on these continents.

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