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Early Progress on the "Problem of Economic Development"

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Per-capita output differs widely across countries, with differences of a factor of 20 not uncommon. These economic statistics reflect substantial differences in the economic well-being of people. While factors like luck and geographic location, factors beyond a country's control, certainly account for some of this inequality, many think much is also due to some countries following good economic policies and others bad. That is why economists have extensively studied the policies of countries undergoing the development process (for example, Harberger 1984, Krueger 1987, Young 1992). If economic policy is a major determinant of the wealth of nations, then the potential benefits of learning which policies work, and which do not, are obviously immense.[1]

The task of determining the impact of any particular policy on the wealth of a nation is extremely difficult. But some recent, important developments have moved us closer to being able to tackle such tasks. One is the significant expansion in the quantity and type of data available to economists. A primary contribution has come from Summers and Heston (1991), who have compiled observations on per-capita output (and other variables) for most of the countries in the world, for most of the post–World War II period. Their construction of per-capita output uses a common set of prices to value the quantities of final goods and services for each country. Good economic statistics are, of course, necessary for any work attempting to understand the impact of economic policies. Another development is the supplementing of these data on per-capita output, by many researchers, with country-specific measures of such things as the stock of physical capital, the stock of education and health, and the type of political system. With these data, researchers have been looking for variables that are correlated with the wealth of nations.

While all of this is important, economists are also well aware of the limitations of basing policy advice solely on data analysis, on correlations among economic variables. The reasons are well known and include at least these: Finding a correlation between two variables does not prove a causation; and even if one were very confident that changes in one variable (say, the stock of education in a nation) caused changes in another (say, the wealth of a nation) in some historical period, that relationship may not continue to hold if new policies are introduced. Data analysis is simply not enough.

Because of these limitations of data analysis, economists have also been exploring theories that might help in policy evaluation. Ultimately, the goal is for theory to provide answers to questions such as, What is the impact of increasing investment in education? Of privatization? Of opening borders to trade? But where should we begin? A natural initial goal is to build models which can replicate the economic statistics of actual economies (for example, the range of per-capita output in the world). This is what Lucas (1988, p. 3) has in mind in his 1985 Marshall lecture when he defines the "problem of economic development" to be the "problem of accounting for the observed pattern, across countries and across time, in levels and rates of growth of per capita income." With this as the goal, there is a natural way to compare competing theories: choose model *A* rather than model *B* to analyze policy if model *A* mimics more features of actual economies. (See Lucas 1980 for a discussion of this methodological view.)

The purpose of this article is to provide a progress report on research on the "problem of economic development." I will describe here some of the recent efforts to build models that produce economic statistics which match the observed patterns across countries in per-capita output. I call these patterns *development facts* and the models *theories of economic development.*

While the model building is at an early stage, so that its relevance for policy is limited at this point, I think progress has been made. In fact, my hunch is that, ultimately, solutions to the development problem could come from those theories that focus on differences across countries in the incentives provided to entrepreneurs to create businesses, adopt technologies, and the like (such as in Parente and Prescott 1991). Admittedly, this hunch may reflect my personal biases, since my own work is in related areas. Still, my view is based in part on the successes of the entrepreneurial approach in explaining development facts and on the failures of two other types of theories in doing so: the neoclassical theory of economic growth, which relies on differences in physical capital per person across countries to explain the wide diversity in per-capita output, and the newer theories of economic development (such as in Lucas 1988 and Mankiw, Romer, and Weil 1992), which stress differences in human capital, or education, across countries.

If the entrepreneurial approach continues to be successful, then the policy implications are somewhat sobering. For if the problem of economic development were, for example, primarily a matter of too little education in poor countries, then the obvious solution would be for the international community to simply subsidize schooling where it is lacking. But if the problem is instead barriers placed in the way of entrepreneurs, then the solution is much less obvious. Barriers to entrepreneurs are created by groups in society, those with vested interests in the status quo. Much must be learned about the forces that lead to such barriers if economists are to be able to offer policy advice about how to design institutions that minimize this behavior.

Some Development Facts

Since the goal of development theory (as defined by Lucas 1988) is to explain the development facts, a key question is, What facts? A good source of some basic facts about the distribution of wealth across nations is the article by Parente and Prescott (in this issue). Their analysis is based on data on most of the countries in the Summers and Heston data set over the period 1960–85. Some of their principal findings are these four *development facts:*

1. There is a huge disparity in wealth across nations each year. According to Parente and Prescott, for example, in 1985 the average per-capita output of the five countries with the highest per-capita output was 29 times the average per-capita output of the five lowest-output countries.
2. The range of the distribution of relative wealth has been roughly constant over this period, where relative wealth is measured relative to the industrial leader, the United States.
3. Several countries have made large moves in the relative wealth distribution—some up (Japan, for example) and some down (Zambia, for example).

4. While the range of relative wealth has not changed much, the distribution of the level of wealth has shifted up over time; that is, wealth has grown.

Besides Parente and Prescott (in this issue), many others have analyzed the Summers and Heston data set. Many of these studies supplement the data with country-specific measures of things like education (Barro 1991, 1992; Benhabib and Spiegel 1992; Mankiw, Romer, and Weil 1992), equipment investment (De Long and Summers 1991), trade (Backus, Kehoe, and Kehoe 1992), and the type of political system.[2] What these studies do, in effect, is break the sample of Summers and Heston countries into groups (defined by things like level of education) and examine the distribution of wealth within those subgroups. Typically the studies examine the mean of the distribution of wealth or the mean growth rate in each subgroup.[3]

In considering how well a model matches the development facts, I focus attention here on the four Parente-Prescott findings listed above. Ultimately, of course, the findings of the other studies (as well as the other findings of Parente and Prescott) must be used in building theories of economic development. But initially, attention must be limited to some extent in order to make progress.

Two final points about data. First, while a good theory must be consistent with the facts, it does not necessarily have to explain, or help us understand, all of them. For example, the neoclassical growth model does not explain productivity growth, but it does help us understand other features of the data, such as the relative constancy of real interest rates and the growth in the real wage. In the same way, a good theory of development might explain only a subset of facts: The particular facts depend on the questions being asked.

For example, the fact that the range of relative per-capita output has not changed much (fact 2) suggests that whatever causes growth (fact 4)—that is, the distribution of wealth to shift up—has benefits for all countries. There appear to be common factors that bind countries together. Hence, those advising developing countries might be happy with a model that explains why there is such large disparity in the wealth of nations (fact 1), or what causes large moves (up and down) in the relative wealth distribution (fact 3). This would be true even if the model does not explain what causes the distribution of wealth to shift up (though the model should at least be consistent with this fact).

But someone advising the G-7 countries (a group of seven highly developed countries) wants a theory that explains growth. After all, these few countries are mainly responsible for determining the rate at which the distribution of wealth shifts up, through their research and development policies, support for academic science, and the like. Indeed, most development theories to date have primarily focused on understanding growth. (See, for example, Romer 1986, 1990; Jones and Manuelli 1990; Grossman and Helpman 1991; and Rebelo 1991.) This literature has been extensively reviewed elsewhere. (See, for example, Helpman 1992.) In this article, I discuss models that have primarily focused on the other three development facts.

Second, while I use the term *facts* for the above findings, keep in mind that, among other things, the data for some countries are still of poor quality, and the time period for which the data are available for most countries is rather short. The practical significance of this is that one should be less confident in abandoning model *A* in favor of model *B* based on model *A*'s inability to match some aspect of the data.

Overview

Since my formal analysis begins with a rather long section that sets up a consistent notation, here I provide a brief guide to the entire article.

Addressing the development facts obviously requires a model with more than one country and, hence, also assumptions about how these countries interact. Below I will study both of the polar assumptions about trade: complete factor mobility and immobility.

I will start by reviewing the neoclassical model of economic growth first developed by Solow in 1956. I will review it generally and then as a theory of economic development.[4] This model has been the workhorse in many areas in economics—in the analysis of tax policy in public finance, for example. (See Prescott 1988 for a discussion of the model's impact.) Because of the model's wide success, it is a prime candidate for a theory of economic development. The Solow model includes a production function that has constant returns-to-scale in two inputs, physical capital and homogeneous labor. To use the model as a theory of economic development, I begin by assuming that there are many countries, that firms in each country have access to the same production technology, and that there is factor mobility. Then capital is allocated so that the marginal product of capital is equal across countries. This means that the capital-to-labor ratio and per-capita output are the same in every country. This, of course, is grossly at odds with development fact 1.

I will study several changes to the Solow model that break this equal-output implication. Most of these, however, do not seem likely to change the general conclusion that the model cannot account for great inequality (fact 1). For example, I will derive a simple formula which expresses (in a world of capital mobility) the relative output of two countries as a function of their taxes on capital rental payments. I will use it to show that large differences in taxes on capital rental payments across countries are associated with small differences in per-capita output (as compared to fact 1).

A more promising change that Lucas (1988) considers is to modify the form of the production function. In considering this change, one is guided by a key question: How can the production function be altered so that the equalization of the marginal products of physical capital across countries (implied by trade) no longer means that the quantity of physical capital per person (and output per person) is also identical? In other words, why is the marginal product of capital not high in countries where it is scarce? The answer Lucas (1988) proposes is that other inputs are also scarce in such countries, in particular, capital inputs complementary to physical capital. Since these other capital inputs are missing from the Solow model, I refer to them as *missing capital.*

What is this missing capital? Lucas (1988) takes it to be *human capital*, by which he means the general skill level of the representative worker. Many others have followed this lead. Under this interpretation of missing capital, physical capital is not attracted to less-developed countries where it is scarce because they lack a skilled work force to do things like operate machines.

Doubts have subsequently been raised about whether human capital will play an important role in explaining the development facts, at least when this type of capital is thought of as years of schooling. I will present some additional doubts below.

These doubts about human capital have led to other candidates for missing capital. One candidate is closely associated with the policies of deregulation and privatization that are often recommended by the International Monetary Fund (IMF) and the World Bank. These policies are implicitly based on the assumption that they will create incentives for entrepreneurs to create new businesses, adopt new technologies, and the like. Such investments by entrepreneurs create a type of capital, capital that exists independently of the entrepreneur. This capital has been given several names: *goodwill* or *intangible capital* by accountants and *organizational capital* by economists (Prescott and Visscher 1980), for example. It has recently been introduced in a development context by Parente and Prescott (1991), who use the term *firm-specific capital.* Holmes and I (1992) call it *business capital,* the term I will use here. Under this interpretation of missing capital, physical capital is not attracted to less-developed countries where it is scarce because entrepreneurs have created very few opportunities in which to invest physical capital (an idea Schultz 1974 emphasizes).

Below I will consider two modifications of the Solow model—one adding human capital, the other adding business capital—and evaluate each as a theory of development.

A model that extends the Solow model by introducing human capital will be presented first. The model includes a production technology that exhibits constant returns-to-scale in two capital inputs, physical and human capital, while the accumulation technologies for each capital good also display constant returns. The model is a version of that Lucas (1988) discusses.[5] The model is consistent with wide differences in per-capita output—that is, fact 1—under all trade assumptions. Other implications of the theory, however, seem to be at odds with the facts. As Parente and Prescott (1991) argue, and as will be shown below, if there are small differences among countries, then the range of relative output in the model economy increases through time (even in a world with trade), thus contradicting fact 2.[6] Lucas (1993) discusses other troubling aspects of the formulation.

A model that extends the Solow model by introducing business capital will be presented next, a version of that of Parente and Prescott (1991). In the model, the production technology facing an entrepreneur exhibits increasing and then decreasing returns-to-scale in three inputs: two capital inputs, physical and business capital, and homogeneous labor. This leads to a unique business size. Regarding the accumulation technology for business capital, some literature suggests that this technology does not display constant returns. Rather, the return to investment in business capital, and to adopting new technology, in a country depends on how far the country's business capital is behind world technology standards. The further behind it is, the greater is its return to investment. The curvature parameter of this accumulation technology is a key parameter in the model. It is chosen so that the model is able to replicate the post-WWII experience of Japan, that is, so that it can produce large moves in the relative wealth distribution (consistent with fact 3).

In a steady state of the model, all countries grow at the same rate (a rate determined by the rate at which world technology expands). Hence, the range of relative output is constant through time (fact 2), as in the Solow model. I derive a new formula for this model which expresses (in a world of capital mobility) the relative output of two countries as a function of their taxes on physical and business capital rental payments. This formula is an analog to that calculated in the Solow model. As a simple example will show, differences in tax rates on payments to capital (of both types) lead to much larger differences in per-capita output than in the Solow model. Still, questions remain about whether the range of taxes necessary to explain fact 1 is believable and, more generally, how to measure effective tax rates on entrepreneurs in these countries.

Neoclassical Growth Theory

The Solow Model . . .

Here I develop a version of the Solow (1956) growth model, as extended by Cass (1965) to include endogenous savings. This is done so that I can then assess the model as a theory of development.[7]

The model is a closed economy. Time is discrete; $t = 0, 1, 2, ...$ At each time t, the economy produces one good, the time t good, that can be consumed or converted into units of investment. The economy is comprised of N identical, infinitely lived households, each endowed with a unit of time each period. For simplicity, leisure is ignored. The time endowment is therefore inelastically supplied each time period.

Let c_t denote per-person consumption of the time t good. (Per-capita quantities are denoted by lowercase letters; total quantities, by uppercase letters.) Then a representative person values sequences of consumption, $\{c_t\}$, according to

$$(1)\qquad \sum_{t=0}^{\infty}\beta^t u(c_t)$$

where the discount factor $\beta \in (0,1)$ and the utility function $u(\cdot)$ is increasing and concave.

Let Y_t denote economywide output of the time t good. Then aggregate production is

$$(2)\qquad Y_t = F(K_t,N_t,A_t)$$

where K_t is the economy's total number of units of capital, $N_t = N$ is its total time endowment, A_t is its level of technology, and the production function $F(\cdot,\cdot,A_t)$ is increasing, concave, and homogeneous of degree one in the first two arguments. Again, output can either be consumed, C_t, or invested, X_t, so that $Y_t = C_t + X_t$. The law of motion for capital is $K_{t+1} = (1-\delta)K_t + X_t$, where $\delta > 0$ is the rate of capital depreciation. Together these imply that

$$(3)\qquad Y_t = C_t + K_{t+1} - (1-\delta)K_t.$$

The level of technology is assumed to follow

$$(4)\qquad A_{t+1} = (1+\mu)A_t$$

where $\mu > 0$ is the rate of technological change. Equations (1)–(4), together with the initial condition (K_0,A_0), describe the economy's preferences, technology, and endowments.

The resource allocation problem facing this economy is simple to describe. At time $t = 0$, the economy inherits a capital stock K_0. This capital stock, the current level of technology A_0, and the time endowment N determine a level of output Y_0. A choice must be made as to what capital stock K_1 to carry forward into time period 1. This is equivalent to choosing investment X_0 (from the law of motion for capital) and, hence, also consumption C_0. As the economy enters time period 1, it inherits the capital stock K_1 determined by choices at time 0. This capital, together with A_1 and N, determine output Y_1, and the choices are repeated. These choices can be made in a number of ways—for example, by command through a central planner or, as examined below, through a market.

☐ *Market Allocation*

For the market allocation studied here, there are three types of actors: households, firms, and banks. Households own the firms and banks (though, by assumption, these make zero profits). Households supply labor to firms in return for wages and then use the wages to purchase consumption goods from the firms. Any excess of wages over consumption purchases is deposited at banks where it earns interest. Firms rent labor input from the households and capital input from the banks. They sell consumption goods to households and investment goods to banks. Banks own the capital stock. They take deposits from households and use the deposits to purchase investment goods from firms to increase their capital holdings. Banks rent the capital to firms, using the proceeds to pay off interest on deposits.

Next I will describe the decision problems of these actors. (Since, given assumptions below, the numbers of firms and banks are indeterminate, assume that the numbers of firms and banks equal the number of households. In this way, the same notation can be used to denote per-capita, per-firm, and per-bank quantities.)

Households face the following prices: w_t, the rental rate for a unit of labor, denominated in units of the time t good, and i_t, the interest rate on deposits, with each unit of the time t good deposited at the bank yielding $1 + i_t$ units of the time $t + 1$ good. Let n_t be the time devoted to work and d_t be the deposits made in the bank at time t. Then the budget constraint of the representative household at time t is

$$c_t + d_t = d_{t-1}(1+i_{t-1}) + w_t n_t. \qquad (5)$$

Terms on the right side of constraint (5) are the sources of income. Wage income is $w_t n_t$, and $d_{t-1}(1+i_{t-1})$ is the income from deposits made at time $t - 1$.[8] Terms on the left side of constraint (5) are the uses of income. Income can either be consumed, c_t, or deposited in the bank, d_t. If households maximize utility, it must be true that

$$u'(c_t) = \beta[u'(c_{t+1})](1+i_t) \qquad (6)$$

where $u'(c_t)$ is the derivative of $u(\cdot)$. If a household is maximizing utility, then the cost of postponing a unit of consumption—the left side of (6)—must equal the benefit of doing so—the right side of (6).[9]

Since firms rent both labor and capital, a firm faces a sequence of static maximization problems. The rental rate on a unit of capital is denoted r_t, denominated in units of the time t good. The profit-maximization problem of the representative firm is[10]

$$\max\{c_t+x_t-w_t n_t-r_t k_t\} \qquad (7)$$

subject to

$$c_t + x_t \le F(k_t,n_t,A_t). \qquad (8)$$

If a firm is maximizing profits, then it must be that

$$r_t = MPK_t(k_t,n_t,A_t) \qquad (9)$$

$$w_t = MPL_t(k_t,n_t,A_t) \qquad (10)$$

$$c_t + x_t = F(k_t,n_t,A_t) \qquad (11)$$

where $MPK_t = F_1(\cdot,n_t,A_t)$ and $MPL_t = F_2(k_t,\cdot,A_t)$ denote the marginal products of capital and labor and where F_i is the partial derivative of F with respect to its ith argument.

Consider next the operation of a representative bank. Suppose at the end of a time period, say time $t - 1$, the bank takes a deposit of a time $t - 1$ good from a household. With the deposit, the bank purchases a unit of investment. Receipts from this operation are zero. At time t, the bank rents the capital to a firm for r_t units of the time t good; after its use, the capital is worth $1 - \delta$ units of the time t good. For the deposit taken at the end of time $t - 1$, the bank owes $1 + i_{t-1}$ units of the time t good. Receipts from this operation are

$$[r_t + (1-\delta)] - (1+i_{t-1}). \qquad (12)$$

Assume that receipts per unit of deposit are independent of the volume of deposits; that is, assume constant returns-to-scale in intermediation.

☐ *Equilibrium*

A *competitive equilibrium* for this economy consists of

- An allocation for households $\{c_t,d_t,n_t\}$
- An allocation for firms $\{c_t,k_t,x_t,n_t\}$
- An allocation for banks $\{d_t,k_t,x_t\}$
- A price system $\{r_t,i_t,w_t\}$

such that

a. Households maximize utility subject to their budget constraints.

b. Firms maximize profits subject to their technology constraints.

c. Banks maximize profits subject to their technology constraints.

d. Markets clear.

e. The net worth of banks is zero.

A *steady-state competitive equilibrium* is a competitive equilibrium in which each variable either is constant or grows at a constant rate.

I am primarily interested in examining conditions that are necessary for equilibrium. Part a of the competitive equilibrium definition implies that (6) is a necessary condition; part b, that (9)–(11) are. To satisfy part c, banks must earn zero profits on each transaction, or

$$r_t = i_{t-1} + \delta. \qquad (13)$$

□ Functional Forms and Parameters

To be able to assess the Solow model as a theory of economic development in the sense above, we must make choices for functional forms and assign values to parameters. Such decisions have been made by researchers using the model to study U.S. time series data. In particular, choices have been made so that quantities and prices in the steady-state competitive equilibrium of the model—such as productivity growth, the capital/output ratio, capital's share in income, and interest rates—closely match the corresponding observed time series averages for the United States. These issues have been extensively discussed elsewhere (Prescott 1986, Lucas 1988, Christiano 1989 and the references there), so here I simply present the choices that have been made.

The production function, equation (2), is typically taken to have a Cobb-Douglas form:

(14) $$Y_t = A_t K_t^{\theta} N_t^{1-\theta}.$$

With this technology, the parameter θ is equal to capital's share of income, that is, $r_t K_t / Y_t$. This parameter can be determined from the national income and product accounts (the NIPA). Capital's share of income differs across studies depending on how one treats, for example, the services of consumer durables. If these are included in capital services, capital's income share is 36 percent, or 0.36 (Prescott 1986). The depreciation parameter δ can also be measured using the NIPA. A typical value is 10 percent, or 0.10.

Another key parameter is the rate of exogenous technological change, μ. This parameter cannot be measured directly. However, the requirement that the model's productivity growth match historical averages is sufficient to determine a value for μ. This can be shown in a few steps: first, note that condition (9) becomes

(15) $$r_t = MPK_t = \theta A_t k_t^{\theta-1} n_t^{1-\theta} = \theta A_t k_t^{\theta-1} = \theta y_t / k_t$$

where $y_t = A_t k_t^{\theta}$ is per-capita output.[11] Second, as argued below, r_t is constant in a steady-state competitive equilibrium, so condition (15) implies that y_t and k_t grow at the same rate, say, γ. This means that in a steady state, y_t and k_t can be expressed as $y_t = y_s(1+\gamma)^t$ and $k_t = k_s(1+\gamma)^t$. Substituting these into the per-capita production function, and rearranging, gives the growth rate of productivity:

(16) $$\gamma = (1+\mu)^{1/(1-\theta)} - 1.$$

With annual productivity growth about 2 percent ($\gamma = 0.02$) and with capital's income share 36 percent ($\theta = 0.36$), the rate of technological change per year is about 1.3 percent ($\mu = 0.013$).

The utility function is typically chosen to be

(17) $$u(c_t) = [1/(1-\sigma)](c_t^{1-\sigma} - 1).$$

In a steady state, since y_t and k_t grow at the rate γ, we can easily verify that $c_t = c_s(1+\gamma)^t$; examine equation (3). Using this fact, and this utility function, we can rewrite the steady-state condition for (6) as

(18) $$(1+\gamma)^{\sigma}/\beta = 1 + i_t.$$

This means that i_t is constant in the steady state; hence, from (13), r_t is too (as claimed above). The studies Prescott (1988) cites indicate that σ is close to one; other arguments suggest a choice for β of about 0.96.

. . . As a Theory of Development

Can the Solow model account for significant differences in per-capita output across countries? To answer this question, consider a world with many economies like the one sketched above. (Call them *countries.*) Let i index countries, and define K_{it} and Y_{it} to be the capital used in country i at time t and the output produced in country i at time t. Note that K_{it} is the capital used at time t, but not necessarily that owned by the residents of country i; also, Y_{it} is the output produced in country i, but not necessarily its income. Begin with the assumption that countries have the same values for $(\beta,\sigma,\theta,\delta)$ and the same technology A_t, but may differ in their initial endowments of labor N_i and capital K_{i0}.

A definition of *competitive equilibrium* in a world with many countries is much the same as that in the closed economy. All that is needed is more notation. Allocations must now specify country. For example, an allocation for households is denoted $\{c_{it}, d_{ijt}, n_{it}\}$, where c_{it} is the consumption per person in country i at time t, d_{ijt} are the deposits made by country i households in country j banks at time t, and n_{it} is the labor supply in country i at time t. Prices must also be indexed by countries. Now the price system is given by $\{r_{jt}, i_{jt}, w_{jt}\}$, where r_{jt} is the rental rate on a unit of capital in country j at time t, i_{jt} is the rate on deposits in country j at t, and w_{jt} is the wage in country j at t.

Necessary conditions for a competitive equilibrium in the world economy include the conditions derived above, but now one for each country. [That is, index by i each quantity and price in (6), (9)–(11), and (13).] Additional necessary conditions are derived from the assumptions made about trade across countries. Take as a starting point the following possibilities for trade. Free movement across borders is allowed capital, both physical capital and deposits, but not households. Banks from country j can take deposits from citizens of any country and rent physical capital to firms in any country. Since the market for deposits is worldwide, in a competitive equilibrium banks with deposits will pay a common interest rate i_t; that is, a necessary condition is that $i_{it} = i_{jt}$.[12] Therefore, the necessary condition (6) for country i can be simplified by indexing only consumption by i. Similarly, in a world of physical capital mobility, the rental rate r_t will be the same in all countries in which capital is employed; that is, a necessary condition is that $r_{it} = r_{jt}$.[13] Therefore, the necessary condition (9) for country i can be simplified by indexing only the marginal product by i. Now the ratio of (9) for two countries will be

(19) $$r_{it}/r_{jt} = r_t/r_t = 1 = [MPK_{it}(k_{it})]/[MPK_{jt}(k_{jt})]$$
$$= (\theta A_t k_{it}^{\theta-1})/(\theta A_t k_{jt}^{\theta-1}).$$

Marginal products of capital are equal across countries, so capital/labor ratios k_{it} are too. Since output per person equals $y_{it} = A_t(k_{it})^{\theta}$, y_{it} is the same across countries. Clearly, the Solow model, in which all countries have the same parameter values and the same technology A_t, cannot account for the wide diversity in per-capita output that is observed.

What modifications of the model will break the equal-output implication of condition (19)? Examination of the condition suggests three possibilities: (1) keep the same functional form for production, but consider the possibility that θ or A_t or both differ across countries; (2) consider changes to the nature of capital mobility that imply that $r_{it} \neq r_{jt}$; and (3) change the functional form for production. Combinations of these three are, of course, also possibilities.

What about possibility (1), that technology A_t differs across countries?[14] Any pattern of per-capita output can, of course, be explained by a particular assignment of A_t across countries and time. If we pursued this possibility, though, we would be saying that a country is more productive because it is more productive. Unless we think productivity differences are purely due to chance, we need another approach. In what follows, A_t is to be interpreted as the level, or index, of world technology common to all countries.

What about possibility (2), that $r_{it} \neq r_{jt}$ because of restrictions on the nature of capital mobility? I explore two such restrictions, each of which implies that capital/labor ratios need no longer be equal, and ask for each whether the resulting differences in physical capital per person can explain development fact 1 (the disparity in wealth across nations).

One factor that influences the flow of capital between countries is government policies. Consider taxes on the capital rental payments to banks. In this example, and all the tax examples that follow, assume that the government uses tax proceeds in a way that has no effect on household utility or firm production. Let r_{it} now denote the rental payment in country *i* per unit of capital before taxes. If a bank rents a unit of capital in country *i*, it pays a per-unit tax at country *i*'s tax rate, denoted τ_i.

The two necessary conditions imposed by trade are now $i_{it} = i_{jt}$ and

(20) $$(1-\tau_i)r_{it} = (1-\tau_j)r_{jt}.$$

In order to see the last condition, note that the receipts of a bank that rents capital in country *i* are $[(1-\tau_i)r_{it} + (1-\delta)] - (1+i_{t-1})$. Zero profits on these transactions imply that the rental rate in country *i* is

(21) $$r_{it} = (1-\tau_i)^{-1}(i_{t-1}+\delta).$$

Condition (19) can now be written as

(22) $$r_{it}/r_{jt} = (1-\tau_j)/(1-\tau_i) = [MPK_{it}(k_{it})]/[MPK_{jt}(k_{jt})].$$

After some algebraic manipulation, this can be expressed as[15]

(23) $$y_j/y_i = [(1-\tau_j)/(1-\tau_i)]^{\theta/(1-\theta)}.$$

Equation (23) expresses the relative output of two countries as a function of their tax rates on capital rental payments. For the typical physical capital shares that are observed, very big differences in tax rates imply small differences in per-capita output. For example, suppose $\tau_j = 1/4$ and $\tau_i = 3/4$. Then, with $\theta = 0.36$, per-capita output in the two countries differs by a factor of 1.86. Take a more extreme example: if $\tau_j = 1/10$ and $\tau_i = 9/10$, per-capita output still only differs by a factor of 3.44. Accounting for observed variations in per-capita output by differences in per-capita capital stocks caused by differences in government policy does not seem like a promising avenue in this model.

A more extreme assumption about the nature of capital markets is that all capital is immobile. With this assumption, as Lucas (1990) points out, the difference in the capital/labor ratio among countries that is needed to explain the difference in their per-capita output is implausibly large. Taking India and the United States as an example, Lucas shows that this difference in capital/labor ratios implies a marginal product of capital in India about 58 times greater than that in the United States. So, changing the nature of capital markets does not work either.

While the second possibility does not work, it is suggestive in its failure. Consider equation (23), which expresses relative output as a function of tax rates. Given any pair of tax rates, the difference in per-capita output depends critically on the magnitude of θ. If the capital share is bigger, the difference is bigger. This suggests examining the third option: change the functional form for production.

Missing Capital

In changing the production function, one must answer the question, Why is the marginal product of physical capital not high in countries where that type of capital is scarce? The answer Lucas (1988) proposes is that other inputs are also scarce in those countries, inputs complementary to physical capital. In particular, Lucas considers the possibility that an important capital good is missing from the Solow technology.[16]

At this point call the missing good *generic capital.* Denote it by *G*. With this new capital good, the production function is now denoted $\tilde{F}(\cdot)$ and is given by

(24) $$Y_t = \tilde{F}(K_t,N_t,A_t,G_t)$$

which replaces equation (2). Suppose that $\tilde{F}(\cdot)$ is such that the marginal productivity of physical capital varies positively with G_t, that G_t differs across countries, and that trade does not imply that G_t is equalized across countries (for reasons discussed below). If these suppositions are true, then condition (19) need no longer imply that physical capital per person, or output per person, is the same across countries.

The law of motion of G_t must also be specified. Denote this function by $\tilde{G}$; that is,

(25) $$G_{t+1} = \tilde{G}(G_t,\cdot).$$

To complete the extension of the Solow model, we must specify two things: What capital good does G_t represent? And what form should $\tilde{F}(\cdot)$ and $\tilde{G}(\cdot)$ take? An answer to the first question is determined, in part, by what policies we think developing countries should be pursuing. Choices about the form of $\tilde{F}(\cdot)$ and $\tilde{G}(\cdot)$ are not easy to make since, as seen below, once we extend the Solow model, the close connection between model variables and the NIPA is lost. Ideally, other sources of evidence, such as panel studies of individuals or firms, can be used to make decisions. Another avenue is to explore what the choices for $\tilde{F}(\cdot)$ and $\tilde{G}(\cdot)$ imply about the development facts. Here I will briefly review how the above questions have been answered in this literature. In later sections, I will analyze the models more formally.

Missing Capital as Human Capital

Lucas (1988) takes G_t to be *human capital*, by which he means the general skill level of the representative worker. Since Lucas' work, much research has been done that assumes the missing capital is human capital (for example, Mankiw, Romer, and Weil 1992; Jones, Manuelli, and Rossi, forthcoming). Much of this research focuses on human capital as years of schooling.

To extend the Solow model in this direction, assume that labor input is measured in efficiency units and that increases in human capital increase the efficiency of labor. Denote human capital by h. Then an individual who works n_t units of time, and has human capital h_t, is assumed to supply $l_t = n_t h_t$ units of effective labor.

In considering how to specify the production function (24) in this case, one restriction that is provided by the choice of human capital as missing capital is that the inputs N_t and $G_t = h_t$ do not enter separately since human capital is embodied in the person. A version of the production function Lucas (1988) uses is

$$(26)\quad Y_t = \tilde{F}(K_t,N_t,A_t,G_t = h_t) = \tilde{F}(K_t,h_tN,A_t) = AK_t^{\theta}(h_tN)^{1-\theta}.$$

With regard to the choice of $\tilde{G}(\cdot)$, assume that human capital can be increased by devoting time t goods to its production. Let x_{ht} denote the goods devoted to human capital accumulation per person; then assume human capital follows

$$(27)\quad h_{t+1} = (1-\delta)h_t + x_{ht}$$

where the rate of depreciation δ is chosen to be that of physical capital.[17] Lucas (1988, p. 19) discusses one possible motivation for such a technology.

Later, I will derive some of the aggregate implications of these choices for $\tilde{F}(\cdot)$ and $\tilde{G}(\cdot)$. As I will show, they imply inconsistencies with some of the development facts. But these inconsistencies alone do not necessarily warrant considering other candidates for missing capital. That is because the choices for the functional forms are not strongly dictated by any microeconomic evidence from the human capital literature. There may be other functional forms that are just as reasonable.

However, there are reasons to doubt that human capital, at least when defined as years of schooling, will be the key factor in understanding differences in per-capita output. This point has been made by Lucas (1993, pp. 257–58) and others. Here I add a few additional (related) points in order to motivate looking beyond the choice of formal education.

Some researchers point to the substantial estimated returns to education in the United States as supporting evidence for the importance of education in a development context. (See, for example, Katz 1992.) But there is also a literature which argues that the returns to education are high in the United States in those periods and in those industries where technological change is most rapid (for example, Welch 1970, Allen 1991). Some argue, for instance, that the growing educational wage premium of the 1980s is attributable in large part to the spread of computer and other technology. If this view is at least partly true, then since the introduction of technology is not rapid in many developing countries, one expects the return to education is not high either. (See my discussion below of the work of Schultz.) Perhaps this is why many of the cross-country regression studies using proxies for education have found mixed results. (See Benhabib and Spiegel 1992.)

The world also has many historical examples of rapid growth being introduced into (or eliminated from) regions in very short periods of time. One example is the recent rapid growth in regions of China, such as Shanghai. How can these important episodes be understood in terms of a theory of development based on accumulation of education? To be responsible for such growth, stocks of education would have to take very large swings, up and down, in very short periods of time.

Finally, some countries have achieved high levels of education and literacy, yet have performed poorly, including the formerly centrally planned economies. (These economies have about the same level of education as countries in the Organisation for Economic Co-operation and Development; see Barro 1992, p. 215, n. 1).

These and other concerns have led researchers in two directions: to extending the concept of *human capital* to mean more than years of schooling, which I will discuss later, and to considering other concepts of missing capital.

Missing Capital as Business Capital

Many policies promoted by the IMF and the World Bank, such as deregulation, privatization, and stable business environments, are implicitly based on the assumption that these policies will create incentives for entrepreneurs to develop new businesses, adopt new technologies, and the like. Those investments by entrepreneurs create a type of capital, capital that exists independently of the entrepreneur, capital that I call *business capital.*

As an example of this type of capital, consider the recent report that the market valuation of Microsoft Corporation exceeds that of IBM Corporation. Now, presumably, the value of the physical assets owned by IBM greatly exceeds that of the physical assets owned by Microsoft. Yet Microsoft is nonetheless valued higher than IBM because the stock market currently places a greater value on the products that Microsoft has developed (that is, its business capital) than those of IBM.[18]

A significant aspect of business capital is that it is often specific to a region. For example, to introduce a new product in an area, an entrepreneur must make adjustments to suit local tastes; to introduce a new technology, the entrepreneur must make the process suitable to local skills. In their analysis of technological leadership, Nelson and Wright (1992, p. 1939) argue that "there is nothing 'simple' about the processes through which firms come to adopt and learn to control technologies that have been in use elsewhere for some time." Concrete examples abound in agriculture. Innovations such as new fertilizers that are developed for one region must often undergo significant changes to be of value elsewhere. This aspect of business capital may play a prominent role in future work.

Parente and Prescott (1991) argue that this type of capital is scarce in many countries because of lack of incentives to accumulate the capital. In their model, the myriad of impediments to entrepreneurs are summarized by effective tax rates that entrepreneurs face.

To extend the Solow model to address such issues, Parente and Prescott (1991) assume that each household can use its time endowment in one of two ways: to manage a business, which also entails adopting new technology (that is, investing in business capital), or to be employed by another business (some other entrepreneur).

Households are still assumed to be identical. For simplicity, assume that at time 0 each household decides to manage a business or to work for another business and that the choice is irreversible.[19] Since now the number of individuals differs from the number of businesses, per-capita and per-business quantities must be distinguished from each other. Let lowercase letters with carets (or hats) denote per-business quantities. Denote the business capital accumulated by an entrepreneur by time t by $\hat{b}_t$. The per-business production function Parente and Prescott (1991) study is

$$(28) \quad \hat{y}_t = \hat{b}_t \hat{k}_t^{\theta}[\min(\hat{n}_t,\bar{n})]^{1-\theta}$$

where $(\hat{k}_t,\hat{n}_t)$ are inputs of physical capital and labor and $\bar{n} > 0$.[20] Before I discuss this function, it will help to introduce the law of motion for $\hat{b}_t$.

There is a literature that is relevant for specifying the law of motion for business capital. It discusses the advantages, in terms of prospective productivity growth, to nations behind the productivity leaders. (See, for example, Abramovitz 1986.) The literature argues that the further a country is behind the technology frontier, the easier accumulating business capital is. In symbols, with $\hat{b}_t$ fixed, the larger is A_t (the technology frontier), the greater is the increase in business capital for a given investment. This literature also stresses diminishing returns-to-investment, or adjustment costs, in adopting technology; that is, increases in investment lead to smaller and smaller increases in business capital. (See, for example, Nelson and Wright 1992.) If $\hat{x}_{bt}$ denotes the goods devoted to investment per firm in business capital, then Parente and Prescott (1991) assume that $\hat{b}_t$ follows

$$(29) \quad \hat{x}_{bt} = \int_{\hat{b}_t}^{\hat{b}_{t+1}} (s/A_t)^{\alpha} ds$$

where $\alpha > 0$.

In specifying models for the two types of capital—human capital and business capital—it would be nice if there were technologies that made sense for one but not the other. This, then, might help distinguish between the two types of capital. Equation (29) may be a case in point. There are good reasons for specifying the accumulation technology for business capital as above. But imagine an accumulation technology for human capital with the property that countries far behind the leader in years of schooling can accumulate years of schooling more rapidly than the leaders. I can't think of much logical support for such a specification: Why should any country's ability to accumulate years of schooling be affected by the schooling levels in other countries?

Now let's return to a discussion of the production function. It is helpful to introduce a change of variables. Integrating the law of motion for business capital yields

$$(30) \quad (1+\alpha)\hat{x}_{bt} = (\hat{b}_{t+1}^{1+\alpha} - \hat{b}_t^{1+\alpha})/A_t^{\alpha}.$$

This expression suggests the change of variables $\hat{z}_t = \hat{b}_t^{1+\alpha}/A_t^{\alpha}$ and $\hat{x}_{zt} = \hat{x}_{bt}$. With this change, the production function of the representative firm becomes

$$(31) \quad \hat{y}_t = \tilde{F}(\hat{k}_t,\hat{n}_t,A_t,G_t = \hat{z}_t) = A_t^{\alpha/(1+\alpha)}\hat{z}_t^{1/(1+\alpha)}\hat{k}_t^{\theta}[\min(\hat{n}_t,\bar{n})]^{1-\theta}.$$

In this form, the degree of homogeneity of the production function with respect to the factors that can be accumulated, $\hat{z}_t$ and $\hat{k}_t$, depends on the sum of the parameters $1/(1+\alpha)$ and θ. If, as assumed below, these parameters sum to less than one, then there are decreasing returns in the factors.

The NIPA alone do not provide a guide to the choices of θ and α. As discussed below, Parente and Prescott (1991) use another means of identification. With the change of variables, the law of motion for $\hat{z}_t$ becomes

$$(32) \quad \hat{x}_{zt} = (1+\alpha)^{-1}[(1+\mu)^{\alpha}\hat{z}_{t+1} - \hat{z}_t].$$

Later I will derive some of the aggregate implications of these choices for $\tilde{F}(\cdot)$ and $\tilde{G}(\cdot)$.

Formally Adding Human Capital

The Lucas Model . . .

Now let's examine more closely these two candidates for missing capital. Let's start with human capital and a version of a model developed by Lucas (1988).[21]

Begin with a closed economy. The model consists of equations (1), (3), (4), (26), and (27) and the initial condition (K_0,h_0), where equation (3), the resource constraint, includes resources used in human capital accumulation. That is, in per-capita terms,

$$(33) \quad y_t = c_t + x_{kt} + x_{ht} = c_t + [k_{t+1} - (1-\delta)k_t] + [h_{t+1} - (1-\delta)h_t]$$

where x_{kt} is per-capita investment in physical capital. Lucas also assumes that $\mu = 0$; that is, $A_t = A$. The resource allocation problem facing this economy is the same as that in the Solow economy, except that at each time period t a decision must be made about the quantity of two capital goods, k_{t+1} and h_{t+1}, to carry into the next period.

☐ *Market Allocation*

Household preferences are the same as in the Solow model. Assume households own the stock of human capital and make investments in improving skills. The budget constraint is

$$(34) \quad c_t + x_{ht} + d_t = d_{t-1}(1+i_{t-1}) + w_t l_t$$

where w_t is now denominated in time t goods per unit of effective labor and l_t is units of effective labor.

The profit-maximization problem faced by firms is the same, too, except that the production function is now given by equation (26) and l_t replaces n_t.

☐ *Equilibrium*

The definitions of equilibrium need little change. In the definition of *competitive equilibrium,* simply change the allocation of households so that it includes h_t; for the allocation of firms, change n_t to l_t.

Necessary conditions for an equilibrium include those above, that is, conditions (6), (9)–(11), and (13). If households are maximizing utility, it must also be true that

$$(35) \quad 1 + i_t = w_{t+1} + (1-\delta).$$

The left side of equation (35) represents the return to investing in bank deposits; the right side, the return to investing in skills.[22]

As with the Solow model, these necessary conditions can be used to derive properties of the steady-state *competitive equilibrium.* To do that, first substitute $i_t = r_{t+1} - \delta$, from (13), into (35), to give $r_{t+1} = w_{t+1}$. Then, equating $w_{t+1} = A(1-\theta)(k_t/h_t)^\theta$, from (10), with $r_{t+1} = A\theta(k_t/h_t)^{\theta-1}$, from (9), solve for the value of k_t/h_t in the steady state, denoted k_s/h_s:

$$(36) \quad k_s/h_s = \theta/(1-\theta).$$

To calculate the productivity growth rate γ, equate the steady-state version of (6), $(1+\gamma)^\sigma/\beta = (1+i_t)$, with (35), to get[23]

$$(37) \quad (1+\gamma)^\sigma/\beta = (1-\delta) + w_{t+1}.$$

Substituting $w_{t+1} = A(1-\theta)(k_s/h_s)^\theta$ into this expression yields

$$(38) \quad (1+\gamma)^\sigma/\beta = (1-\delta) + A(1-\theta)(k_s/h_s)^\theta.$$

After the expression for k_s/h_s is substituted into equation (38), the growth rate in productivity becomes

$$(39) \quad \gamma = \{\beta[A(1-\theta)^{1-\theta}\theta^\theta + (1-\delta)]\}^{1/\sigma} - 1.$$

. . . As a Theory of Development

To begin the analysis of the model as a theory of development, consider a world composed of many countries with the same values for parameters, as well as the same technology, *A.* Begin with the assumption that each country is closed from the others. Also, assume that each country is in a steady state. Hence, in each country, the ratio of physical to human capital equals $k_{is}/h_{is} = \theta/(1-\theta)$ and the growth in productivity is γ. Notice that in this world, the levels of k_{it} and h_{it} can differ across countries, with countries with larger k_{it} having larger h_{it} as well.[24] The closed economy, then, is consistent with any degree of diversity in per-capita output.

Now open the world to trade. That is, starting from this steady state, assume that both physical capital and deposits are free to move across borders, but households are not. We can easily show that there will be no trade in this world, so that the differences in per-capita output will persist. To demonstrate this, I now show that all of the necessary conditions implied by trade are satisfied in the closed economy.

There are two conditions that must be checked. First, from arguments above, the world will have a single interest rate i_t and a single rental rate r_t. Hence, forming the ratio of (9) for two countries produces

$$(40) \quad r_{it}/r_{jt} = r_t/r_t = 1 = MPK_{it}/MPK_{jt}$$
$$= [\theta A(k_{it}/h_{it})^{\theta-1}]/[\theta A(k_{jt}/h_{jt})^{\theta-1}].$$

In a world of trade, k_{jt} and h_{jt} must be such that equation (40) is satisfied. Equation (40) is, of course, satisfied by quantities from the closed economy since k_{is}/h_{is} is the same across countries. Hence, there is no incentive to move physical capital.

Second, how about human capital? While, by assumption, households are not mobile across borders, the fact that a market in deposits exists means that individuals can invest in banks that can invest in human capital in other countries. Hence, the returns to human capital will be equalized.[25] That is, with a common interest rate, from (35), there will be a common wage $w_t = w_{it}$ for all i. Forming the ratio of (10) for two countries thus produces

$$(41) \quad w_{it}/w_{jt} = w_t/w_t = 1 = MPL_{it}/MPL_{jt}$$
$$= [(1-\theta)A(k_{it}/h_{it})^\theta]/[(1-\theta)A(k_{jt}/h_{jt})^\theta].$$

Equalization of wage rates is also satisfied by quantities from the closed economy. The conclusion is that even in the presence of trade, the level of per-capita output across countries can be very different.[26]

While this model presents new possibilities, the particular functional forms yield implications that seem to be inconsistent with development fact 2 (a roughly constant range of relative wealth). For example, suppose the countries of the model differ in small ways, say, in the parameters δ or σ or in the technology constant *A.* Then, in a steady state of a closed world, each country has $k_{is}/h_{is} = \theta/(1-\theta)$, and each grows at a different rate γ_i [that is, $y_{it} = y_{is}(1+\gamma_i)^t$]. As before, if trade were introduced, there would be no incentive for movement of capital. Each country would continue on its steady-state path. In such a world, the ratio y_{kt}/y_{it} would either converge to zero or increase without bound, which is apparently at odds with fact 2. (See also the discussion in Lucas 1993.)[27]

Note that the fact that the production function has constant returns-to-scale in the factors that can be accumulated does not necessarily imply the inconsistency with fact 2. Lucas (1993) sketches a model with such a production function but in which the human capital of the leading nation (or the average of all nations) is an argument of each country's accumulation technology. This change insures that outputs do not spread out through time. But as discussed above, that does not seem to be a reasonable way to specify an accumulation technology for education (not that Lucas seriously offers it as one). However, note that the linearity of the production function has troubling aspects on its own.[28]

Other Models

These considerations suggest that other models of human capital be explored. Let's examine two.

Some of the earliest work on human capital was actually done in the context of developing countries, by Schultz (1975, 1980). His theories, however, have not been used in the new literature on economic development (though they have been examined to some extent in related areas, in Holmes and Schmitz 1990, 1993). From his study of farm people in developing countries, Schultz (1975) concludes that a key function of human capital is to improve the ability of farmers to reallocate their work effort and resources in response to changes in their economic environments (such as when new fertilizers and farming techniques become available).

In making this point, Schultz distinguishes between traditional and modern farming economies. In traditional economies, the farm environment changes very little. In these settings, Schultz (1975, pp. 831–32) says, "farm people know from long experience what their own effort can get out of the land and equipment." In such economies, "there is, for all practical purposes, no premium for the human ability to deal with secular economic changes." However, in modern economies, Schultz says, farmers must "deal with a sequence of changes in economic conditions [such as the availability of new fertilizers], which are in general not of their own making because they originate mainly out of the activities of people other than farm people."

Schultz (1975, 1980) argues that the value of education is high in environments where significant changes, such as new technology adoption, are occurring. In some countries, these changes are not occurring (for whatever reason); hence, there the value of education is limited.[29] The work of Schultz suggests that the link between economic development and human capital is more complex than is typically imagined in existing models.

Lucas (1993) extends the notion of human capital as well. In this work, human capital is capital that can be accumulated "in schools, in research organizations, and in the course of producing goods and engaging in trade" (Lucas 1993, p. 270). He sketches theories of human capital accumulation based on learning while producing goods (following Stokey 1988, 1991 and Young 1991). Lucas presents evidence—data based on production of Liberty Ships (cargo ships used during WWII)—that such learning-by-doing can be quantitatively significant. But as Lucas (1993, p. 262) admits, "There is also considerable ambiguity about what this evidence means." Is the capital accumulated in the Liberty Ship example best described as *human* capital?

Similarly, recall the Microsoft example. The products that Microsoft has developed—the code for its programs—is not very well described as either physical capital or human capital. Perhaps models of economic development need to include another concept.[30]

Formally Adding Business Capital

The Parente and Prescott Model . . .

Again, Parente and Prescott (1991) have developed a model that includes the concept of *business capital*. Here I will describe a version of their model.

Begin with a closed economy. The model consists, essentially, of equations (1), (3), (4), (31), and (32) and the initial conditions for physical capital and business capital [and where the resource constraint (3) is understood to include resources used in business capital accumulation]. I say *essentially* because equations (31) and (32) are expressed in per-business form. In Parente and Prescott 1991, these equations are expressed in total and per-capita form.

☐ *Market Allocation*

In this model, households again have the preferences given in equation (1). Households are distinguished by their occupational choice; some work as employees, some as entrepreneurs. Households that work as employees have budget constraints identical to those in the Solow model. Households that are entrepreneurs manage their firms and invest in business capital. In order to keep the analysis similar to the above models, assume that entrepreneurs rent business capital to their firms and that their compensation from being an entrepreneur comes entirely from these rental payments. Imagine that these entrepreneurs rent $\hat{z}_t$ to firms for a payment q_t per unit of capital.[31] A fraction ψ of this payment is due as taxes.[32] The budget constraint for such a household is

(42) $$c_t + \hat{x}_{zt} + d_t = d_{t-1}(1+i_{t-1}) + (1-\psi)q_t\hat{z}_t.$$

The decision problems faced by firms and banks are essentially the same as those in the Solow model. In particular, assume that firms continue to rent physical capital from banks and labor input from households (those that are employees). Firms also rent business capital from households (those that are entrepreneurs). If firms are maximizing profit, it must be that

(43) $$q_t = MPZ_t(\hat{k}_t,\hat{z}_t,\hat{n}_t)$$

where MPZ_t is the derivative of the production function in (31) with respect to $\hat{z}_t$. The tax paid by banks per unit of capital rental receipts is τ.

☐ *Equilibrium*

The definition of *competitive equilibrium* in the Solow model needs little change. However, a condition must be added that each household is indifferent to changing occupations.

While only minor changes are needed in the definition, a major question arises about the existence of an equilibrium. That is, there may not be a solution to the firms' maximization problem since the production function (31) may exhibit increasing returns-to-scale. Hence, assume that $\alpha > \theta/(1-\theta)$. With this assumption, the production function (31) displays increasing returns-to-scale in the inputs $\hat{z}_t, \hat{k}_t$, and $\hat{n}_t$ for $\hat{n}_t < \bar{n}$ and decreasing returns for $\hat{n}_t > \bar{n}$. From this assumption, each firm that operates does so at $\hat{n}_t = \bar{n}$.

Necessary conditions for an equilibrium include those for the Solow model, that is, conditions (6), (9)–(11), and (13), as well as (43). It must also be true that

(44) $$1 + i_t = [(1-\psi)q_{t+1} + (1+\alpha)^{-1}][(1+\alpha)^{-1}(1+\mu)^{\alpha}]^{-1}.$$

The left side here represents the return to investing in bank deposits; the right side, the return to investing in business capital. Households that are entrepreneurs have these two investment options open to them.

As before, the necessary conditions can be used to derive the rate of productivity growth γ in the steady state. First, substitute $i_t = r_{t+1} - \delta$, from (13), into (44). This provides an equation in r_{t+1} and q_{t+1}. Then substitute $r_{t+1} = MPK_{t+1} = \theta(\hat{y}_{t+1}/\hat{k}_{t+1})$ and $q_{t+1} = MPZ_{t+1} = (1+\alpha)^{-1}(\hat{y}_{t+1}/\hat{z}_{t+1})$ into this equation. Clearly, $\hat{k}_{t+1}$ and $\hat{z}_{t+1}$ must grow at the same rate in a steady state. One can argue from this equation that $\hat{y}_{t+1}$ must also grow at that rate. Substituting $\hat{y}_t = \hat{y}_s(1+\gamma)^t$, $\hat{z}_t = \hat{z}_s(1+\gamma)^t$, and $\hat{k}_t = \hat{k}_s(1+\gamma)^t$ into (31) and rearranging gives

(45) $$\gamma = (1+\mu)^{\alpha/[\alpha-\theta(1+\alpha)]} - 1.$$

. . . As a Theory of Development

In order to assess this model as a theory of development, values for key parameters must be chosen. As will be seen, the share of physical capital θ and the curvature parameter in the law of motion for business capital α are two parameters which determine some of the key quantitative properties of the model. [They enter (55) below, which is the analog of (23).] Both of these parameters enter equation (45), which shows that the rate of productivity growth γ depends on them (θ and α) as well as on the rate of world technology growth μ. As before, parameters are chosen so that productivity growth is consistent with the long-run annual average of about 2 percent ($\gamma = 0.02$). The parameter θ is derived from the NIPA. Given θ, there are, of course, any number of pairs (α, μ) that imply a productivity growth rate $\gamma = 0.02$. Hence, another condition is needed to identify the relative importance of world technology and business capital accumulation in determining productivity growth. Parente and Prescott (1991) use the post-WWII experience of Japan and the United States for this purpose; they choose the parameter α so that the model can produce the large moves in the relative wealth distribution that have been observed, making the model consistent with development fact 3.

To sketch their approach for choosing α, assume that the U.S. economy is in steady state in 1950, with productivity growing 2 percent per year. The Japanese economy of 1950 is assumed to be the same as that of the United States, including its tax rates, except that the Japanese economy is not in steady state. Given the same tax rates, the Japanese per-capita output level converges in the model to the U.S. level. The amount of time it takes to converge depends on the nature of capital mobility and, as discussed below, the pair (α, μ). In this exercise, assume that there is no capital mobility. Choose the pair (α, μ) so that the convergence in the model resembles the actual experience of Japan. The actual record is that Japan's per-capita output was about 1/6 that of the United States in 1950; that fraction had grown to 3/4 by 1985. The parameter values that yield $\gamma = 0.02$ and a path for Japanese output that matches the record are $\alpha = 1.155$ and $\mu = 0.012$.[33]

Now turn to the other development facts. Consider a world composed of many countries with the same values for parameters but with different tax rates τ_i and ψ_i. Begin with the assumption that markets in both physical capital and deposits are worldwide. In a world with trade, where countries have different tax rates on capital, the level of per-capita output will differ across countries. As I show below, the range of output is much greater here than in the Solow model.

Two necessary conditions imposed by trade are $i_{it} = i_{jt}$ and $(1-\tau_i)r_{it} = (1-\tau_j)r_{jt}$. There are many reasons to assume business capital is less mobile than physical capital. Here I assume business capital is immobile. Still, the existence of a market in deposits means that individuals can invest in banks that can invest in business capital in other countries. With a common interest rate, (44) implies that $(1-\psi_i)q_{it} = (1-\psi_j)q_{jt}$. Forming the ratio of (9), and then (43), for two countries gives

$$(46) \quad r_{it}/r_{jt} = (1-\tau_j)/(1-\tau_i) = MPK_{it}/MPK_{jt}$$

$$(47) \quad q_{it}/q_{jt} = (1-\psi_j)/(1-\psi_i) = MPZ_{it}/MPZ_{jt}.$$

These conditions can be used to express the ratio of per-capita output as a function of tax rates. Dropping hats for the moment, use the per-business production function[34]

$$(48) \quad y_{it} = A_t^{\alpha/(1+\alpha)} z_{it}^{1/(1+\alpha)} k_{it}^{\theta} \bar{n}^{1-\theta}$$

to express k_{it} as a function of y_{it} and z_{it}; namely,

$$(49) \quad k_{it} = [y_{it}/a_{it}]^{1/\theta}$$

where

$$(50) \quad a_{it} = A_t^{\alpha/(1+\alpha)} z_{it}^{1/(1+\alpha)} \bar{n}^{1-\theta}.$$

Substitute this expression into the MPK_{it} function. Then marginal products can be related to per-capita output; namely,

$$(51) \quad MPK_{it} = \theta a_{it} (y_{it}/a_{it})^{(\theta-1)/\theta}.$$

The ratio MPK_{it}/MPK_{jt} is then given by

$$(52) \quad [y_{it}^{(\theta-1)/\theta} (z_{it}^{1/(1+\alpha)})^{1-[(\theta-1)/\theta]}]/[y_{jt}^{(\theta-1)/\theta} (z_{jt}^{1/(1+\alpha)})^{1-[(\theta-1)/\theta]}].$$

Since

$$(53) \quad MPZ_{it} = (1+\alpha)^{-1}(y_{it}/z_{it})$$

condition (47) can be used to arrive at the expression

$$(54) \quad z_{jt}/z_{it} = [(1-\psi_j)/(1-\psi_i)](y_{jt}/y_{it}).$$

Using this in the expression for MPK_{it}/MPK_{jt} and evaluating (46) yields

$$(55) \quad y_j/y_i = [(1-\tau_j)/(1-\tau_i)]^{\theta(1+\alpha)/[\alpha-\theta(1+\alpha)]} \times [(1-\psi_j)/(1-\psi_i)]^{1/[\alpha-\theta(1+\alpha)]}$$

which is the analog of equation (23) in the Solow model.

Let $\tau_i = \psi_i$, so that tax rates are the same within a country. Consider initially the same range of tax rates as in the Solow model. Given $\theta = 0.217$ and $\alpha = 1.155$, tax rates of $\tau_j = 1/4$ and $\tau_i = 3/4$ imply that per-capita output differs in this world by a factor of 10.5, as compared to 1.86 in the Solow model.[35] In the more extreme example, with $\tau_j = 1/10$ and $\tau_i = 9/10$, per-capita output differs by a factor of 110, as compared to 3.44 before. These are certainly much bigger differences than calculated for the Solow model. However, suppose that τ_j represents the tax rate in a developed country, so that $\tau_j = 1/2$ is not unreasonably high. Then if τ_i represents the tax rate in a less-developed country, $\tau_i = 9/10$ is needed to make per-capita output differ by a factor of about 30. This tax rate of 9/10 that is needed to explain development fact 1 may be too big to be believed. In any case, much more work is needed to actually measure tax rates on entrepreneurs in developing countries.

Conclusion

The neoclassical theory of economic growth, that relies on differences in physical capital per person across countries to explain the wide disparity in per-capita output, cannot explain the observed inequality in the world. Neither, it seems, can the new theories of economic development that stress differences in human capital, or education, across countries. However, theories that stress differences across countries in the incentives provided to entrepreneurs to adopt new technology and create businesses may have focused on a key aspect of the development process. Still, questions remain about such things as how to measure effective tax rates on entrepreneurs.

The high tax rates on entrepreneurs assumed to prevail in poor economies are a summary of the many barriers to such efforts as adopting new technology and creating new businesses. These barriers are obviously created by groups in society, those with vested interests in the status quo. (See Rosenberg and Birdzell 1986, Mokyr 1990.) Economists are only beginning to understand the forces that lead to such barriers. (See Krusell and Rios-Rull 1992.) Once progress is made on that subject, we will be better able to offer good policy advice on things like how to design institutions which minimize resistance to the adoption of technology.

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[1]I use the term *wealth of nations* synonymously with the term *productivity of nations* (as do Parente and Prescott, in this issue).

[2]Quah (1990) analyzes the raw Summers and Heston (1991) data set.

[3]More formally, these studies typically examine the conditional mean or conditional growth rate of the wealth of nations.

[4]Note that the discussion here borrows much from Lucas 1988, 1990.

[5]The model is actually the first of two models that Lucas 1988 develops. Many versions of the model have appeared since.

[6]Note that this failure of this particular specification does not alone necessarily warrant abandoning human capital. That is because the choices for the functional forms are not strongly dictated by any microeconomic evidence from the human capital literature. There may be other functional forms that are just as reasonable. More on this below.

[7]The exercise may be a bit tedious for some readers, but is included to make the paper's arguments accessible to as wide an audience as possible.

[8]The assumptions on the production function F insure that firms earn zero profits each period. Assumptions below insure that banks do too. Also, an equilibrium condition will be that banks have zero net worth. Hence, firm and bank profit, and bank net worth, can be dropped from the budget constraint.

[9]To see this algebraically, express the budget constraint, equation (5), as $c_t = d_{t-1}(1+i_{t-1}) + w_t n_t - d_t$, and substitute this for c_t in the objective function, equation (1). Then differentiating the objective function with respect to d_t and rearranging yields (6).

[10]Note that since the number of households and the number of firms are the same, I use the symbol n_t to denote both labor supply and labor demand.

[11]I use $n_t = 1$ in equation (15) because this is a necessary condition for equilibrium.

[12]If banks in country i and j both had deposits, yet banks in one country paid a lower interest rate, then consumers with deposits in banks with a lower interest rate could not be maximizing utility.

[13]For example, suppose that $K_{it} > 0$, $K_{jt} > 0$, and $r_{it} > r_{jt}$. Then for banks to earn zero profits on rentals in country j, it must be that $r_{jt} = i_{t-1} + \delta$, where i_{t-1} is the common interest rate. But then banks would earn positive returns on rentals in country i, which is inconsistent with a competitive equilibrium.

[14]The other possibility, that θ differs across countries in a way that can explain some of the facts, has been discussed by Lucas (1988, p. 14).

[15]The per-capita production function can be used to express k_{it} as a function of y_{it}; namely, $k_{it} = (y_{it}/A_t)^{1/\theta}$. Substitute this expression into the MPK_{it} function; then marginal products can be related to per-capita output: $MPK_{it} = \theta A_t(y_{it}/A_t)^{(\theta-1)/\theta}$. Finally, substituting this expression for MPK_{it} in equation (22) and rearranging gives the result.

[16]Another way to change the production function is to assume physical capital has external effects. Romer (1986) considers this type of change, and Benhabib and Jovanovic (1991) evaluate it.

[17]Both the production technology and the law of motion for human capital are somewhat different than those Lucas (1988) uses. This specification, and many more general ones, are studied in Jones, Manuelli, and Rossi, forthcoming.

[18]Of course, the market is also valuing, to some extent, the prospects for future product development, which depend to some degree on the market's evaluation of how long Microsoft's chair and co-founder, Bill Gates, will remain at the company. Also, IBM presumably has greater unmeasured liabilities (for example, commitments to employees).

[19]This is done for convenience; see Parente and Prescott 1991 for a more general analysis.

[20]The production technology is motivated by Lucas 1978. For a given level of business capital, there are ultimately diminishing returns to increasing physical capital and labor since $\bar{n}$ is a finite number. The source of these diminishing returns is assumed to be the loss of control by managers who have limited span of control.

[21]For an analysis of this model and more general formulations of it, see Jones, Manuelli, and Rossi, forthcoming.

[22]Note that the return to investing in skills equals the value of an additional unit of effective skill, which consists of the wage on that unit, plus the value of the undepreciated skill after use.

[23]Note that the same arguments that led to the steady-state version of (6) in the Solow model apply here. That is, in a steady state, since the ratio of physical to human capital is constant, k_t and h_t grow at the same rate, say, γ. Hence, y_t grows at this rate as well. To verify that $c_t = c_s(1+\gamma)^t$, examine equation (3).

[24]Such differences can arise because of differences in initial conditions.

[25]There may be reasons, of course, why such markets do not operate. Here, finally, is a potential reason for pursuing policy regarding education. (See below as well.)

[26]Note that in the economy with trade, the wage paid to someone of skill level h_t in country i is $h_t MPL_{it}$. Since MPL_{it} does not vary across countries, the wage paid to skill level h_t does not either. However, migration from poorer to richer countries is typically at the maximal permitted rate, and the pressure for further migration seems large. To provide pressure for migration in this setup, Lucas (1988) uses the technology $Y_t = A_t K_t^{\theta}(h_t N)^{1-\theta} h_{at}^{\xi}$, where h_{at} represents the average human capital in the country and $\xi > 0$. In this formulation, the marginal product of a worker is influenced by the skill of co-workers. In such a formulation, policy may have a role.

[27]It is interesting to note that if the tax example presented for the Solow model is repeated, then the two necessary conditions (40) and (41) implied by trade cannot both be satisfied.

[28]As an example, consider a one-capital-good model with constant returns, the *AK* model. In this model, the production technology is $Y = AK$. In a world without external effects, the parameter A plays two roles. Note first that A is the marginal product of capital; hence, $MPK = A = r = i + \delta$, which implies that $A \cong 0.14$. But A is also the inverse of the capital/output ratio; hence, $A = Y/K$, which implies that $A \cong 0.33$ (if $K/Y \cong 3$). These numbers differ by a factor greater than 2.

[29]The reason individuals may be educated in such economies is that education is typically a subsidized investment.

[30]Another model of human capital is that of Barro, Mankiw, and Sala-i-Martin (1992). They are motivated by the work of Barro and Sala-i-Martin (1992), who have run regressions of the growth of per-capita output on initial per-capita output and other variables. (They argue that countries have different steady states and that these other variables are used as proxies for the steady states.) Barro, Mankiw, and Sala-i-Martin focus on explaining the estimated coefficient on initial per-capita output; they do not address the determinants of the different steady states (that is, disparity).

[31]A zero-profit condition for firms in the definition of equilibrium will insure that these payments to entrepreneurs exhaust profits of firms.

[32]Since Parente and Prescott (1991) emphasize the importance of the incentive effects of tax rates, they calibrate their model under the assumption of particular values for tax rates. Hence, I introduce taxes in this section. Also, as above, assume taxes are used in a way that has no effect on household utility or firm production.

[33]Consider how the choice (α, μ) influences the path to the steady state. Suppose α were arbitrarily large. Productivity growth would then be a function of world technology alone. The model would behave the same way as the Solow model. As is well known, the Solow model implies a much faster Japanese convergence toward the United States than actually happened. (See, for example, Christiano 1989.) If α were finite, then business capital would play a role in productivity growth. The smaller is α, the smaller is μ, and the larger is the role of business capital in productivity growth. The smaller is α, the more protracted is the path to the steady state.

[34]Note that I am using the per-business production function to discuss differences in per-capita output. This is not a problem since the conversion factor is the same for all countries.

[35]Note that from the NIPA Parente and Prescott (1991) calculate θ to be 0.217.

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