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Endogenous Growth Theory: Intellectual Appeal and Empirical Shortcomings

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Following along the path pioneered by Romer (1986) and Lucas (1988), endogenous growth theory has led to a welcome resurgence of interest in the determinants of long-term growth. But have the recent theoretical insights succeeded in providing a better guide to explaining actual growth experience than the neoclassical model? This is doubtful. Most empirical research generated by endogenous growth theory has tested earlier growth models, rather than testing endogenous theory itself. Moreover, most of the empirical work has utilized observations across countries and imposed extremely strong assumptions about international production functions. Unless there is some demonstration forthcoming that the theory is useful in explaining the growth pattern over time of national economies, it will remain a rich expansion of existing growth theory rather than a powerful organizing framework for thinking about actual growth phenomena.

It can be rather difficult, using aggregate economic data, to distinguish between the traditional neoclassical model of growth theory, and the more recent endogenous growth theory. The standard production function employed in neoclassical growth models is $Y = Ae^{\mu t}K^{\alpha}L^{1-\alpha}$, where Y is gross domestic product, K is the stock of human and physical capital, L is unskilled labor, A is a constant reflecting the technological starting position of society, and e^{μ} represents the exogenous rate at which that technology evolves (Solow, 1956). In this formula, α indicates the percentage increase in gross domestic product resulting from a 1 percent increase in capital. Empirically, α is usually obtained from the share of capital in the national income accounts of individual countries. This assumes that capital is paid its private marginal product and

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that it confers no external economies. As long as α is less than 1, this formulation displays diminishing returns to capital and labor.

In such a model, increases in saving, reflected in investment, will spark additional growth for a time. However, as the ratio of capital to labor increases, the marginal product of capital will decline and the economy will then evolve back to a steady state, in which output, capital, and labor (corrected for quality) are all growing at the same rate. Growth in income per worker will continue and will equal μ, the annual rate of productivity improvement. In the neoclassical model μ can be interpreted in many ways: as improvements in knowledge such as organization routines, rearrangement of the flow of material in a factory, better management of inventory, or other changes that do not require knowledge to be embodied in new equipment. A different view holds that changes in knowledge are embodied in equipment. But the central issue from the viewpoint of recent analysis is that the determinants of the size of μ, the rate of growth of income per capita, is left unexplained within the model. The new theory seeks to remedy this omission.

The essence of many endogenous growth theories is reflected in the equation $Y = AK$ (Lucas, 1988; Romer, 1986; Rebelo, 1991). Here, A should again be understood as an expression representing factors that affect technology, while K includes both human and physical capital. Notice in this case that there are no diminishing returns to capital; this is achieved by invoking some externality that offsets any propensity to diminishing returns. Investment (whether physical investment by a firm or human capital investment by an individual) leads to an increase in productivity that exceeds the private gain. This model leaves open the possibility that an increase in the investment rate (in physical and human capital) could lead to sustained growth if strong external economies were generated by investment itself so that α in the Solow model becomes unity. It offers an exciting alternative to the diminishing returns and absence of any sustained impact on growth that is characteristic of the simplest version of the Solow model.

Another route to obtaining an equation like $Y = AK$ is to postulate that an increasing variety or quality of machinery or intermediate inputs offsets the propensity to diminishing returns. In this interpretation, K now represents the variety or quality of inputs. Research and development are necessary to obtain this variety and firms devote skilled labor to this activity. The outlays for R&D that generate these inputs are recouped by firms that operate in monopolistically competitive markets (Romer 1990a; Grossman and Helpman, 1991).

In both the steady state of the Solow-style neoclassical growth model, and the "AK" version of the endogenous growth model, the ratio of capital to output will be a constant. Any set of observations of aggregate output and capital will be consistent with either approach. Thus, while endogenous growth theories have emphasized that externalities may be important, it is difficult to construct tests of their presence.

Two types of empirical evidence are available. First, economic historians have identified individual cases of external economies where the interaction of producers and users of intermediate and capital goods have permitted improved total factor productivity (output per combined unit of capital and labor) in the user industry which was not accompanied by a higher payment for the improved input (Rosenberg, 1976; Lyons and Caballero, 1991). If such interactions are quantitatively important, the value of α in the national accounts would understate the true elasticity of output with respect to new investment.

Rather than assume that the share of capital in the national accounts measures α, a second approach is to use cross-country regressions to test whether in regressions of value added on capital (broadly defined) and labor, α might be equal to unity. If it is, then a glance back at the basic Solow-style model implies that decreasing returns will not set in. However, rather than finding unity, such tests have found that α is between .4 to .6 (Romer, 1987; Englander and Mittelstadt, 1988). This is greater than the share of capital in the national income accounts, usually employed to determine the empirical value of α, but still much less than unity, the value required to justify equation the "*AK*" formulation.[1]

De Long and Summers (1991) have argued that a particular sort of investment—investment in equipment—has been a critical variable explaining differences in growth performance across countries. They find that the equipment share of investment has a disproportionate effect on output growth, akin to a real externality.[2] Why might machinery investment be critical? For countries that undertake their own R&D, much of the resulting knowledge is embodied in equipment. For non-producers, imported equipment may improve the average technology level within a country. An alternate interpretation is that many countries have little domestic capacity to produce machinery and must thus import it. If as a result of misguided exchange rate and macroeconomic management, they are unable to increase export earnings, they cannot pay for equipment from abroad. The data will show that countries with a low rate of growth tend also to have a low share of machinery investment. The slow growth rate is fundamentally attributable to a bad policy regime, one symptom of which is the absence of machinery investment. In this interpretation, equipment investment itself depends on the policy environment rather than being an independent variable.

Finally, the model proposing that R&D has an important effect on growth rates has not generated much confirmation in an economy-wide context (Griliches, 1988), though more recent evidence (Lichtenberg, 1992) offers some

[1]Testing a somewhat different variant of externalities, Benhabib and Jovanovic (1991) also fail to confirm the importance of spillovers.

[2]However, recent research by Auerbach, Hassett, and Oliner (1993) suggests that the differential returns to equipment and other investment may be an artifact. Omitting Botswana from the set of observations leads to coefficients for equipment and structures that are similar.

corroboration of it. Illustrative calculations of the importance of R&D in Grossman and Helpman (in this issue) also indicate its potential significance.

Despite the absence of specific empirical confirmation, endogenous growth theory has the advantage of attempting to explain the forces that give rise to technological change, rather than following the assumption of neoclassical theory that such change is exogenous. In particular, the formulations of Grossman and Helpman (1991) and Romer (1990a) provide important insights into the relation between R&D and growth and place them within a general equilibrium growth model. They provide an internally consistent connection between the R&D literature pioneered by Schmookler (1966), Griliches (1958), and Mansfield (1968), and aggregate growth theory. It is now possible to see the links between the capital and labor markets, imperfect markets for produced inputs that allow firms to obtain rents from R&D, household intertemporal optimization, and the now endogenous growth rate of the economy.[3]

This paper will explore the available evidence on a number of subjects related to growth theory, including the slowing of growth in the OECD countries over the last two decades; the acceleration of growth in several Asian countries since the early 1960s; studies of the determinants of growth in a cross-country context; and sources of the differences in international productivity levels. As I will illustrate, there have been very few systematic tests of endogenous growth theory. Most of the empirical work motivated by endogenous growth theory has actually tested implications of the Solow-style neoclassical growth model rather than endogenous growth theory itself.

The OECD Countries

There have been many efforts within a neoclassical framework to explain the high growth rates of the OECD countries in the quarter century after World War II and their slower rates of growth since 1973 (Denison, 1985; Maddison, 1987). The basic approach is to explain the growth in national income by an equation which contains the rate of growth of each of the productive factors, a parameter indicating the elasticity of output with respect to each factor, and a residual that indicates the growth in output unaccounted for by the growth in measured inputs. A typical regression equation is $Y^* = A^* + \alpha K^* + (1 - \alpha)L^*$ where Y^* is the rate of growth of value added, K^* is the rate of growth of physical and human capital, is the elasticity of output with respect to capital and $1 - \alpha$ the elasticity of output with respect to labor. A^* is

[3]The emphasis in endogenous growth theories on R&D and investment in physical and human capital revives themes that were the staple of policy advice in the 1960s. See, for example, the 1961 and 1962 volumes of *The Economic Report of the President*. For analyses of growth and policies emphasizing many of the same variables and policy instruments as emphasized in endogenous growth theory, see Nelson (1964) and Tobin (1964).

the growth in value added that is unexplained by the increase in measured factors of production.

Many analysts have augmented the simple production function to include not only investment in physical and human capital, but also changes in measured R&D levels, the effects of environmental and safety regulation and a large number of other variables; for example, Maddison (1987) considers ten factors in addition to quality adjusted capital and labor. The decrease in the growth rate of human and physical capital explains only a small part of the slowdown in the GDP growth rate since 1973. Inclusion of other variables that can be measured does explain more of the slowing in output growth but the adjustments, while imaginative, are difficult to base on a generally accepted theory.

How would endogenous growth theory modify the various growth accounting studies to provide a better explanation of the growth slowdown of the early 1970s? The critical variables in such models are R&D and investment in physical and human capital. No empirical study of the determinants of the growth of an individual country over time simultaneously incorporates all of these strands. However, clues can be gleaned from some of the existing growth accounting studies. They typically find that slower growth of physical and human capital are minor sources of the slower growth rate of aggregate output. Even if greater response of output to each of these variables to reflect externalities were used, the result does not change very much (Maddison, 1991). Similarly, the slowing in R&D, if any, has had a minor effect (Griliches, 1988). Moreover, the data suggest that changes in the ratio of R&D to GDP have not been large and that countries such as Japan whose R&D continued to grow rapidly were subject to the same slowing in total factor productivity growth.[4] In sum, the direct support for endogenous growth theory in explaining recent performance in the OECD countries is weak.

Slower growth in the United States, particularly as compared to Japan, has fostered many studies of factors not addressed by endogenous growth theory. Management practices including labor relations, innovativeness in devising new systems such as just-in-time inventory management, quality circles (Dertouzos, Lester, and Solow, 1989), and the capacity to devise organizational strategies that allow quick development of new models of consumer products (and generate rents) have all been viewed as potential sources of the more rapid growth of Japanese total factor productivity though it too has declined. While product and process innovations emphasized in some strands of endogenous growth theory are clearly important contributors to long-term growth, so is the organizational ability to take full advantage of such innovations as emphasized by Schumpeter and recently by Chandler (1977, 1990). If growth came from R&D-based innovation alone, then the major breakthroughs in information and

[4]Romer (1990b) has proposed an alternative calculation of the impact of R&D but it has not been tested in any of the OECD countries. Feenstra, Markusen and Zeile (1992) attempt to implement this framework for Korea.

communication technologies in the last two decades might have prevented the OECD-wide slowing of productivity growth from occuring. David and Blum (1987) argue, however, that substantial time is required before the potential productivity benefit of a new technology such as microcomputers is realized by the reorganization of production and societal arrangements, a requirement discussed more generally by Abramovitz (1986).

Ironically, the new generation of growth models relies on externalities and R&D at precisely the time that a sense is emerging that one of the important factors determining intermediate and perhaps long-term productivity growth is organizational.[5] Indeed, the earliest growth models, which viewed μ as reflecting disembodied sources of productivity growth, conform more to the spirit of the new focus on organization than models emphasizing externalities. Changes in organization and institutions do not stem from R&D, at least as usually conceptualized and measured. In endogenous growth models, even those emphasizing research and development, organizational determinants of total factor productivity levels and growth are presumably included in the technological constant A, which is generally assumed to be identical internationally. However, differences in organization probably help to explain how a sustained difference in income levels can occur between two countries, even if capital (measured in whatever augmented fashion) is identical. On the other hand, organizational structures are unlikely to explain differences in growth rates—countries with very different structures have experienced similar declines in total factor productivity growth in the post-1973 years.

The Asian NICs

A general theory of growth should be able to explain a variety of performances, including the decline in absolute income per capita in most African countries since 1973 and the stagnation of the Latin American countries during the 1980s. Most explanations of this record rely on factors not emphasized in either type of growth theory, including changes in international terms of trade and the impact of the debt crisis. Consider, however, the cases of Hong Kong, Korea, Singapore and Taiwan, nations that have grown at the historically unprecedented rates shown in Table 1. A satisfactory theory of growth should provide insight into the acceleration of their growth in the 1960s. In the context of a neoclassical model, the key determinants of the acceleration are a faster rate of physical capital accumulation, to a lesser extent the formation of human capital, and a high rate of total factor productivity growth. Through the prism of endogenous growth theory, such calculations do not capture the

[5]For an analysis of the implications of organizational structure for productivity, see Stiglitz (1988).

Table 1
Rates of Growth of GDP Per Capita

Years	*1950-60*	*1960-65*	*1965-70*	*1970-81*	*1981-90*
Hong Kong	4.2	8.1	6.0	7.4	5.2
Korea	3.0	3.8	7.8	7.2	8.8
Singapore		2.6	10.8	6.9	5.6
Taiwan	4.0[a]	6.3	7.2	7.3	6.8
Note: a-1952-60.					

Sources: Rows 1-3, Columns 1-4, The World Bank, *World Tables*, third edition. Column 5, *World Tables*, 1993. Row 4, *Taiwan Statistical Data Book*, 1992.

externalities stemming from increased capital accumulation (at least not if they attach too little weight to capital accumulation).

Models that posit externalities from physical or human capital cannot account for the extraordinary GDP growth rates unless such externalities are very strong, so that α is indeed close to unity, even though national accounts data show values of about .4. In one set of endogenous growth models, such externalities arise from improved designs in the domestic machinery-producing sector. But for much of the period of rapid growth, these countries imported a very large percentage of their machinery. There is little theoretical basis for arguing that externalities, as opposed to improved productivity in the purchasing firm, are generated by the use of foreign-produced equipment. Investment externalities are unlikely to have prevented diminishing returns. By 1960, most of the newly industrializing economies already had a higher level of education than would have been predicted by their national income—but many other poor countries that did not grow had similarly high levels (Pack and Page, 1994). Although there was substantial investment in education in these nations, growth in educational levels has not greatly exceeded that in many other less developed countries which have failed to grow (Behrman, 1990). Finally, there was relatively little formal R&D in these newly industrializing countries until the mid-1980s.

One group of models do provide an important clue to the potential sources of growth in these newly industrializing countries (Grossman and Helpman, 1991, ch. 6; Rivera-Batiz and Romer, 1991; Romer, 1990a). They posit that expanded international trade increases the number of specialized inputs, increasing growth rates as economies become open to international trade.[6] The

[6]This result is not unambiguous. Several models suggest that under some conditions, opening an economy to trade may discourage domestic R&D, for example, by inducing the poorer country to allocate its labor to manufacturing rather than to R&D.

specific mechanism assumed to increase productivity—namely, more specialized intermediate inputs and machinery available from trading partners—has not been empirically verified. There are many types of useful knowledge that are not embodied in material inputs, such as production engineering and information about changing product patterns, that are likely to be transferred as a result of expanded trade (Pack, 1992). Suggestive firm-level empirical evidence of the importance of transfers of knowledge rather than machinery has been identified for Korea by Westphal, Rhee, and Pursell (1981) and for Taiwan by Dahlman and Sananikone (1991). Pack and Page (forthcoming 1994) provide evidence that exports, on measure of trade, are important in explaining international differences in productivity growth. Romer (1992) also emphasizes the importance of the transmission of ideas rather than new inputs.

Endogenous growth models emphasizing the role of international trade suggest that high productivity growth is possible in initially poor countries as a result of the diffusion of knowledge already available in industrial countries. Their initial relative backwardness offers an opportunity to be exploited. A closing of the productivity gap between actual and best practice could account for part of the acceleration in growth in the newly industrializing Asian countries, though faster capital growth (however measured and augmented) also played an important role (World Bank, 1993).

Part of this growth in productivity stemming from increasing international trade is undoubtedly facilitated by improved domestic absorptive capacity made possible by higher levels of human capital, as suggested by both Lucas (1988) and Romer (1990a, b). In fact, Nelson and Phelps (1966) argue that human capital is productive only when technology is changing—education increases the ability of individuals to deal with rapid changes in knowledge. This would suggest the Asian countries benefited from the interaction of rapid transfers of technology and a highly skilled labor force able to adapt it to local needs. Econometric confirmation of such a mechanism in a cross-section of countries is provided by Dollar (1992).

If the extent of international trade and the resulting transfer of knowledge and inputs affect the rate of productivity growth, then the pure production function approach to explaining growth, as captured in either neoclassical or early versions of endogenous growth theory, loses some of its force. In terms of the equations in this paper, the level of technology for any given country is changing with the allocation of GDP between domestic sales and exports, partly offsetting any effect of diminishing returns to capital. The ability to close the gap between current and best practice technology is partly dependent on the level of international trade.

A pattern is beginning to emerge about endogenous growth models. They feel intellectually satisfying, since they do not rely on an unexplained source of technical change as the engine of growth. However, for more empirical phenomena—like the productivity slowdown in the OECD countries and the growth acceleration in some Asian nations—only a few of the many strands of endogenous growth theory offer explanatory power.

Convergence Across Countries

Neoclassical theory can be viewed as implying convergence across countries in either growth rates or income levels. Poorer countries will initially exhibit lower capital-labor ratios, which implies a higher marginal product of capital. Given equal rates of domestic saving, labor force growth, and technical progress, their capital stock growth will exceed that in richer countries and they should converge to the capital-labor and capital-output ratio (and the income levels) of richer countries. There may be an added fillip to growth from direct investment in factories and purchases of financial assets by foreigners who can obtain higher rates of return.[7] As convergence occurs, the growth rates of the poorer nations should be greater.

In contrast, endogenous growth theory implies the possibility of sustained differences in both levels and rates of growth of national income. Because of the externalities or the productivity gains obtained from the availability of specialized inputs made possible by research, diminishing returns to human and physical capital do not occur, and the mainspring behind convergence disappears. In neoclassical growth theory, however, convergence will also not occur if differences exist across countries in the production function and its rate of shift. If the ability to tap international technology varies, income per capita can continue to differ even if poorer countries accumulate more capital.

Empirical tests of endogenous growth theory have, paradoxically, focused on tests of convergence implied by neoclassical theory rather than efforts to directly test endogenous growth theory itself. The most basic version of the neoclassical model assumes that: (1) lower income countries have similar fixed savings rates as richer ones; (2) population growth rates are the same; (3) countries have costless access to an identical international production function as well as any shifts in it, although production functions may differ because of country-specific factors such as weather and institutions (Mankiw, Romer, and Weil, 1992). Variation in any of these yields different predicted levels of steady-state income per capita. It is thus necessary to test for "conditional convergence," which simply means examining whether per capita income levels converge after adjusting for differences in investment/GDP ratios and population growth rates. If conditional convergence is found, it is interpreted as confirming the existence of diminishing returns to capital. Its absence constitutes support for endogenous growth theory.

[7]See, however, Lucas (1990) who attempts to explain the limited amount of capital flows from rich to poor countries.

The standard test for conditional convergence has been to regress the growth rates of GDP per capita against investment/GDP rates, initial education levels (as a proxy for human capital), the initial level of per capita income relative to that of the United States, the population growth rate, and a constant. If the coefficient on the initial relative level of per capita income comes up negative, it is taken to mean that initially poor countries grow faster, which is what convergence requires.[8] Using this test, conditional convergence has occured among the OECD countries (Barro, 1991; Dollar, 1992; Mankiw, Romer, Weil, 1992).

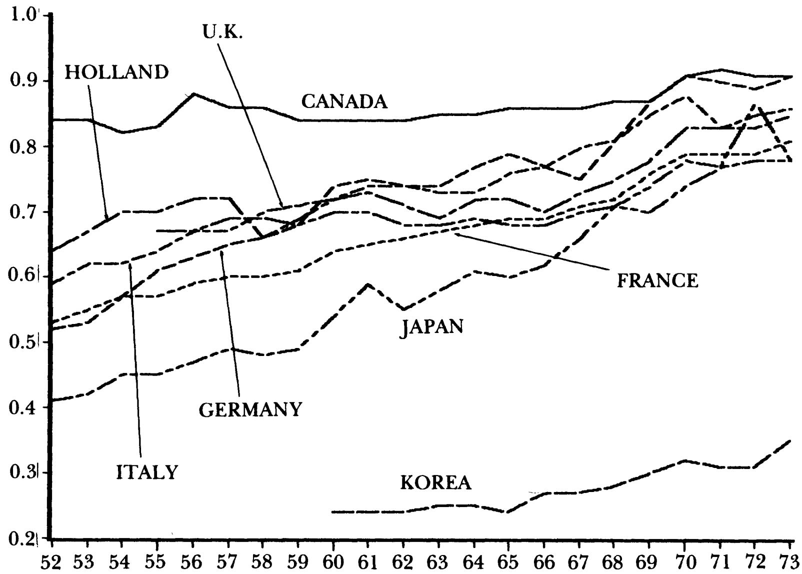
There are two interpretations, not mutually exclusive, of the reasons for convergence. First, with a given ratio of investment to GDP, poorer countries that begin with a lower capital-labor and capital-output ratio will have a faster rate of growth of the capital stock.[9] If the production function is identical for all countries, this will enable poorer ones to move towards the per capita income of richer ones. A second interpretation is that countries with a low level of income at the beginning of the period are operating along a lower production function, obtaining less output from the same quantity of labor and capital than do richer nations. They have the possibility of borrowing more productive technologies, both equipment and the knowledge of how to effectively organize and use it, from the advanced countries (Gerschenkron, 1962; Abramovitz 1986). This second view underlines the potential benefits to lagging countries from technology diffusion and corresponds to the emphasis on this mechanism in the analysis of some open economy endogenous growth models.

In the postwar period, at least until the onset of the productivity slowdown in the early 1970s, the growth of total factor productivity was an important source of catching up. Figure 1 shows the level of total factor productivity relative to the U.S. for a number of countries from 1947-73, the period in which considerable convergence occurred. It demonstrates the importance of the closing of the productivity gap between actual and best practice as one of the sources of economic growth in the period after World War II. This was facilitated by the transfer of knowledge stemming from extensive trade in products (including capital and intermediate goods as well as consumer goods), direct foreign investment among the OECD nations, and technology licensing agreements. On the other hand, such convergence was not an inevitable consequence of initial backwardness. Many countries in Latin America, Africa, Asia, and Eastern Europe did not converge, even conditionally.

[8]A typical regression would be $Y^* = b_0 + b_1 Y_0 + b_2 \frac{\mathrm{I}}{\mathrm{GDP}} + b_3 ED + b_4 N^*$, where Y^* is the growth in per capita income for 1960 to 1985 using the Heston-Summers figures, b_0 is a constant, Y_0 is the level of per capital income relative to that in the U.S. in 1960, I/GDP is the investment to GDP ratio for 1960–85, ED is a measure of the level of education in 1960, and N^* is the rate of population or labor force growth rate between 1960 and 1985.

[9]Note that the rate of growth of the capital stock is I/K, or in terms of the ratios discussed here, (I/GDP)/(K/GDP). If the ratio in the numerator is fixed, then a lower capital stock in the denominator implies faster growth.

Figure 1
Total Factor Productivity Relative to U.S.



Source: Christensen, Cummings, Jorgenson (1980)

Cross-county regressions of growth rates on a variety of determinants are very sensitive to the choice of countries, the years included, and the particular variables included in a regression (Levine and Renelt, 1992).[10] Moreover, even where the regressions show conditional convergence, the data reveal that many countries have suffered from increasing absolute income gaps relative to the United States for long periods of time.

Even when conditional convergence does not occur as measured in these regressions, it does not prove that the endogenous growth theory (in whatever form) is true, nor does it necessarily invalidate the Solow model. For example, conditional convergence in per capita income levels will not occur in the neoclassical model if there are differences in the technological constant A and its rate of increase across countries. Such variations can result in sustained differences in income levels, even with greater growth rates of reproducible

[10]Levine and Renelt (1992) also consider the effect of data quality, utilizing the assessment of quality offered by Summers and Heston (1988) of the quality of national accounts data and purchasing power parity figures. More fundamental questions about the data have been raised by Srinivasan (1992) and Behrman and Rosenzweig (1993).

capital in poorer countries. For example, the estimation of "best practice" production functions and direct calculations of output per unit of capital and labor at sectoral and plant levels reveals that in less developed countries, levels of total factor productivity are often 25 to 50 percent of U.S. levels (Pack, 1987, 1988).[11] Such variations in the level of A are larger than many intercountry differences in saving and population growth rates.

The potential "benefit" of backwardness is that, if countries could capitalize on their backwardness, they could enjoy a rapid spurt of catch-up growth. However, unlike the implication of convergence models if taken literally, the benefits from backwardness do not accrue automatically but result from purposive activities on the part of individual firms within a generally favorable policy environment. This includes a stable macroeconomic policy and institutions designed to facilitate the identification and absorption of technology. Many countries have not experienced conditional convergence and their failure to do so can be attributed to failed policies and weak institutions. Nigeria received huge windfalls from the oil price increases of 1973 and 1979, yet now exhibits absolutely lower per capita income than it had in 1973.[12]

Differences in the technological constant A across countries have implications for endogenous growth models, as well as for tests of the neoclassical implication of conditional convergence. Less developed countries which employ policies such as protecting the domestic market by imposing tariffs are likely to obtain low values of A—for any given value of the capital stock, income levels will be lower though growth rates will not be affected. There is also considerable evidence that capital-output ratios increased dramatically in many countries, notably in sub-Saharan Africa, suggesting that simple versions of endogenous growth models may have a limited range of applicability. The diversity of growth experience thus is consistent with values of A that differ across countries. Regardless of whether one is using a neoclassical or endogenous growth approach, it thus seems necessary to examine one country at a time, insofar as there is no identical international production function along which changes in capital exert their effect.

[11]This at first may seem to be at variance with estimates of efficiency losses due to tariffs in developing countries. These have usually been calculated as being less that 5 percent of GDP. Such small losses might imply that even poor countries are roughly on the same production function as richer ones. However, these numbers are calculated as the loss in industrial output relative to GDP. If the measured loss in industrial value added is 30 percent and industry accounts for 15 percent of GDP, the calculated loss is 4.5 percent. This calculation takes no account of the loss in output in other sectors from technical inefficiency. Yet the evidence is that in the agriculture and service sectors, the deviation from best practice in the OECD countries may be comparably large. As one example, Jorgenson and Nishimizu (1979) found that as late as 1972, the Japanese agricultural sector was less than half as efficient as that in the United States. Moreover, many of the countries in which relatively small losses in annual output have been calculated are in the more advanced developing countries. Few were in Africa, the poorer countries in Latin America, or Asia. Thus an economy-wide figure for A relative to the United States of .3 to .5 does not contradict available evidence.

[12]De Long (1988) shows that many initially rich countries failed to maintain their position with other countries that are now high income nations.

Sources of International Productivity Differences

Why does the level of the technological constant A differ across countries? Among many reasons are imperfections in the market for knowledge, the requirements for local technology absorption, and protectionist policies that decrease the need for cost-reducing behavior.

Acquiring the ability to realize high total factor productivity requires expenditures on equipment and knowledge. Both are expensive. Diffusion of technological know-how occurs through direct foreign investment, licensing, consultants, and informal knowledge transfers. Each of these modes of transfer is facilitated by international trade.[13] For example, the rapid growth of exports enabled the newly industrializing Asian countries to overcome imperfections in these technology markets, such as monopolistic licensing fees, that limit the diffusion of proprietary knowledge and hinder a move toward international best practice (Pack, 1992).

Where knowledge becomes available, costly local adaptation and diffusion effort are often required to achieve levels of total factor productivity realized in industrialized countries with the same machinery. Even if the market for knowledge were perfect, there would be lags in diffusion due to differences in the profitability of adoption (Mansfield, 1968). Moreover, the reward to such effort is not always appropriable by private firms. For example, the increased use of high-yield seeds known as the Green Revolution, which increased productivity of agriculture in developing countries, required publicly provided research on adaptation. Despite the need for public provision, many governments have been reluctant to engage in the necessary activity.

Finally, protectionist policies allow firms to avoid a commitment of resources, even where benefits are appropriable in activities such as quality control and product specialization (Pack, 1987). Although firms shielded from rivals could increase their profits by such activities, the absence of competitive pressures allows the indulgence of a preference for an easy life.

Problems in Sorting Out the Sources of Growth

The same sort of regression equations that have been used in the study of conditional convergence have been used as a basis for more extensive investigations of the determinants of growth. In these studies the variables employed in testing for conditional convergence are supplemented by a large number of other variables. Levine and Renelt (1992) review many of these studies and analyze their robustness. Fischer (1993) demonstrates that macro variables such as inflation and budget deficits have a significant effect on growth. Barro (1991) includes measures of political stability, potential rent-seeking, and other

[13] On the role of technology licensing in Japan's closing of the actual-best practice gap, see Nagaoka (1989).

political variables and finds some to be significant. Easterly, Kremer, Pritchett, and Summers (1993) uncover little persistence in GDP growth rates across decades (with the exception of some of the Asian countries). Shocks, particularly changes in the terms of trade, have had a major impact on measured growth rates. Thus, even if countries are fully utilizing their primary inputs, their growth performance will be affected.

Once both random shocks and macroeconomic policy variables are recognized as important, it is no longer clear how to interpret many of the explanations of cross-country growth—including the subset that analyze convergence alone. Variables such as terms of trade shocks and measures of macroeconomic performance imply that the agents in a country may be inside their production function or, if on it, earning more or less than would have been the case with a different economic policy such as export diversification. Many of the right-hand side regression variables are endogenous: for example, investment reacts to policy, and policy reacts to perceived conditions in the economy.[14]

When a variety of variables are included, the clarity of the tight production theoretic framework becomes blurred. The production function interpretation is further muddied by the assumption that all economies are on the same international production frontier, which runs contrary to the evidence already discussed. Even within countries there are very large intra- and inter-sectoral differences in total factor productivity. It is possible for countries to experience considerable productivity growth as laggard firms close the gap with respect to best practice.[15] Moves toward best practice may result from greater competitive pressures, like those that stemmed from the steady liberalization of the OECD economies under the impetus of GATT. The latter was quite important for much of the post-World War II time period for which the cross-country models have been estimated.

Most of the regressions and production functions also do not take into account changes in sectoral composition of output, despite the research of Denison (1985) and others which finds intersectoral shifts in production to explain part of aggregate growth. Some of the growth attributed to investment and education may simply reflect the fact that they facilitate a change in the sectoral structure of production. What would Japan's GDP per capita growth have been if it had not been able to move from agriculture and low quality textiles to chemicals, metal based products, and electronics?

Finally, regression equations that attempt to sort out the sources of growth also generally ignore interactions in the growth process. For example, a

[14] In this issue, Grossman and Helpman emphasize the possibility that investment responds to the research-induced development of new technology.

[15] For evidence about the considerable variation in total factor productivity among firms in developed countries see the studies in Dogramaci and Fare (1988) which utilize firm level data to derive efficient production frontiers. Handoussa, Nishimizu, and Page (1986) have shown that Egypt experienced considerable total factor productivity growth as laggard firms closed the gap between themselves and the most efficient firms within the country though the latter did not improve their own productivity.

significant coefficient on initial education levels is typically found. But if new knowledge from abroad had not been introduced, or domestic productivity based on R&D had not increased as substantially, the return to education would have been less. Indeed, the external effects of high education levels suggested by Lucas (1988) are most likely to occur when new technology is being introduced rapidly. Conversely, the investment/GDP ratio would have been less had its return been lower because fewer educated workers had undergone the necessary training. Thus, the coefficients for investment and education are proximate rather than fundamental determinants of the growth rate. For all of these reasons, cross-country regressions explaining growth rates may offer a systematic way of explaining some basic facts, but their correlations should not be swallowed as a causal story. Such regressions provide rough orders of magnitude and indications of where to search for explanations of growth, but cannot articulate the connection between factor accumulation and economic growth. These strictures are true of growth accounting as well, but the various studies in this mode have explicitly acknowledged that they are proximate measures.

The recent spate of cross-country regressions also obscures some of the lessons that have been learned from the analysis of policy in individual countries. For example, the newly industrializing Asian nations and Japan have exhibited persistent growth over the last several decades. These countries were quite adversely affected by the two oil shocks because of their openness and could have experienced serious declines in growth rates. Many Latin American countries had high levels of education and investment comparable to many of the Asian nations but were unable to adjust to the higher oil prices. Clearly, microeconomic flexibility and good macroeconomic policy has been a differentiating feature of successful economies. While everyone knows this at some level, the lesson can be lost in some of the papers on sources of growth, buried amidst the large number of factors affecting growth performance.

Conclusion

The major contribution of endogenous growth theory has been to reinvigorate the investigation of the determinants of long-term growth. In addition, endogenous growth theory is clearly setting the terms of the discussion for current researchers. The typical arguments over neoclassical growth theory involved issues like how long a burst of investment might spur a higher growth rate of per capita income before reversion to a steady state, and whether the marginal product of capital had some minimum bound. Those questions now seem less interesting than articulating a new perspective on the underlying determinants of the rate of productivity growth. Yet, the long-term imprint of any growth theory must ultimately depend on the extent to which it generates a productive empirical literature. In this task, endogenous growth theory has led to little tested empirical knowledge.

Tests of the neoclassical growth framework will not, in and of themselves, prove very much about the value of endogenous growth theory. The challenge for empirical work is to test the implications of the new theory more directly. In practice, this means testing its insights against the economic evolution of individual countries using time series data. At the national level, it is possible to examine the timing of growth in GDP, investment in machinery, R&D, and so on, as well as changes in government macro policy. The suggestive empirical results established in the cross-country analyses of convergence provide a guide for such country studies.

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