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ECONOMIC DEVELOPMENT CENTER

**GROWTH ECONOMICS AND DEVELOPMENT ECONOMICS:
WHAT SHOULD DEVELOPMENT ECONOMISTS LEARN (IF
ANYTHING) FROM THE NEW GROWTH THEORY?**

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Abstract

Since their emergence as a distinct fields of inquiry in the early post World War II period there has been an uneasy relationship between growth economics and development economics. The emergence of a richer 'new growth economics' has opened up the possibilities of a more fruitful dialogue between the two subdisciplines. In spite of recent advances, particularly with respect to the human capital, and understanding of differences in growth rates and income levels across countries remains elusive. Further advances will require that growth economists broaden their research agenda to embrace a number of concepts that have become conventional in development economics.

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FROM THE NEW GROWTH THEORY?**

Vernon W. Ruttan*

Both growth economics and development economics emerged as distinct fields of inquiry in the early post World War II period. Growth economics emerged out of a concern with the preservation of full employment in modern capitalist economies. Development economics focused on growth initiation and acceleration in less developed traditional societies. Growth economics was committedly macro-economic in orientation and the province of the practitioners of 'high theory.' Development economics was more micro-economic in orientation and drew on knowledge from related research in anthropology, sociology and political science and on the insight of practitioners [[Krugman, 1996:1-29](#)].

There has been an uneasy relationship between these sub-disciplines. Growth economists have tended to view the development economics literature as lacking in rigor and burdened with irrelevant organizational and behavioral detail. Development economists have often felt that the only message growth economists were sending them was to get interest rates (and other prices)

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right. After a hiatus of over two decades there has emerged, since the mid-1980s, renewed interest in the theory of economic growth. With the emergence of a new and richer growth economics literature the possibilities of a more fruitful dialogue between growth economics and development economics now may be possible. The purpose of this paper is to address the question, what should development economists learn from the new growth economics?¹

There have been three waves of interest in growth theory in the last half century. The first was stimulated by the work of Harrod [1939:14-33; 1948] and Domar [1946:137-47; 1947:343-55]. The second wave began in the mid-1950s with the development by Solow [1956:65-94] and Swan [1956:343-61] of a neoclassical model of economic growth. The third wave was initiated in the mid-1980s by Romer [1983; 1986:1002-37] and Lucas [1988:3-42; based on his 1985 Marshall Lecture].²

KEYNSIAN AND NEO-CLASSICAL GROWTH ECONOMICS

The question posed by Harrod and Domar, using somewhat different terminology, was under what circumstances is an economy capable of achieving steady state growth? This question had forced itself onto the economic agenda by the Great Depression of the 1930s and the expectation that the end of World War II would be followed by renewed instability. In the Harrod-Domar view instability in economic growth was the result of failure to equate a 'warranted' and a 'natural' rate of growth. The warranted rate of growth is dependent on the savings rate and on a given capital requirement per unit of output. The natural rate is the maximum long run sustainable rate of growth. It is determined by the rate of growth of the labor force and the rate of growth of output per worker (Box 1). This central proposition of the Harrod-Domar model arises from the assumption that investment is both capacity creating and income generating.

Box 1

THE HARROD-DOMAR MODEL

The question posed by Harrod and Domar, using somewhat different terminology, was under what circumstances is an economy capable of achieving steady state growth? This question had forced itself onto the economic agenda by the Great Depression of the 1930s and the expectation that the end of World War II would be followed by renewed instability.

In the Harrod-Domar view instability in economic growth is the result of failure to equate a “warranted” and a “natural” rate of growth.

When the warranted rate is given by s/v and the natural rate by $n+m$ the equilibrium expression is:

$$s/v = n+m$$

where:

s = the saving rate (a fixed fraction of net output)

v = the capital requirement per unit of output

n = the rate of growth of the labor force (and population)

m = the rate of labor saving technical change.

Thus, if the savings rate were 10 percent of income and the capital output ratio 4, the warranted rate of growth would be 2.5 percent. If the labor force was growing at 1.0 percent and labor productivity at 1.5 percent per year, the warranted and natural rates would be equal.

An attraction of the Harrod-Domar model was that it attempted to study long run growth with the tools of Keynesian economics that had recently become familiar to economists. Use of the model diffused rapidly to the planning agencies of many newly independent countries. It seemed to confirm the widely held belief among development economists and planners that the transition from slow to rapid growth required a sustained rise in the rate of savings and investment.³ It provided a rationale for interventions designed to raise savings rates and encourage investment in heavy industry in order to remove the constraints on production resulting from capital equipment. And it provided the conceptual foundation for the two gap (in savings and foreign exchange) model developed by Chenery and associates to estimate foreign aid requirements of developing countries [Chenery and Strout, 1966:679-735]. It was also interpreted as consistent with the view that achieving sustained growth would be more difficult for capitalist economies than for economies where the central planning apparatus would have more direct access to the instruments needed to force a rise in the saving rate and to allocate investment to its most productive uses.⁴

The second wave in the development of modern growth theory began with the neo-classical model introduced by Robert M. Solow (1956) and Trevor W. Swan (1956). Solow was motivated by skepticism that a sustained rise in the savings rate is the key to the transition from a slow to a fast growth path and by a concern that the capital-output ratio be replaced by a richer and more realistic representation of technology [Solow, 1988:303]. Solow's departure from the Harrod-Domar model was to substitute a variable capital-output ratio for the fixed coefficient capital-output ratio of the Harrod-Domar model. He insisted that the primary effort in his 1956

paper 'is devoted to a model of long run growth which accepts all the Harrod-Domar assumptions except that of fixed proportions' [Solow, 1956:66].

The initial version of the Solow neo-classical model (Box 2) has been succinctly described by Prescott. 'The model has a constant returns to scale aggregate production function with substitution between two inputs, capital and labor. The model is completed by assuming that a constant fraction of output is invested' [Prescott, 1988:7]. The model was employed in a 1957 paper in which an aggregate two factor production function was used in accounting for growth in the U.S. economy. To Solow's surprise, and to the surprise of the profession generally, four-fifths of the growth in U.S. output per worker over the 1909-1949 period was accounted for by changes in the technology coefficient. The two papers triggered a whirlwind of theoretical and empirical research that lasted well into the 1970s.

In the initial Solow-Swan neo-classical model steady state growth can hardly be avoided. A country that succeeds in permanently increasing its savings (investment) rate will, after growing faster for a while, have a higher *level* of output than if it had not done so. But it will not achieve a permanently higher *rate* of growth of output [Solow, 1988:308] (Fig. 1). What were the implications of the Solow neoclassical growth theory and related growth accounting exercises for development economics? The initial results seemed to completely reverse the earlier Harrod-Domar implications. Technological change replaced growth of capital equipment as the primary source of growth. Subsequent growth accounting exercises employing broader definitions of capital resulted in somewhat lower estimates of the contribution of technical change. But technical change continued to outweigh growth of physical capital stock by a substantial margin in studies conducted in the United States and other presently developed

Box 2

THE NEOCLASSICAL (SOLOW-SWAN) GROWTH MODEL

Solow's departure from the Harrod-Domar model was to substitute a variable capital-output ratio for the fixed coefficient capital-output ratio.

"The model has a constant returns to scale aggregate production function with substitution between two inputs, capital and labor. The model is completed by assuming that a constant fraction of output is invested," (Prescott, 1988, p. 7).

$$c_t + i_t = f(k_t, n_t)$$

$$k_{t+1} = k_t + i_t$$

$$i_t = \sigma f(k_t, n_t)$$

where

c is consumption

i is investment

k is capital

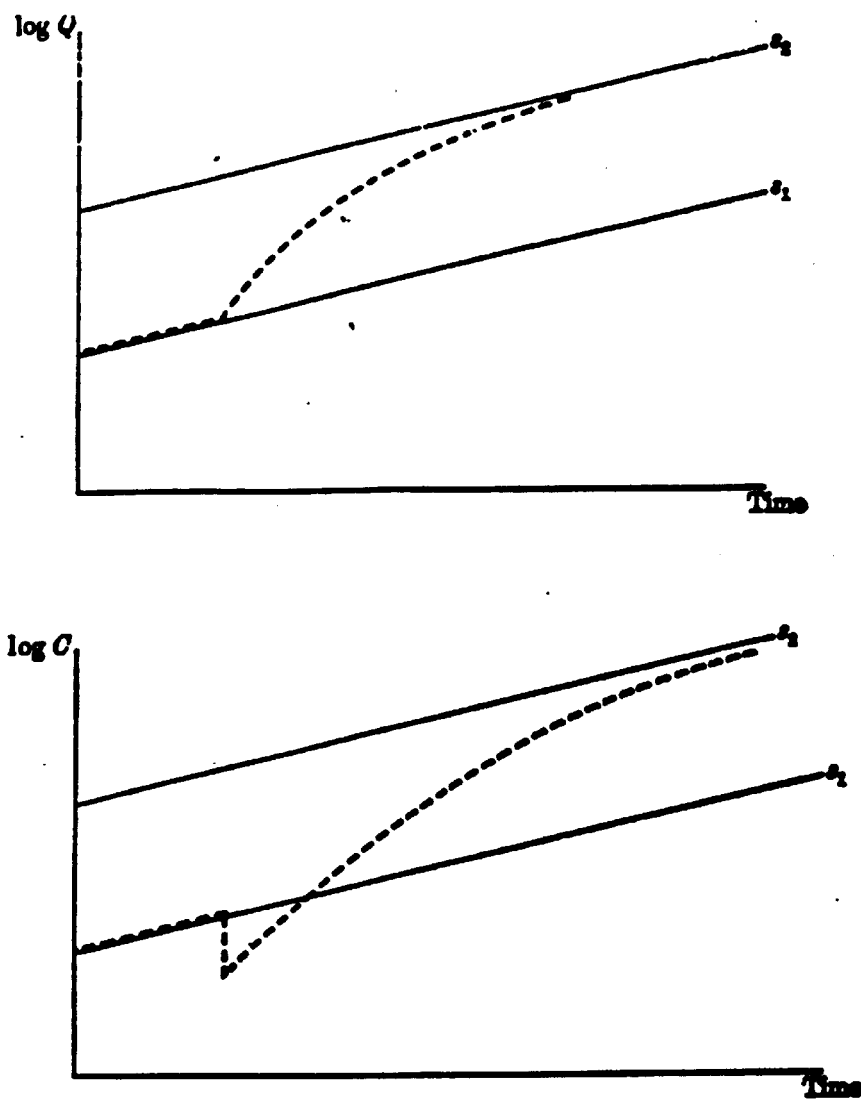
n is labor

σ the fraction of output invested.

If factors are assumed to be paid their marginal product, then given k_t and n_t the date t national income and product accounts can be computed for the model economy.

In Prescott's exposition, and in Solow's original model there is no technical change. Some authors, however, seem to interpret the Solow labor variable as "effective labor," as in the Harrod-Domar model

Figure 1. Time profile with a sudden increase in saving rate.



Source: Robert M. Solow, *Growth Theory: An Exposition* (New York: Oxford University Press, 1970), pp. 24-26.

countries. Research on sources of growth in poor or newly developing countries typically found that a much smaller share of economic growth was accounted for by productivity growth. This was often interpreted as an indication that inappropriate technology transferred from high wage economies, where it had been developed, to low wage economies failed to generate as high productivity gains in low wage as in high wage economies.⁵ In addition research carried out within the neoclassical framework did not shed much light on the driving forces behind the proximate sources of growth--on the determinants of the growth of physical and human capital and technical change.

ENDOGENOUS GROWTH THEORY

Massive divergence in absolute and relative percapita income across countries is a dominant feature of modern economic history [Kuznets, 1955; 1966; Maddison, 1979:27-41; Pritchett, 1995; Prescott, 1997]. The 'new' growth economics literature was initially motivated by the apparent inconsistency between the implications of the neoclassical theory and (a) lack of evidence of convergence toward steady state growth even among presently developed economies [Romer, 1983:3] and (b) by the inability to successfully account for differences in income growth rates or income levels across countries [Romer, 1994:3-22].⁶ 'By assigning so great a role to 'technology' as a source of growth, the theory is obliged to assign correspondingly minor roles to everything else, and so has very little ability to account for the wide diversity in growth rates that we observe' [Lucas, 1988:15]. Romer argued that what is needed is 'an equilibrium model of endogenous technical change in which long-run growth is driven primarily by the accumulation of knowledge by forward-looking, profit maximizing agents' [Romer, 1986:1003].⁷ A primary goal of the new growth economics is to build models that can 'ensure that the long run

growth rate of income depends not only on the parameters of the production and utility functions, but also on fiscal policies, foreign trade policies, and population policies' [Srinivasan, 1995:46].⁸ The effect was to challenge the neoclassical assumption that policy can affect the level of economic activity but not the rate of economic growth. In this section I first review the contributions by Romer and Lucas and then some related contributions.

In the initial endogenous growth models advanced by Romer [1983; 1986:1002-37] long-run growth is driven primarily by the accumulation of knowledge. The production of new knowledge exhibits diminishing returns at the firm level. However, the creation of new knowledge by one firm is assumed to generate positive-external effects on the production technology of other firms. Furthermore, the production of consumption goods, which is a function of both the stock of knowledge and other inputs, exhibits increasing returns. The three elements, decreasing returns in the production of new knowledge, externalities associated with new knowledge, and increasing returns in the production of output insure that a competitive equilibrium with externalities will exist.⁹ The initial Romer model, and other closely related models are frequently referred to as closed economy AK models after the assumed production function (Box 3).

The initial models advanced by Romer abandon the neo-classical assumption of perfect competition and require either constant or increasing returns to capital. An important implication of the model is that the market equilibrium is suboptimal since the external effects of the accumulation of knowledge is not considered by the firm in making production decisions. Another implication is that factor shares, typically employed as the elasticity coefficients in the neo-classical production function, can no longer be used to measure the contribution of capital

Box 3

ENDOGENOUS GROWTH THEORY (ROMER-LUCAS)

The “new” endogenous growth literature was motivated by a presumed lack of evidence of convergence toward steady state growth in the presently developed economies and by the inability to successfully account for differences in growth rates or income levels across countries.

The initial models are frequently referred to as AK models after the assumed production function $Y = AK$ where K can be thought of as a proxy for a composite capital good that includes physical and human components.

$$Y = K^{1-\alpha} (\tilde{A} L_Y)^\alpha$$

$$\dot{\tilde{A}} = \delta L_A$$

where

Y is output,

A is productivity, knowledge is ideas,

K is capital.

δ parameterizes the efficiency of R & D. Labor is used in two activities, the production of output (L_Y) and the search for innovations (L_A) so that $L_Y + L_A = L$.

The increasing returns to scale in this production function reflect the nonrivalrous nature of knowledge: given some level of knowledge A , doubling capital and labor inputs into production is sufficient to double output; doubling the stock of knowledge as well would lead to more than doubling of output.

and labor. Romer suggests that the typical capital coefficient (.25) severely underestimates the contribution of capital and the labor coefficient (.75) severely over-estimates the contribution of labor. In his model the capital coefficients, adjusted to take into account the accumulation of knowledge (or of human capital), would have to be (implausibly) close to one in order to generate the extremely high growth rates of the East Asian NIC's [Romer, 1987:163-202].

Lucas [1988:3-42], drawing on Uzawa [1965:18-31], proposed a second alternative to the neoclassical model. In his model human capital serves as the engine of economic growth. He employed a two sector model in which human capital is produced by a single input, human capital, and in which final output is produced by both human and physical capital. Two alternative human capital models are analyzed. In the first, the schooling model, the growth of human capital depends on how a worker allocates his or her time between current production and human capital accumulation. In the second, the learning-by-doing model, the growth of human capital is a positive function of the effort devoted to the production of new goods.

In both Lucas models there are, as in Romer, in addition to the 'internal effects' on the workers own productivity, 'external effects' that are the source of scale economies and that enhance the productivity of other factors of production.¹⁰ In both cases the accumulation of human capital involves a sacrifice of current utility. In the first model this sacrifice takes the form of a decrease in current consumption. In the second it takes the form of a less desirable mix of current consumption goods than could be obtained with slower human capital growth [Lucas, 1988:18]. Lucas argues that this deficiency could, in principle, be solved in the first case by subsidizing schooling and in the second case by subsidizing research and development. In 1990 Romer advanced an alternative endogenous growth model in which he followed Lucas in

emphasizing the importance of human capital in the development of new knowledge and technology. He departed from Lucas, and from his own earlier work, by treating technical change as embodied in new producer durables. The basic inputs in the model are capital, raw labor, human capital and an index of the level of technology. The technology component is disembodied nonrival knowledge that can grow indefinitely. Human capital is the cumulative embodied product of formal education, on-the-job training and learning-by-doing. The model economy has three sectors: (a) a research sector that uses human capital and the stock of knowledge to produce new knowledge in the form of designs for producer durables; (b) an intermediate goods sector that uses the designs from the research sector together with foregone output to produce the producer durables used in the production of final goods; and (c) a final goods sector that uses raw labor, human capital and producer durables (but no raw material) to produce final output--which can be consumed or saved as new capital [Romer, 1990:571-5102].

In this model growth in the stock of capital used in the production of final goods takes the form of growth in the number of intermediate inputs rather than in the quality of each input. Growth in the number of intermediate inputs implies monopolistic competition in the market for producer durables and assures external scale economies as a result of the growth in output of each consumer durable. The critical allocative decision is the share of human capital employed in research. As in his earlier model, and in the Lucas models, the optimum rate of growth exceeds the market rate since the externalities from knowledge creation are not considered by the firm making production decisions.¹¹

As his work continued to mature Romer has turned to the contribution of ideas as the primary source of economic growth [Romer, 1993:543-573; 1996]. 'Neoclassical growth theory

explains growth in terms of interactions between two basic types of factors: technology and conventional inputs. New growth theory...divides the world into two fundamentally different types of productive inputs that we can call 'ideas' and 'thing.' Ideas are nonrival goods.... Things are rival goods. ...Ideas are goods that are produced and distributed just as other goods are' [Romer, 1996:5,6]. For Romer, scale effects are important because ideas, as nonrival goods, are expensive to develop but are inexpensive to use.¹² Their value increases with the size of the market. This implies that large countries, with large internal markets, have a greater incentive to produce ideas than small countries. As a result large countries can be expected to grow more rapidly than small countries--particularly when small countries burden themselves with the control and regulatory structures that characterise large countries.¹³

What are the implications of the Romer-Lucas inspired endogenous growth literature for development economics? Bardhan insists that the most substantive contribution 'is to formalize endogenous technical progress in terms of a tractable imperfect-competition framework in which temporary monopoly power acts as a motivating force for private innovations' [Bardhan, 1995:2985]. Griliches notes the importance of their work in emphasizing that (1) 'technical change is the result of conscious economic investments and explicit decisions by many different economic units and (ii) unless there are significant externalities, spillovers, or other sources of increasing returns, it is unlikely that economic growth can proceed at a constant undiminished rate into the future' [Griliches, 1992:294].

In my judgment the most important substantive contribution has been their endogenization of human capital formation. This led to the important analytical result that when investment takes place in an economic environment with increasing returns to scale the marginal product of capital

need not decline over time to the level of the discount rate. Thus the incentive to accumulate human and physical capital may persist indefinitely and long-run growth in per capital income can be sustained.

Even more important than the results of their own research has been the stimulus that the Romer-Lucas work has provided for a new burst of theoretical and empirical research in the field of both growth and development economics and, by the mid-1990s, several graduate level textbooks incorporating and extending the work in growth economics conducted over the previous decade [Barro and Sala-i-Martin, 1995; Aghlon and Howitt, 1998]. At the theoretical level there has been a proliferation of models, each of which attempt to introduce greater realism, in order to account for both a general failure of convergence and the 'miraculous' growth of a few countries such as Korea and Taiwan. The theoretical literature has been complemented by efforts to analyze the effects of different national policies, tax rates for example, in accounting for different national growth rates [King and Rebelo, 1990:S126-S150]. In a later section I turn to the implications of the new growth economics for development.

TRADE AND GROWTH

The potentially most important extension of the new growth economics, particularly for development economics, is the synthesis of the new growth economics and the new trade theory by Gene Grossman and Elhanan Helpman. Their contribution is the result of an exceedingly ambitious research agenda that began in the late-1980s [1990a:86-91; 1990b:796-815; 1991:517-576] and culminated in the publication of Innovation and Growth in the Global Economy [1991].

Following Romer and Lucas they stress that industrial research not only generates specific proprietary technical information that allows a firm to produce new products, but also

contributes to general scientific knowledge, which can be exploited by other firms to develop even better products. To illustrate the point that externalities in R&D activities are essential to maintain growth they develop and analyze two alternative models of technological competition. As in Romer [1990:571-5102] one innovation takes the form of expanding product variety; the other takes the form of quality improvement.

Grossman and Helpman first introduce a one sector closed economy model in which accumulation can take the form of (a) investment in plant and equipment and (b) in specialised skills by agents. Physical capital is treated as a homogeneous commodity produced by the same means as consumption goods. The physical capital is then used, along with labor and human capital, to produce output. The equilibrium determines an endogenous supply of human capital and a residual supply of unskilled labor. The steady state stocks of the two types of labor determines long-run rates of growth [Gosh, 1994:47-49]. Analysis of the model leads to the counter intuitive conclusion that physical capital can play only an accommodating role in long run economic growth. In the interest of simplicity (and tractability) they then drop capital equipment from their analysis of the closed economy world - and from the rest of the book! Further analysis of factor accumulation and allocation is confined to the two labor categories - unskilled labor and human capital.

In the second half of their book Grossman and Helpman extend these models to analyze the interactions between trade and growth. With each step they introduce greater realism in the assumptions employed in the models. They abandon the traditional assumption employed in growth economics (but not in development economics) that technological opportunities are the same throughout the world.¹⁴ Countries are not characterised by a common production function.

They insist that the process of assimilating existing technologies in the less developed countries is not unlike that of creating entirely new technologies in the developed world. Countries in which technological research is carried out acquire a comparative advantage in the form of human capital resource endowments that may persist for some time.

Starting from these more realistic assumptions Grossman and Helpman proceed to show how external relationships affect a country's growth performance: (a) international exchange opens channels of communication that facilitate the transmission of technical information; (b) international competition encourages entrepreneurs in each country to pursue new and distinctive ideas and technology; (c) international integration enlarges the size of the market in which the innovative firm operates; and (d) international trade induces a reallocation of resources (labor and human capital). In this process countries can lose as well as gain from trade. Countries with a larger high technology sector (and employing labor with a high human capital component) may experience long term gains relative to countries with relatively abundant supplies of raw labor [Grossman and Helpman, 1991:237-238].

In a world in which the Grossman-Helpman assumptions hold, there can be a substantial role for public policy. An appropriate policy regime can help speed the transition from traditional manufacturing into becoming an exporter of high technology goods. It may also modify the impact on income distribution of the 'creative destruction' associated with technical change. The policy instruments discussed by Grossman and Helpman are the conventional instruments that are commonly analyzed in the trade literature - lump sum taxes, subsidies to R & D and on production for export, and tariffs. In spite of the importance they place on technical change discussion of science and technology policy is exceedingly thin. Grossman and Helpman have

pushed their analysis further than the other scholars working in the new growth economic tradition to incorporate the international movement of goods, capital and ideas. Drawing on Romer and Lucas, they have formerly incorporated 'the process of introduction of an ever-expanding set of new goods and technologies [Bardhan, 1995:2992].

The results obtained by Grossman and Helpman represent an important contribution to the formal analysis of trade and growth. But their analysis is characterised by a curious 'industrial fundamentalism'.¹⁵ It provides rather 'thin gruel' for the appetites of development economists and practitioners. It will be necessary to extend their analysis beyond the rather narrow confines of the industrial sector and embrace a richer institutional environment before their research agenda will be very useful to development economists [Krueger, 1997:1-22].

DIALOGUE WITH DATA

The assault by the proponents of the new endogenous growth theory on the neoclassical model was beginning, by the mid-1980s, to generate a substantial backlash. Some of the qualifications were theoretical in nature.¹⁶ Most, however, have challenged the consistency of the empirical implications with growth experience.

Much of the initial empirical work has not attempted to directly test the endogenous growth models but rather to rehabilitate the neoclassical model [Pack, 1994:55,63]. An important landmark in this effort is the cross country analysis by Mankiw, Romer and Weil [1992:407-38].¹⁷ The authors first reject the Romer-Lucas characterization of the neoclassical model. When they incorporate saving, population growth rates and human capital accumulation into the cross country regressions, along with physical capital and raw labor, Mankiw, Romer and Weil find that the 'augmented' neoclassical model accounts for about 80 percent of the cross country

variation in income. They also find that the augmented model predicts what they term 'conditional convergence' across counties (Figs. 2.1-2.3).

There have also been several studies that have attempted to explore the sources of growth of the rapidly growing newly industrializing countries of East Asia (NICs)--Hong Kong, Singapore, South Korea and Taiwan. The results challenge the conventional wisdom that high productivity growth in the manufacturing sectors largely account for the rapid overall rate of economic growth in these countries (World Bank, 1993; Kim and Lau, 1994:235-271; Easterly, 1995:267-284; Young, 1995:641-680). Young concludes, from a traditional neoclassical growth accounting exercise, that the very high rates of growth of the East Asian NICs are primarily accounted for by (a) a rise in labor force participation rates, (b) a rise in investment to GDP ratios, (c) improvements in education and (d) the intersector transfer of labor from agriculture. Annual rates of total factor productivity growth (Hong Kong-2.3%; Taiwan 2.1%; South Korea 1.7%, Singapore 0.2%) have been high, but not high enough to explain miracles.

A second line of inquiry questions the ability of familiar public policy instruments to bring about permanent changes in growth rates, at least in the presently developed countries. Islam [1995:1128-70] employs a dynamic panel data model (combining cross-section and time series data) with individual country effects. This enables him to incorporate differences in the aggregate production function both across groups of countries (convergence clubs) and for individual countries. Islam's results suggest that growth in each country converges to its own steady growth rate, conditional on differences in technology and institutions. He notes that this conclusion is hardly optimistic. "There is probably little solace to be derived from the finding that countries in the world are converging at a faster rate when the points (and growth paths) to

Figure 2.1 - Absolute convergence to natural growth rate from different levels

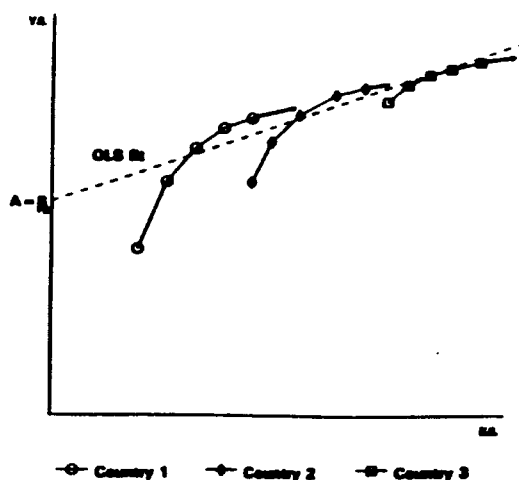


Figure 2.2 - Conditional convergence of growth rate from different levels

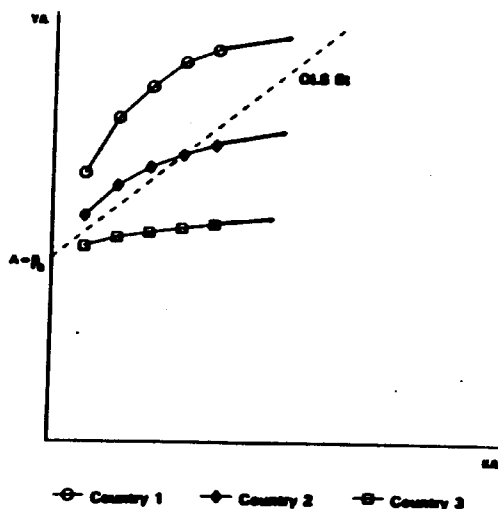
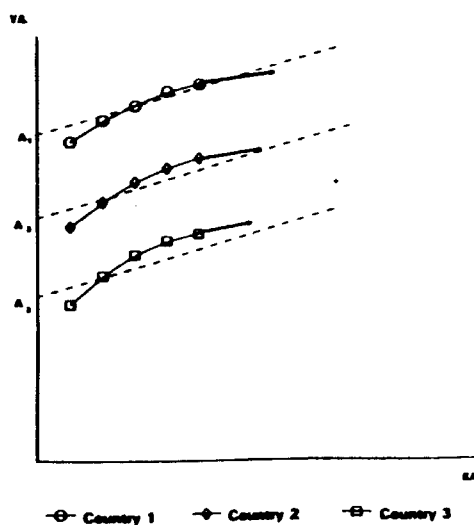


Figure 2.3 - Different natural growth rates starting from different levels

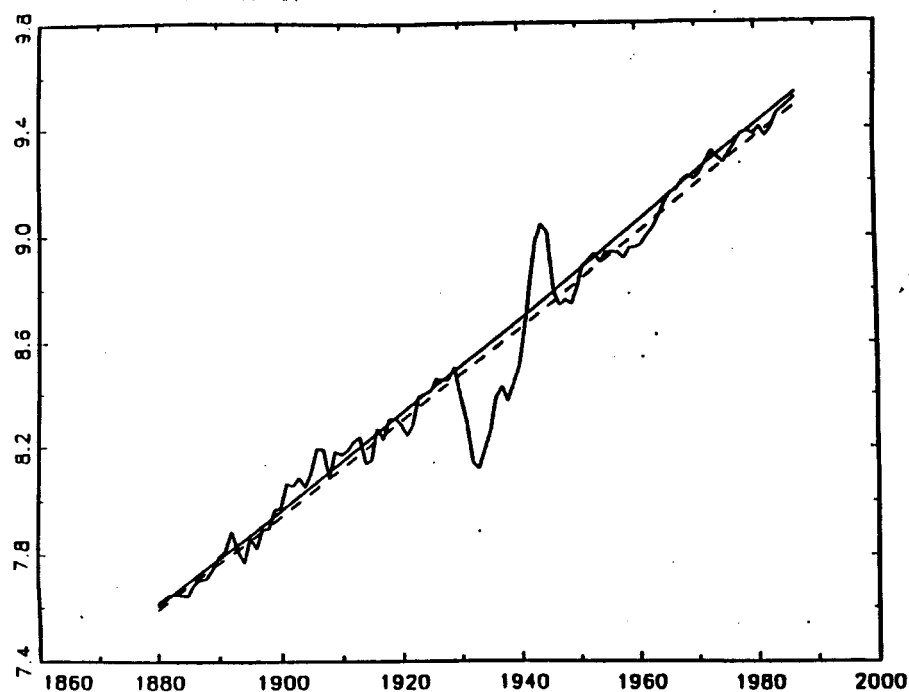


which they are converging remain very different” [Islam, 1995:1162].

A number of recent papers have focused on the growth experience of particular counties or regions. Jones [1995a:495-526] shows that in spite of permanent changes in a growth-increasing direction of a number of the variables identified as potential determinants of long run growth in the new growth economics literature (openness to international trade, human capital investment, population growth and others) they have had little or no impact on growth in the OECD economies during the post World War II era. The rate of growth in per capita income in the United States, for example, has apparently remained essentially unchanged during the entire 1880-1987 period (Fig. 3). Jones draws the startling conclusion that 'either nothing in the U.S. experience since 1880 has had a large persistent effect on the growth rate, or whatever persistent effects have occurred have miraculously been offsetting' [Jones, 1995a:499; Pritchett, 1997].¹⁸ And Griliches has insisted even more strongly: 'Knowledge externalities are obviously very important in the growth process but do not help us explain what has happened (in the United States) in the last two decades' [Griliches, 1994:16].

A third line of inquiry has involved attempts to test the returns to scale hypotheses that is central to the new growth economics. In spite of its intuitive plausibility the evidence from cross-industry and cross-county studies provides only minimum support for the role of scale economies as an important source of growth [Burnside, 1996:177-201; Backus, Kehoe, and Kehoe, 1995:377-409]. Backus, Kehoe, and Kehoe [1995:477-409] have attempted to test the sources of scale economies -- learning by doing, investment in human capital and specialised intermediate inputs -- emphasised by Lucas and Romer. In their search for evidence of scale

Figure 3. Per Capita GDP in the United States, 1880-1987 (Natural logarithm)



Source: The data are from Maddison (1982, 1989) as compiled by Bernard (1991). The solid trend line represents the time trend calculated using data only from 1880 to 1929. The dashed line is the trend for the entire sample.

Source: Charles I. Jones, "Time Series Tests of Endogenous Growth Models," *Quarterly Journal of Economics*, Vol. (May 1995), p. 498.

economies from these three sources they find modest support for scale economies in the manufacturing sector but fail to find evidence of economy wide scale economies ¹⁹. In their cross country agricultural production function studies for 1960-1980 Hayami and Ruttan [1985:143-157] found scale economies across conventional inputs (land, labor, capital and operating inputs) for developed countries but not for developing countries. Using an augmented production function they did, however, find economies of scale across conventional inputs plus human capital for both developed and developing countries. They interpret the evidence of economies of scale as the disequilibrium effects of prior technical change rather than as pure scale economies.

What should development economists learn from this more recent research carried out within a neoclassical framework? When the neoclassical model is extended to incorporate the variables of an augmented production function to explain differences in the level of per capita income or of partial or total factor productivity reasonable results are obtained [Hayami and Ruttan, 1970:138-162; Kawagoe, Hayami and Ruttan, 1985:113-132; Mankiw, Romer and Weil, 1992:407-38; Mankiw, 1995:275-376; Pritchett, 1997].

These advances in our understanding are important. But they are a reflection of surface phenomena - the proximate sources of economic growth. Answers to more fundamental questions, such as why some countries save and invest more than others, why some countries invest a larger share of GNP on education or on R&D, why some countries were able to put the package of high pay-off inputs together more effectively than others, or why some countries have responded to shocks (the great depression of the 1930s; the food crises of the 1960s or the oil shocks of the 1970s) more effectively than other countries continue to remain beyond the reach

of the models employed by both the neoclassical and the new growth economists [Nelson and Pack, 1997].

Much of the work in development economics has focused on the changes in technology and institutions that enter into the country specific term. Islam's results, and those of Jones, suggest a return to the research agenda advanced by Abramovitz [1952:132-78]; Kuznets [1954:1-28] and Rostow [1956:25-48; 1960] in the 1950s--a focus on the deeper sources of the technical and institutional changes associated with the 'preconditions' and 'take off' into self sustained growth.

GROWTH ECONOMICS AS DEVELOPMENT ECONOMICS

It is now time to turn to a fuller assessment of the implications of the new growth economies for development economics.²⁰ Lucas attempted to answer this question in his 1991 lecture at the European meeting of the Econometric Society [Lucas, 1993:251-272]. He was very explicit about what he wanted to accomplish. He wanted to be able to encompass both the Korean 'growth miracle' and the Philippine 'growth failure.' And he viewed growth miracles as productivity miracles. Just as Solow in the mid-1950s viewed his contribution as a modest modification of the Harrod-Domar model, Lucas viewed his contribution as adapting the neoclassical model to fit the observed behavior of both rich and poor economies. He saw the new growth economics as displacing not only the older neoclassical growth economics, but development economics as well. The new growth economics includes 'those aspects of economic growth we have some understanding of, and development (economics) those we don't' [Lucas, 1988:13].

As an exercise in the integration of the several strands of the new growth economics into a coherent system, the Lucas paper is an exciting *tour de force*. Lucas, Romer and other

practitioners of the new growth economic must be credited with an attempt to reach behind the proximate sources of growth and to treat as endogenous some of the more fundamental sources. This was achieved by importing three concepts that have been conventional in development economics. One was the concept of scale economies that occupied a prominent role in the early development literature.²¹ A second was the insight into the role of human capital advanced initially by development economists.²² A third was the concept of endogenous technical change, that, under the rubric of induced technical change, had achieved substantial success in the hands of development economists and economic historians in interpreting the rate and direction of technical change.²³

There are several other concepts that must be imported before the new growth economics can successfully lay claim to success as a 'new development economics,' or provide new insights for development practice. I list below some of the more fundamental concepts that are employed by development economists but which continue to be ignored by practitioners of growth economics. The list is not intended to be exhaustive.

Structural transformation. The issue of structural transformation, the transition from a primarily agrarian to an industrial-commercial economy, has represented a core issue in development economics since the publication of Colin Clark's classic work in 1940 [Clark, 1940; Jorgenson, 1961:309-34; Ranis and Fei, 1961:533-65]. The assumptions of homothetic preferences and neutral technical change employed by most growth economists rules out any analyzes of structural transformation [Matsuyama, 1992: 383-395; Bardhan, 1995:2984-98]. Once these assumption are abandoned, structural change emerges as a central feature of the process of development [Syrquin, 1994:3-21; Echevarria, 1997:431-452]. An attempt to

analyze economic development with a model in which there is no mechanism to generate structural transformation can hardly be regarded as serious. It resembles an attempt to perform Hamlet with no role for the Prince of Denmark.²⁴

The demographic transition. The demographic transition is one of the more familiar processes associated with economic development. It strikes one as somewhat negligent that attempts to develop an endogenous theory of per capita income growth have failed to address the issue of growth of population and labor force. This seems particularly negligent given the attention that has been focused on East Asia in the new growth economics literature. Development economists have made substantial progress in constructing endogenous models of family fertility decisions. Less progress has been made in our understanding of such factors as investment in health and nutrition that influence infant and child mortality rates and the growth of human capital [Nerlove, 1974:S200-S218]; 1994].

Natural resource constraints. While sometimes acknowledged, natural resource constraints are only just beginning to be incorporated into the growth economics literature. [Musu and Lines, 1995:273-286; Echevarria, 1996]. At the very least it is important to incorporate land (and other natural resource endowments) and environmental constraints into growth models.²⁵ When environmental effects are more adequately incorporated the comment by Solow in his classic 1956 paper will become more apt: 'The scarce-land case would lead to decreasing returns to scale in capital and labor and the model would become more Ricardian' [Solow, 1956:66]. It is also important to separate those investments in technology development that represent maintenance research and development — the R & D necessary to offset declines in natural

resource quality or loss of productivity in biological technology - from R & D investment in productivity enhancing technical change.²⁶

Income distribution. The issue of the relationship between income distribution and economic development is a central issue in development economics. Much of the earlier literature has focused on the U shaped Kuznets income distribution curve [Kuznets, 1955:1-28; Bacha, 1977:52-87]. The conditions under which economic growth leads to a widening or narrowing of income distribution and the conditions under which changes in income distribution enhance or threaten economic growth are the subject of a large literature in development economics [Kanbur, 1997]. The literature on sources of poverty and poverty alleviation has been enriched by the large literature on entitlements stimulated by Sen [1981, 1983:745-762]. Attempts have been made in recent literature to endogenise the mechanisms that generate the Kuznets inverted-U relationship between inequality and income growth [Galor and Tsiddon, 1996:103-117]. But neither the models employed by the neoclassical or the new growth economists have explicitly addressed the issues of poverty and income distribution.

Institutional change. The formal analytical literature on sources of institutional change remains underdeveloped. A beginning was made in the literature by development economists on land tenure reform in eastern Europe and West Asia in the 1950s and 1960s [Hayami and Ruttan, 1985:389-397]. Recent advances include the literature on contract choice [Stiglitz, 1974:219-55; Otsuka, Chuyama and Hayami, 1992:1965-2018] and on the role of property and contract rights in the transition to democracy [Clague, Keefer, Knoch and Olson, 1996:243-276]. But the success of the new growth economics in endogenizing technical change has not been followed up by an effort to endogenise the process of institutional change or to incorporate institutional

design theory.²⁷ Mancur Olson notes that neither the old or the new growth literature has successfully confronted the empirical observation that in spite of the widening disparity between rich and poor countries 'the fastest moving countries are never the countries with the highest per capita incomes but always a subset of the lower income countries' [Olson, 1996:20]. And he insists that the only explanation available for the emergence of the rapidly growing subset of poor countries is institutional change. Prescott [1997:33] has urged that inquiry be directed to those factors that determine the strength of resistance to transfer and adoption of knowledge and technology.

Why have growth economists been so slow to incorporate such fundamental issues and concepts into growth theory? The answer seems to be that it is primarily because of analytical and modeling tractability. Insistence on working within the narrow constraints of steady state growth models has represented a fundamental obstacle to building on the rich body of literature initially advanced by development economists.²⁸ In retrospect it seems clear that a pervasive obsession with the conditions for convergence (or the traverse) to steady state growth accounts for much of the failure of both the old and the new growth economics to extend its reach to encompass some of the more fundamental sources of economic development.²⁹

Furthermore, the distinction between level effects and rate effects, however important analytically, does not carry over well into development economics. The growth obtained by exploiting the transition dynamics from one balanced growth pattern to another is as welcome to a developing country as a source of an improvement in welfare as growth along a balanced growth path (if such exists). For a low income country, it is not particularly interesting to insist that the 'pay-off from a higher saving rate is not a permanently higher rate of growth; it is a

permanently higher output per man' [Solow, 1970:20]. The distinction between a policy leading to a growth rate effect rather than a level effect will not be obvious to even the best economists employed in national planning or finance agencies or in multilateral development banks [Solow, 1997:81]^{30,31}.

PERSPECTIVE

The new growth economics, like the neoclassical growth economics has advanced our understanding of the process of economic growth in industrial economies characterised by reasonable stability of expectations regarding factor and product markets, legal institution and civic culture. It is not about the problems facing the poor economies of the world that have attracted the attention of development economists (Solow, 1997, p. 71). There are, however, more countries today than half a century ago where the institutional arrangements that remain implicit in growth economics prevail. And if development economists pursue their research with appropriate rigor and relevance there may be more as we approach the end of the next half century.

My own sense is that the most significant advances in knowledge about economic development will continue to emerge from research conducted at the micro level. The real sources of growth that result from efficiency gains, technical change, institutional reform and design can only be observed and understood by investigations conducted at the household, firm, and sector level. The effects of those technical and institutional changes generate the disequilibrium effects that are captured at the aggregate level in measures of scale economies and total factor productivity growth [Harberger, 1990].

I am not arguing, however, that development economists and growth economists should continue to follow their natural inclination to ignore each others work. There needs to be a continuing dialogue between development economists working in the fields of household economics, agricultural economics, labor economics, and industrial organization and the practitioners of growth economics. There is too much interesting and important data being generated by the development process that is begging to be understood and interpreted to confine development economics within the straight jacket of growth economics. Those of us who are development economists or practitioners simply can not wait until the growth economists are able to incorporate a deeper understanding of the sources of economic development into their models.

NOTES

1. In this paper I draw on an earlier paper in which some of the issues are treated in greater detail.
2. For other reviews of the new growth economics literature from a development economics perspective see Bardhan [1993: 129-142; 1995:2984-98]. For a review from the perspective of economic history see Crafts [1995:475-772] and Williamson [1995].
3. This view was articulated by W. Arthur Lewis, 'the central problem of the theory of economic development is to understand the process by which a community which was previously saving 4 or 5 percent of its national income or less converts itself into an economy where voluntary savings is about 12 to 15 percent of national income or more' [Lewis, 1954:155].

4. These views were argued most forcefully by the Indian Planner P.C. Mahalanobis [1953:307-312; 1955:3-62]. See also Bhagwati, [1966:203]. In the development planning literature it became common to refer to the Harrod-Domar-Mahalanobis model.
5. See for example the literature on appropriate technology [Schumacker, 1973; Eckhaus, 1977, 1987:612-71; Stewart, 1987a, 1987b:101-109].
6. There are a number of useful surveys of the new growth economics literature [Verspagen, 1992:361-96; Van de Klundert and Smulders, 1992:177-203; Hammond and Rodriguez-Clare, 1993:391-425; Amable, 1994:20-44].
7. It should be kept in mind that Romer and Lucas were not the first to attempt to endogenise the process of technical change. Kaldor [1957:591-624] advanced a Keynesian model with an endogenous 'technical progress function' [Palley, 1996:113-136]. The early Romer [1986:1002-37; 1990:571-512] and Lucas [1988:3-42; 1993:251-272] both acknowledge inspiration from Arrow [1962:155-73] and Uzawa [1965:18-31]. But neither Romer or Lucas refer to the Kaldor article. In the 1960s several attempts were made to rescue neoclassical growth economics from the limitations of exogenous technical change under the rubric of induced technical changes [Fellner, 1961:305-308; Kennedy, 1964:541-547; Ahmad: 1966:344-357]. For reviews see Nordhaus [1973:209-19]; Thirtle and Ruttan, [1987]; and Ruttan, [1997:1526-1629]. I find it somewhat difficult to imagine that Romer and Lucas were so unfamiliar with this earlier literature on endogenous technical change that they were forced to reinvent it 'from scratch'.
8. Srinivasan [1995:37-70] points out that the neoclassical growth models could also generate sustained long-run growth in per capita income, even in the absence of technical progress,

provided the marginal product is bounded away from zero by a sufficiently highly positive number. He also notes that this is not a particularly attractive assumption 'since it implies that labor is not essential for production!' [Srinivasan, 1995:46]. It also assumes that non-renewable resources are either not essential or have easily available substitutes.

9. The initial Romer model, and other closely related models, are frequently referred to as closed economy AK models after the assumed production function ($Y = AK$). In expanded versions of the model K can be thought of as a proxy for a composite of capital goods that includes physical and human components [Barro and Sala-i-Martin, 1995:146]. Amable and Solow have pointed out that this initial Romer model has not been able to avoid the razor-edge balance of the older Harrod-Domar model. If the elasticity of production coefficients of the accumulated factors are greater than one the growth is explosive [Amable, 1994:30; Solow, 1995:51, 1997:7-14].
10. '-- the spillover effect of the average stock of human capital per worker in the Lucas model and of knowledge in the Romer model are externalities unperceived (and hence not internalised) by individual agents. However, for the economy as a whole they generate increasing scale economies even though the perceived production function for each agent exhibits constant returns to scale' [Srinivasan, 1995:43]. In effect Romer and Lucas have completed, or have attempted to complete, the agenda initially advanced by Jorgenson and Griliches [1969:249-83]. They have substituted a new 'black box' -- termed 'scale effects' -- for the old black box of 'technical change' as a source of productivity change.
11. A somewhat similar model has been proposed by Aghion and Howitt [1992:323-51] in which innovation takes the form of improvements in the quality of intermediate goods that,

in turn, improve the productivity of the intermediate goods in final good production. This is consistent with Schumpeterian 'creative destruction' as each improved producer good takes the place of an older producer good [Amable, 1994:33].

12. There is, however, a large literature that suggests that ideas are much more expensive to transfer than implied by the literature that treats knowledge as a pure public good [Teese, 1977:242-61; Hayami and Ruttan, 1985:255-298].
13. In a later paper Romer [1994:3-22] extends the model in his 1990 paper to incorporate the introduction of new consumer goods as a source of welfare gains.
14. Romer seems of two minds on this issue. In a comment on Mankiw [1995:275-376] he notes: 'Mankiw argues that technology is a public good that is available everywhere in the world. I argue that there is ample evidence that this assertion is wrong' [Romer, 1995:315]. Yet in his 1993 paper on idea gaps and knowledge gaps he asserts that 'people in the industrial nations of the world already possess the knowledge needed to provide a decent standard of living for everyone on Earth' [Romer, 1993:546]. In our research on technical change in agricultural development Yujiro Hayami [Hayami and Ruttan, 1985:255-298] and I show that what is available to be transferred to the developing countries is not only technology, which tends to be location specific, but the capacity to develop or adapt technology consistent with the resource endowments and economic environment of poor countries.
15. The share of employment in industry is typically higher in newly industrializing countries than in either the OECD countries or developing countries. For example, the share of the labor force in industry in Korea is approximately 35 percent; in the U.S. 26 percent and in

Nigeria 7 percent [World Bank, 1995:146-148]. The simple arithmetic of population and employment growth rates suggest that for lowest income developing countries with population growth rates in the 2-3 percent per year range exceedingly high growth rates of employment in industry would be required to raise the share of employment in industry from less than 10 percent to 30 percent over a 50 year period [Dovring, 1959:1-11].

16. Solow pointed out that Lucas [1988:3-42] had emphasised that 'a touch of diminishing returns to capital (human capital in this case) would change the character of the model drastically, making it incapable of generating permanent growth. He did not notice that a touch of increasing returns to capital would do the same' [Solow, 1995:49]. With increasing returns the growth of capital became infinite in finite time. Thus Lucas' version of the endogenous growth model is very un-robust. It can not survive without exactly constant returns to capital' [Solow:1995:51]. See also Solow [1997:7-14].
17. See also Barro [1997]. There has been a virtual explosion of aggregate cross country studies since the early 1980s. Levine and Renelt [1992:942-963] subjected the studies that had been completed by the early 1990s to a careful sensitivity analysis. They found that almost all of the results were fragile. However, they did find three robust results: (a) a negative relationship between the initial level of per capita income and subsequent economic growth, (b) a positive correlation between the share of investment in GDP and growth, and (c) positive correlation between the investment share and the ratio of trade to output. Much of the more recent empirical research has abandoned the discipline of the production function for an unstructured 'search for variables,' such as equipment quality, market distortions, government spending, tax policy, financial capital, trade policy, ethnicity, legal

culture, religion and even distance from the equator [Sala-i-Martin:1997]. A reviewer of this paper has pointed out that the negative sign on the per capita income term should not be taken as a sure indicator of rehabilitation of the neoclassical model because it could be picking up the dynamic effects of catch up or structural change. It should be noted that the macro-cross country studies have completely ignored the sector level cross country studies by development economists. For example a series of cross country studies for the agricultural sector using augmented neoclassical production functions (that included land, labor, capital, intermediate inputs, education and research and development) have been highly successful in accounting for differences in output and productivity levels among countries [Hayami and Ruttan, 1985:138-160; Lau and Yotopoulos, 1985:241-269].

18. Rostow [1956:25-480; 1960] had earlier argued that the 'preconditions' for economic growth in the U.S. were established between the 1780s and 1840s. He dates the US 'take-off' into rapid industrial development between 1843-1860.
19. Intra-industry trade is sometimes taken as evidence of scale economies. Chipman [1992a:67-92; 1992b] has argued, however, that evidence of intra-industry trade is frequently based on aggregation bias from an inappropriate industry classification system that obscures the fact that the great bulk of what is often classified as intra-industry trade consists of trade in distinct commodities. He then goes on to demonstrate that even when commodities are correctly classified intra-industry trade can not be taken as evidence of scale economies. Burnside [1996:177-201] also stresses aggregation bias in cross industry studies in the US that purport to show economies of scale.

20. I do not, in this section, attempt to present an exhaustive exposition of the scope of development economics. A useful tour is presented in the three volume Handbook of Development Economics [Chenery and Srinivasan, 1988; 1989; Behrman and Srinivasan, 1995]. Apparently, as an afterthought, the editors commissioned a final paper in volume 3B on 'The Contribution of Endogenous Growth Theory to the Analysis of Development Problems: An Assessment' [Bardhan, 1995:2984-98].
21. Economies of scale played an important role in what Krugman [1993:1-29] has termed the 'high development theory' of the 1940s and 1950s. Krugman identifies the period of high development theory as beginning the 1943 with the publication, drawing on Harrod [1939:14-23] for inspiration, of the 'big push' model by Rosenstein-Rodan [1943:202-11] and ending with the popularization of ideas of forward and backward linkages by Hirschman [1958]. Attempts to implement policies based on these ideas left many developing countries stuck in low-level equilibrium-burdened with non-viable capital intensive industries [Bardhan, 1995:2984-98]. For an attempt to rehabilitate the big push approach within the framework of the new development economics, see Murphy, Shliefer, and Vishny [1989:1003-1026].
22. Emphasis on the role of human capital in development thought extends back to at least the 1950s. See, for example, the presidential address to the American Economic Association by Theodore W. Schultz [1961:1-17]. In an early cross-country analysis, Krueger found that 'differences in human resources between the United States and less developed countries accounted for more of the differences in per capita income than all other factors combined'

[[Krueger, 1968:658](#)]. For additional examples, see Bardhan [[1993](#)]. See also the papers on human resources and labor markets in Chenery and Srinivasan [[1988:129-142](#)].

23. For reviews of the literature, see Thirtle and Ruttan [[1987](#)] and Ruttan [[1997:1520-29](#)].
24. It is hard to over-emphasise the importance of structural transformation, particularly the transition from a predominately agrarian economy to an industrial and then a service economy, in the development literature. The classic empirical studies are Clark [[1940](#)] and Kuznets [[1966](#)]. For the evolution of thought see Lewis [[1954:139-191](#)], Jorgenson, [[1961:309-34](#)]; Ranis and Fei, [[1961:533-65](#)]; Fei and Ranis [[1964](#)], Dixit [[1973:325-52](#)] and Ranis [[1988:73-92](#)]. See also the papers on structural transformation in Chenery and Srinivasan [[1988](#)]. Because of the importance of structural transformation development economists have generally preferred to work with two sector models of the Lewis and Jorgenson and Ranis-Fei type rather than two sector models in the Uzawa [[1961:40-47](#); [1963:105-118](#)] tradition. Failure to incorporate the role of growth in agricultural production and of agricultural trade in the early stages of structural transformation represents a serious deficiency in any attempt to understand the development process [[Echevarria, 1995:631-647](#); [Park and Johnston, 1995:181-208](#); [Tomich, Kilby and Johnston, 1995](#)].
25. For an empirical exploration of the relationship between environmental indicators and economic growth see Grossman and Krueger [[1995:353-377](#)]. For an attempt to incorporate environmental effects in a closed economy endogenous growth model for the United States see Elbasha and Roe [[1995](#)].

26. Maintenance research can represent a relatively high share of R&D expenditures in the field of biological technology. The resistance of new crop varieties to pests and pathogens is eroded by the evolution of new races. The effectiveness of new drugs to control animal and human disease is eroded by the coevolution of infectious disease organisms [Ruttan, 1982:59-60].
27. For an attempt to treat institutional changes as endogenous see Ruttan and Hayami [1984:203-23]. The concept of incentive comparable institutional design was introduced by Hurwicz [1972:297-333]. For a more recent treatment see Groves, Radner and Reiter [1987].
28. For a detailed iteration of both the rediscovery and the neglect of ideas initially advanced by development economists see Bardhan [1993:129-142]. A similar perspective has been advanced by Romer [1993:543-573] in what appears to be a remarkable departure from his papers of the late 1980s. For an example, see Lucas' uncomfortable discussion on the incorporation of the rise in schooling levels in East Asia. He notes that, 'the percentage of school age children in school has little leverage in explaining differences in growth rates. The fast growing Asian economies are not, in general, better schooled than some of their slow growing neighbors.' [1993:257]. He then goes on to note that although schooling levels are increasing in virtually all societies 'it cannot be pursued within a steady state framework' [Lucas, 1993:258].
29. More than 25 years ago Solow suggested that 'the steady state is not a bad place for growth theory to start, but may be a dangerous place for it to end [Solow, 1970:7; see also Hicks, 1985:10]. Griliches [1994:1-23] made a similar point, somewhat more cautiously, in

questioning an excessive commitment to equilibrium economics in his 1994 presidential address to the American Economic Association. See also Nelson [1996].

30. The time scale for transition effects in neoclassical models has generally been estimated to be quite long [Atkinson, 1969:137-152]. They may also be quite difficult to distinguish from rate effects. Rivera-Batiz and Romer [1991:531-555] present a model in which economic integration of countries 'with identical endowments and technologies' can result in a permanent increase in growth rates primarily because it results in an increase in the extent of the market. For an excellent review see King and Robelo [1993:908-931].
31. A promising start toward a more fruitful articulation between growth economics and development economics has recently opened in the work of a group of 'new neoclassical' growth economists associated with the Department of Economics at the University of Minnesota and Minneapolis Federal Reserve Bank [Parente and Prescott, 1991:3-16; 1993:298-321; 1974:298-321; Backus, Kehoe and Kehoe, 1992:377-409; Prescott, 1997; Schmitz, 1993:17-33; Chari, Kehoe and McGrattan, 1996:298-321]. Chari, Kehoe and McGrattan depart from the traditional neoclassical model by abandoning the deterministic transition path between steady state growth paths in favor of stochastic transition probabilities. Their motivation is that they find little persistence in individual country growth rates. Parente and Prescott are pursuing a research agenda designed to explain differences in per capita income levels rather than growth rates. They invoke institutional constraints on the efficient use of existing technologies and on the development and adoption of new technologies to explain the large and persistent productivity and income gaps that can not be explained by differences in physical and human capital. For an analysis

that is quite similar in spirit to that advanced by the 'Minnesota school' but argued more intuitively, see Olson [1996:3-24].

A Postscript on Method

The issues raised in this review of the continuing dialogue between growth economics and development economics is related to the more general problem of the relationship between science and technology, advances in scientific knowledge precede and become the source of advances in technology. This view is no longer held by most historians of science and technology. Instead of a single path running from scientific discovery through applied research to development it is more accurate to think of science oriented and technology-oriented research as two interacting paths that both lead from and feed back into a common pool of scientific and technical knowledge. I take it as axiomatic that the primary source of demand for advances in natural science knowledge arises from demand for technology development. Similarly the primary source of demand for social science (including economic) knowledge arises from a demand for policy design and institutional innovation.

The history of growth economics is clearly not consistent with the standard view that advances in science precede development and practice. The major thrust in growth economics has been an attempt to develop formal theory to provide a more coherent interpretation of what is already known. A major thrust of the neoclassical growth economics, as noted earlier, was to attempt to analyze the properties of steady state growth. Solow's initial model was quickly extended to incorporate productivity growth in the form of labor saving (Harrod-neutral) or Hicks-neutral technical change. Attention quickly shifted to attempts to account for and explain the residual.

But neither growth in partial productivity (output per worker) or total productivity (output per unit of total input) were new in the mid-1950s. Research on labor productivity had received

major attention in the 1930s. Growth in output per unit of total input had been identified by several scholars in the late 1940s and early 1950s [Griliches, 1996]. Even after the initial Solow research on productivity growth, particularly that carried out at the sectoral level, was seldom motivated by the growth economics paradigm. The early research by Kendrick (1996) and Dennison (1962) on trends in productivity and growth owed little or no debt to neoclassical growth theory. Nor did the initial attempt by Griliches (1963) and later by Jorgenson and Griliches (1967) to provide a complete accounting of the growth of output based on changes in the quality of inputs rather than total factor productivity. The theoretical foundation on which much of this work was based was the straightforward Hicksian neoclassical production theory rather than neoclassical growth economics.

The new growth economics is even more explicitly motivated than neoclassical growth economics by an attempt to understand what we already know. Much of it has been directed to understanding the perceived failure of substantial convergence of growth rates implied by the neoclassical theory. The issue of convergence was stimulated by a growing body of literature in the late 1970s and early 1980s on the productivity slowdown in the U.S. and in other developing countries. It was further stimulated by research on long term productivity and output growth rates by Madison (1979, 1982), which were interpreted by Baumol (1986) as indicating convergence in productivity and output growth among developed countries and the challenge to the Baumol findings by De Long (1988).

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