ECONOMIC GROWTH: AN INTRODUCTION

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INTRODUCTION

This introduction to growth economics starts with an outline of the fundamental issues in growth economics. This is an appropriate starting point since some of the early developments in growth economics failed to clearly address the big issues in economic growth, instead concentrating on less-than-fundamental issues. In this paper, it is asserted that the fundamental issues in growth economics are:

- The reasons why we study growth economics (the why of growth);
- The meaning of economic growth (the definition of growth);
- The economies whose growth is being analysed (the where of growth);
- What time periods of growth are being covered (the when of growth);
- What are the fundamental cause of growth (the how of growth).

The second section of the paper indicates that there is no shortage of possible explanations of the determinants of economic growth. The accepted theoretical models highlight a number of causal factors, but other parts of the economics literature indicate many (additional) possible causes.

The third section of the paper examines how economic growth has been analysed in the literature. It briefly discusses endogenous growth models and contemporary empirical studies of economic growth before moving on to a critique of contemporary growth econometrics and of endogenous growth models.

The fourth section of the paper examines areas in which growth economics needs to develop in the future. It discusses creative destruction, endogenous versus exogenous elements in economic growth, and what might be termed and engineering approach to analysing growth. The fifth section suggests a wide range of empirical studies that should be utilised in growth economics. The paper concludes with a brief summing up.

THE FUNDAMENTAL ISSUES IN GROWTH ECONOMICS

THE FUNDAMENTAL QUESTIONS

Jones and Romer (2009) examine the stylised facts of economic growth, both those that underlay the development of the neoclassical economic growth model and the current list of stylised facts that are addressed by the endogenous growth models. Together, these facts provide a portrait of modern economic growth. But we must ask ourselves, what are the primary questions that provide a justification for pursuing growth economics?

I start with posing five questions, the answers to which are of fundamental importance to an understanding of growth economics and the role it might play in the broader field of economics as a whole. These five questions are:

1. Why study growth?
2. What do we mean by economic growth?
3. In which economies is growth being analysed?
4. Over what time periods is growth being analysed?
5. The fundamental causes of growth.

WHY?

Why study growth economics?

Four main arguments can be given for the study of economic growth.

1. Economic growth may be desired for its own sake. This is a particularly important issue for the poorer parts of the world, although concerns about the stability of economic growth have also been an important political issue in many of the leading advanced economies in recent times.
2. Growth tends to be a pre-condition for social progress and for the development of environmental goods and services – it creates the means for funding progress in these areas, and increases the demand for these factors. However, growth does not guarantee progress in social areas nor in environmental conditions – it is a necessary condition in the long run, but not a sufficient condition. Growth economics provides a necessary, although not sufficient, input into development economics and environmental economics.
3. Growth economics is largely about innovation, which is also the key to non-material progress in such areas as the environment, health, and education. If the study of growth economics leads to a greater understanding of the economics of innovation, it also clears the way for analysing solutions to social and environmental problems. This is a further argument for using growth economics as part of the tool-kit for development economics and environmental economics.
4. Growth economics enables us to address one of the very long-run questions of sustainable economic development – economic costs and benefits in the very long run.

The last point requires some elaboration. Consider the economics of climate change. Business As Usual economic projections based on sophisticated growth economics will enable the impacts of climate change on economic growth under the BAU Scenario to be incorporated and the comparisons with Scenarios that allow for the adoption of climate change policies (such as carbon taxes and the funding of emissions-saving R&D projects). Similar arguments apply with respect to other environmental issues, and social and political issues. In each case, very long time horizons are involved. Where we are dealing with factors that can only be changed in the long run we need to have an economic framework that deals with that long run situation. This is where growth economics comes in.

WHAT DO WE MEAN BY ECONOMIC GROWTH?

The growth literature takes growth in *per capita* GDP (or GNP) as the measure of economic growth rather than GDP/GNP unadjusted. The latter concept has relevance for macroeconomics. Robert Lucas, in his seminal article on the mechanics of economic growth, says “By the problem of economic development I mean simply the problem of accounting for the observed pattern, across countries and across time, in levels and rates of growth of per capita income.” (Lucas, 1988, p. 3). The dynamic concept is the rate of growth over time of GDP/GNP per capita for a country or group of countries, the static concept is the comparison of GDP/GNP per capita across countries at a single point of time. This becomes the central focus of the endogenous growth models.

Lucas (1988) emphasises growth as the key aspect of development. However, the overall goal of development is related more to social outcomes than the maximisation of GNP. The latter may be an important means of achieving the former, but issues relating to income distribution, poverty levels, regional dispersions, and the opportunity for different groups in the population to achieve acceptable standards of health and education are of prime importance (note Meier and Rauch, 2000, pp. 5-7). Nevertheless, the above aspects of economic development cannot be divorced from economic growth. In analysing the why of growth, it is the fact of growth in the sense defined above that is the initial point for addressing these reasons for studying growth, with the exception of the third reason, where it is the causes of growth that are most important.

WHERE?

The second question concerning growth economics is in which economies is growth being analysed? While many studies analyse growth across all the economies for which adequate data is available, seeking a meta-explanation that holds for all economies, it is more useful to focus on three specific aspects of the where of growth:

1. Economic growth at the frontier of the world economy;
2. Growth in the developed economies; and
3. Growth in the other economies.

The overall framework in which growth is analysed must account for the divergence between developed and developing economies and the widely varied performance among developing economies, and the tendency in the long run for convergence among developed economies. It also needs to account for the differences that exist in the economics of breakthrough innovations, the economics of incremental innovations, and the diffusion of innovations. This is why a distinction needs to be made between the frontier of economic growth and growth behind (beneath?) the frontier.

Growth at the Frontier

The notion of the frontier in the world economy is the place where ideas (new types of knowledge) are developed and implemented in production systems, with the potential to spread to other geographic areas later on. The notion of the frontier facilitates a separation of the analysis of the development of new ideas and their implications for growth once implemented in production from the diffusion of new knowledge across countries and its impact on growth. This turns out to be of crucial importance in analysing growth, particularly in the Schumpeterian endogenous growth models. Howitt (2000) explicitly incorporates the frontier into a Schumpeterian growth model.

The frontier could be crudely defined as the whole United Kingdom economy in the 19th century and the United States subsequently. Alternative measures would be (1) a (changing) group of countries that dominate breakthrough innovations, or, in a micro-sense (2) by industries in their leading locations. In the latter case, the notion of the frontier becomes more complex if one takes into account ‘leapfrogging growth’.

Jones and Romer (2009) indicate that one of the main characteristics of contemporary economic growth has been the increase in the extent of the market. They point out that increased flows of goods, ideas, finance, and people via globalization have increased the extent of the market. Globalisation has also stimulated growth at the frontier by increasing the potential returns from developing new ideas.

Convergence among the Developed Economies

One of the notable features of the history of economic growth is the stability among the group of most advanced countries – the so-called developed economies. For nearly two hundred years this group has seen very few entrants and virtually no exits. The frontier of the world economy may on occasions leap ahead of the overall group of developing economies (as happened with Great Britain in the first half of the 19th century and the United States in the first half of the 20th century[1]). However, convergence is the rule in the longer run for these advanced economies. This convergence process has been a major focus of growth economics over recent decades. Aghion and Howitt (2005) is noteworthy for applying Schumpeterian growth theory to comparisons in the recent growth of European economies with the American economy.

The Developing Economies

The term “developing economies” is applied to the remainder of the world’s economies. This term is something of a misnomer. The experience of these economies has varied enormously and has encompassed:

- Contracting economies;
- Growth, but increasing divergence from the leading economies;
- Growth, but no convergence;
- Partial convergence;
- Rapid convergence and, in some areas, even leapfrogging.

Jones and Romer (2009) indicate that the variation of growth rates is much smaller for the richest countries than for the poorest. Both rapid catch-up growth and tremendous lost opportunities can be seen in the growth experiences among the poor. They note that one of the main reasons the variance far from the frontier can be so high is that the rate at which rapid catch-up growth can occur is now faster than it has ever been. The accumulated growth at the frontier has created over time an enormous gap that

[1] The US also accelerated ahead of most of the other advanced economies in the 1990s.

could potentially be filled by a "tiger" economy. At the same time, lagging or stagnant economies fall further and further behind the frontier in proportional terms. Growth analysis needs to encompass this great diversity of experiences.

WHEN?

The third question is over what time periods is growth being analysed? Growth economics is *not* concerned with short-run fluctuations in economic growth, whether quarterly or annual in time-span. These are the concern of macroeconomics. Growth economics is concerned with the analysis of economic growth over longer periods of time – average growth over the whole duration of a business cycle, or over time periods of a decade or longer. There is a raft of studies of economic growth from around 1960 up to the present time. Such studies have been facilitated by the richness of data for this time period. But growth economics can take in much longer time periods. Charles Jones (2005) argues that models of economic growth, usually constructed with an eye toward 20th century growth, can also be an aid to understanding the history of growth from thousands of years ago to the present. However, the forces at work that determine growth over shorter time periods, like growth over the timespan of a business cycle, and growth over many decades, will not be exactly the same. Some factors will be relevant to the shorter time periods but not the longer, and vice versa. The study of growth over very long periods is pertinent to addressing the issues of environmental economics and also to many of the social issues pursued in development economics.

THE MANY POSSIBLE CAUSES OF GROWTH

The fifth fundamental question for growth economics is what causes growth? Referring back to the earlier questions posed, this question breaks down into a number of components:

- What determines growth at the frontier?
- Why is there a long-term tendency to convergence in the growth of the most advanced economies and what accounts for occasional divergences in the medium term?
- What accounts for the very diverse growth experiences of all other economies?
- What are the differences in the causes of growth between the medium term and the long term?

The problem for growth economics is that there are a very large number of possible causes of economic growth identified in the literature. Working out how these possible causes interact with each other and the circumstances under which they impact on growth represents the major challenge for growth economics. We are only in the first stage of meeting this challenge.

The major *endogenous theoretical models* developed for growth economics tend to identify one or other of the following influences on growth.

1. Knowledge/Ideas: Paul Romer (1990), Charles Jones (2005), Grossman and Helpman (1991); also Schumpeterian theories such as those of Aghion and Howitt (2000).
2. Human Capital: Robert Lucas (1988), Paul Romer (1990).

3. Learning (by-doing; by-using): Arrow (1962), Robert Lucas (1988).
4. Economies of scale: Charles Jones (2005).

Competition has been identified as a key aspect of growth models, particularly in the Schumpeterian theories. Competition has traditionally been seen as a spur to growth, but under certain circumstances it is identified as being negative. Empirical studies of growth attempt to estimate the importance of entry and exit of firms to aggregate growth. The regulation of product markets, labour markets and capital markets can have complex impacts on growth.

As these models began to be developed, discussion about the factors affecting the *convergence or divergence* of countries with respect to economic growth drew attention to such factors as education; the provision of other social capital (such as health care, nutrition and family planning); the development of an enabling climate in terms of competition, infrastructure and institutions; integration with the global economy through openness to international flows of goods, services, capital, labour, technology and ideas in general; and the provision of a stable macroeconomic environment. Technological leapfrogging has been recognised as a possibility: late arrivals may skip intermediate aspects of development and may even outreach leaders for some specific new technologies that are not immediately economic in leading countries. Income distribution may matter because of possible links between inequality and growth.

The relationship between *population* and growth has been the subject of much analysis. In the simplest models, an acceleration in population growth increases absolute growth but diminishes per capita income growth. Complex interactions between population and growth are allowed for in unified models that jointly determine demographic variables and economic variables. High population densities at low levels of development may inhibit growth, but at high levels of development encourage agglomeration economies. Population, the extent of the market and the role of scale economise is the subject of some endogenous growth models.

The role of *human capital* in growth has attracted a vast literature covering the role of education in general, the composition of education spending, the quality of education, learning, the efficiency of capital and labour markets, and complementarities with other factors of production.

International economics and economic growth has also been a prominent feature of the growth literature. Three sources of growth have been analysed: (1) international flows of knowledge (R&D and licensing, foreign direct investment, trade in intermediate inputs bringing technological spillovers, the movement of people bringing with is international flows of knowledge); (2) international flows of capital, and constraints on such flows; and (3) the international movement of people. The impact of openness on national economic growth has examined its role in promoting flows of knowledge, capital and people; its effects on economic structure, which in turn may have positive or negative impacts on knowledge flows; and the implications of trade restrictions.

The neoclassical growth models prescribed a strictly limited role for the volume of *investment* in economic growth. Subsequent growth analysis restored investment to a more prominent role in economic growth. The key has been the recognition of complementarity between growth-enhancing innovation and particular forms of capital accumulation. Secondary factors have been the particular importance of the physical infrastructure in economic growth and the links between finance and complementary innovation and capital accumulation.

The literature on *intangible capital* points to yet another possible cause of growth. Part of intangible capital is comprised on knowledge creation (e.g. R&D), a second part relates to the development of human capital (e.g. investment in training), while a third part comprises investments (such as external consultants or internal training) in organisational innovation. *Complementarities* may exist between technological innovation, organisational innovation, and human capital.

Social capital has also been advanced as another factor in economic growth. Social capital can refer to the cohesiveness of the population in terms of trust, collaboration, and networks. It can also refer to the *social infrastructure* – the political system, and the institutional framework.

Another area of growth economics is the *geography* of economic growth. The location of economies may influence their growth opportunities both in terms of accessibility (to international trade and to human networks) and in terms of natural resources. The exploitation of natural resources can have positive impacts on growth in the shorter term and negative impacts in the long term. Networking economies may give rise to growth poles through agglomeration economies.

There is also a considerable literature on the links between *macroeconomic policy* and economic growth. Growth might be discouraged by defects in macroeconomic policy that result in high inflation, budget imbalances, and real overvaluation of the exchange rate, with consequential macroeconomic instability. Financial and banking crises may (but not necessarily do) impinge on longer term growth. Financial market imperfections can persist and have long-term implications for growth.

History is another possible influence on economic growth. History plays an important role when path dependence occurs. This situation occurs if there are potential multiple equilibria (note threshold externalities e.g. human capital and alternative development paths), or multiple technological paths with technological lock-in. This can also arise in relation to interacting industries, with particular growth paths driven by leading sectors.

Conclusion. There are no shortages of possible explanations for growth as an empirical phenomenon. The problems for growth economics are over-identification, and analyses that explain some aspects of growth but not others. We need to place these possible causal factors in the right framework that addresses their possible interactions. This is the role for growth economics.

ANALYSING GROWTH

The development of national accounts furnished a data base on the overall dimensions of economic growth from 1960 for the great majority of the world's economies, and also encouraged the development of an historical data base stretching back into the

19th century and even earlier. This empirical data has led to a clearer focus on the fundamental issues in economic growth. It has also encouraged the construction of a suite of theoretical growth models – the so-called ‘endogenous growth models’. Empirical research has attempted to estimate the parameters of these endogenous models, and has tested other hypotheses about growth through the use of additional data. In what follows, we briefly outline the key features of this contemporary analysis of economic growth, consider the critique of this analysis, and discuss the possibilities of alternative approaches to analysing economic growth.

ENDOGENOUS GROWTH MODELS

The distinctive characteristic of modern endogenous growth models is that the marginal product of capital remains bounded a way from zero, thereby inducing positive long-run growth in equilibrium. That growth is determined by the agents in the model (e.g., parameters or preferences; Larry Jones and Manuelli, 2005, p. 19).

The key agents of endogenous growth occur as a consequence of the continuing growth in the stock of ideas and the stock of human capital. The defining characteristic of ideas or knowledge is nonrivalry, and this encourages the extension of the market and the persistence of economic growth (Romer, 1990). The growth in the endowment of human capital per worker facilitates the continuing growth in the stock of ideas and it also encourages the discovery and utilisation of such ideas. These two factors have made a major contribution to our understanding of economic growth. Jones and Romer (2009) note that “human capital per worker is rising rapidly, and this occurs despite no systematic trend in the wage premium associated with education” (page 24).

Endogenous growth models can not only provide insights into the enduring nature of growth at the frontier, they can also be enlightening on the diffusion of growth across countries. This is because the diffusion process necessitates certain minimal endowments in potentially recipient economies – most notably, human capital, but also institutional capabilities. At any point of time, the existing endowment of human capital in a country is the consequence of accumulation over many decades. Major improvements in the stock of human capital therefore necessitate investments that would have to accrue over a very lengthy period of time. Hence existing endowments shape the capabilities for growth in the medium-term, and enable us to understand the differing circumstance of countries with greater or lesser current endowments.

There are other possible contributors to the growth process as the discussion in the previous section indicates. We can, conceptually, endogenise most of the influences on economic growth. This might add to the complexity of growth models, although many of the additional influences may act indirectly rather than directly on growth.

Institutions, or certain aspects of institutions, are of paramount importance in considering these additional influences. Jones and Romer (2009) argue that “the enormous income and TFP differences across countries as well as the stunning variation in growth rates far behind the technology frontier testify to the importance of institutions and institutional change” (p. 24). They argue that the principal challenge for growth theory is the construction of a unified model embracing the current endogenous growth theory plus a simple model of institutional evolution.

EMPIRICAL STUDIES OF ECONOMIC GROWTH

One hallmark of recent work on economic growth, in contrast to the work of the 1950s and 1960s, is its empirical emphasis. Largely because of the important work undertaken in the Penn World Table (Heston et al, 2009), international data suitable for cross-sectional analysis are now available for most countries from 1960 (and in some cases, from 1950). These data have allowed systematic examination of the differences between economies that have experienced rapid growth and those that have not. Data for earlier periods has been explored in the various publications by Angus Maddison (note Maddison, 2007).

Empirical research on economic growth has come to be dominated by a particular type of growth econometrics. As Mankiw (1995, p.70) indicates, the typical empirical paper on economic growth follows a particular pattern. A sample of countries is chosen and a cross-sectional regression is run. On the left-hand side of the regression equation is each country's average growth rate over a long period. On the right-hand side is a set of variables expected to determine the growth rate.

Mankiw (1995, p. 70) notes the following findings emerging from this literature.

1. *A low initial level of income is associated with a high subsequent growth rate when other variables are held constant, implying conditional convergence.*
2. *The share of output allocated to investment is positively associated with growth.*
3. *Various measures of human capital, such as enrolment rates in primary and secondary schools, are positively associated with growth.*
4. *Population growth (or fertility) is negatively associated with growth in income per person.*
5. *Political instability, as measured by the frequency of revolutions, coups, or wars, is negatively associated with growth.*
6. *Countries with more distorted markets, as measured by the black market premium on foreign exchange or other impediments to trade, tend to have lower growth rates.*
7. *Countries with better developed financial markets, as measured, for instance, by the size of liquid assets relative to income, tend to have higher growth rates.*

Mankiw (p. 70) goes on to observe *"each of these findings has been confirmed independently in several studies. Most of them depend to some extent on which other variables are included in the regression.*

It is easy to reconcile these results with existing theories of growth. In terms of the neoclassical model, these regressions show a tendency for convergence toward a steady state that is determined by the control variables. And, as discussed above, endogenous growth models with more than one sector are consistent with a similar interpretation. Even the signs on the control variables make sense. What economist doubts that growth is fostered by high investment, widespread education, low population growth, political stability, free markets, and well-developed financial institutions

A CRITIQUE OF CONTEMPORARY GROWTH ECONOMETRICS

The contemporary approach to analysing economic growth is subject to a number of criticisms. A critique of contemporary growth econometrics is considered first, followed by some comments on endogenous growth models.

There are three problems associated with the use of cross-country growth regressions in growth economics. These problems are simultaneity, multicollinearity, and limited degrees of freedom (Mankiw, 1995).

The Simultaneity Problem

As Mankiw (1995) indicates, the most obvious problem with cross-country growth regressions is *simultaneity* – the fact that the right-hand-side variables are not exogenous, but are jointly determined with the growth rate. As he puts it, does high investment cause high growth, does high growth cause investment, or dies some third variable cause both high investment and high growth? This question can be posed for all the variables commonly used in growth regressions. In order to solve the problem of simultaneity there is a need to find exogenous variables to use as instruments. These are difficult to find in the cross-country data sets.

Mankiw (1995, pp. 70-71) comes to the following conclusion. “Very simply, we are left with a bunch of correlations among important endogenous variables. The cross-country data can never establish, for instance, the direction of causality between investment and growth. It says that any explanation of international experience must be consistent with these two variables moving strongly together. In other words, correlations among endogenous variables can rule out theories that fail to produce the correlations, and they can thereby raise our confidence in theories that do produce them, but these correlations can never establish causality beyond reasonable doubt.”

The Multicollinearity Problem

The second problem noted by Mankiw with respect to the interpretation of cross-country regressions is multicollinearity – the strong correlation among all the right-hand-side variables. To the extent that country residuals are correlated with each other, reported standard errors cannot be relied upon to warn us about the problem of multicollinearity. Moreover, the prevalence of measurement error in international data sets can bias upward the coefficients on variables correlated with the variable measured with error, for these other variables stand in for the error-prone variable (Mankiw, 1995, pp. 71-72).

The Degrees-of-Freedom Problem

Mankiw argues that, with only about one hundred countries on which to run cross-country regressions, there are too few degrees of freedom to answer all the questions being asked. “Yet including only a subset of variables does not help matters much. It just means that the results of the study are contingent upon what variables the study chooses to exclude.” (Mankiw 1995, p. 72)

These three problems – simultaneity, multicollinearity, and limited degrees of freedom, are important constraints on these types of international growth studies.

A CRITIQUE OF ENDOGENOUS GROWTH MODELS

The critique of endogenous growth models considers three issues:

1. The linearity critique;
2. Transition dynamics; and
3. Discontinuities in growth.

The Linearity Critique

The so-called “linearity critique” of endogenous growth models in its broadest form asserts that endogenous growth models rely on a knife-edge assumption that the key differential equation in the model is linear in some sense. If the linearity is relaxed slightly, the model either does not generate long-run growth or exhibits growth rates that explode (the reference for this critique is Charles Jones, 2005, pp. 1103-1105).

Jones points out that in the human capital model of Lucas (1988), it is the law of motion for human capital accumulation that is assumed to be linear. On the other hand, in the first-generation idea-based growth models of Romer (1990) and Grossman and Helpman (1991), it is the idea production function itself that is assumed to be a linear differential equation. In fact, Jones argues that *any* model of sustained exponential growth requires such a knife-edge condition.

If one wants a model that produces a stable equilibrium path for economic growth in the long term, we need to look for an economic explanation for why linearity should hold and/or seek empirical evidence supporting the linearity. Charles Jones fails to find such an explanation in the case of the Lucas model (which requires constant returns to the stock of human capital from incremental increases in the time invested in acquiring new skills, independent of the pre-existing level of skills). In the case of the Romer and Grossman and Helpman models the critical parameter could be less than zero if it gets harder over time to find new ideas or greater than zero if knowledge spillovers increase research productivity, or even zero if researchers produce a constant number of ideas with each unit of effort, but the case of it being 1 “appears to have little in the way of intuition or evidence to recommend it”. It is only in the population/increasing returns/model that he expounds in Charles Jones (2005) that linearity might be plausible.

Transition Dynamics[2]

Growth accounting in a neoclassical framework finds a residual, which is labelled "total factor productivity growth" (TFP growth). In some ways, endogenous growth models can be understood as trying to find ways to endogenise TFP growth, i.e. to make it something that is determined within the model rather than assumed to be completely exogenous.

Jones conducts one of these growth accounting exercises in an economic environment based on Charles Jones (2005). In the long run in that model, per capita growth is proportional to the rate of population growth of the idea-producing regions. Off a balanced growth path, of course, growth can come from transition dynamics, for example, due to capital deepening or to rapid growth in the stock of ideas. Given the stylised fact that US growth rates have been relatively stable over a long period of time, one might be tempted to think that the U.S. is close to its balanced growth path so that growth due to transition dynamics is negligible. On the contrary, Jones shows that the opposite is true. Approximately 80 percent of U.S. growth in the post-war period is due to transition dynamics associated in roughly equal parts with increases in educational attainment and with increases in world R&D intensity. Only about 20 percent of U.S. growth is attributed to the scale effect associated with population growth in the idea-producing countries.

This finding raises a couple of interesting questions. How is it that growth rates can be relatively stable in the United States if transition dynamics are so important? The Answer proposed by Charles Jones (2002) can be seen in a simple analogy. Consider a standard Solow model that begins in steady state. Now suppose the investment rate increases permanently by one percentage point. We know that growth rates rise temporarily and then decline. Now suppose the investment rate, rather than staying constant, grows exponentially. We know that this cannot happen forever since the investment rate is bounded below one. However, it could happen for a while. In such a world, it is possible for the continued increases in the investment rate to sustain a constant growth rate that is higher than the long-run growth rate. In the idea-based growth model analysed by Charles Jones (2002), it is not the investment rate in physical capital that is driving the transition dynamics. Instead, educational attainment and research intensity (the fraction of the labour force working to produce ideas in advanced countries) appear to be rising smoothly in a way that can generate stable growth, at least as an approximation.

The second natural question raised by this accounting concerns the future of U.S. growth. If 80 percent of U.S. growth is due to transition dynamics, then a straight-forward implication of the result is that growth rates could slow substantially at some point in the future when the U.S. transits to its balanced growth path. To the extent that population growth rates in the idea-producing countries are declining, this finding is reinforced. Still, there are many other qualifications that must be made concerning this result. Most importantly, it is not clear when the transition dynamics will run out, particularly since the fraction of the labour force engaged in research seems to be relatively small. In addition, the increased development of countries like China and India means that the pool of potential idea creators could rise for a long time.

[2] Based on Charles Jones (2005) pp. 1101-1103.

Discontinuous Growth

The endogenous growth models provide an analytical framework describing a stable long-term equilibrium path for economic growth at the frontier that accounts for the persistence of growth at the frontier over almost two centuries. An alternative analytical framework is one in which discontinuous waves of growth overlap to some extent, thereby accounting for the persistence of growth in the very long run.

Charles Jones argues that “the current research practice of modelling the idea production function as a stable Cobb-Douglas combination of research and the existing stock of ideas is elegant, but at this point we have little reason to believe that it is correct. One insight that illustrates the incompleteness of our knowledge is that there is no reason why research productivity in the idea production function should be a smooth, monotonic function of the stock of ideas. One can easily imagine that some ideas lead to a domino-like unravelling of phenomena that were previously mysterious, much like the general purpose technologies of Helpman (1998). Indeed, perhaps the decoding of the human genome or the continued boom in information technology will lead to a large upward shift in the production function for ideas. On the other hand, one can equally imagine situations where research productivity unexpectedly stagnates, if not forever then at least for a long time. Progress in the time it takes to travel from New York to San Francisco represents a good example of this” Charles Jones (2005, p. 1107).

The stable idea production function assumes a smooth process of knowledge creation. Implicit in this assumption is that (1) the unknowns outside the current knowledge stock are known unknowns for which a research methodology is available to the transform them into knowns; and (2) the stock of human capital in qualitative terms is sufficient to accomplish this transformation.

Suppose, however, the known unknowns can only be resolved through a process of trial and error. Then the rate of knowledge creation for particular areas of knowledge is likely to proceed in fits and starts. If the knowledge frontier is made up of a multitude of independent pieces of knowledge each of which is of small importance in relation to the whole knowledge frontier, the aggregate rate of knowledge creation may still average out to a smooth pattern. However, if the knowledge frontier is lumpy and individual bits of knowledge are complementary to other bits of knowledge (a more realistic picture of the knowledge frontier than the earlier assumption) we have the situation posited by the general purpose technology literature. Discontinuities (stops and surges) will occur at the aggregate knowledge frontier because of the trial and error approach of discovery necessary at critical points in the frontier.

A third possibility is that a substantial amount of the potential new knowledge that could be gained represents unknown unknowns. If, in addition, we have powerful complementarities across the knowledge frontier, we face ongoing surprises that may result in surges of advance in knowledge creation or, on the other hand, setbacks to progress and bottlenecks.

SUMMING UP

How do these endogenous growth models rate in addressing the key questions of growth economics? Three key questions are addressed:

- The persistence of economic growth at the frontier over the very long run;
- Convergence vs divergence in growth patterns between countries; and
- The way in which the innovation system works, medium-term and long-term.

The Persistence of Economic Growth at the Frontier

The importance of this question

The persistence of economic growth in the advanced economies of the world since the second quarter of the 19th century has been one of the two main features of world economic growth. Given the tendency to convergence among the advanced economies, growth at the frontier of the world economy becomes the main energising force in world economic growth over this period. This is made explicit in the Schumpeterian endogenous growth models where distance from the frontier is a key parameter in national economic growth.

The achievements of endogenous models

The contemporary growth theory seeks to develop models that incorporate an endogenous equilibrium rate of growth approximating the historical experience of the leading economies, thereby ‘explaining’ persistent growth. The continuing growth in the stock of knowledge and the stock of human capital is the key to such a solution. An explicit recognition of the growth frontier is rare in this literature.

A critique of endogenous models

With the exception of an article by Howitt (2000), the endogenous growth models do not *explicitly* analyse growth at the frontier, although the general analysis implicitly covers frontier conditions.

The *linearity critique* suggests that the endogenous growth model either does not generate long-run growth or exhibits growth rates that explode. Moreover, the critique on *transition dynamics* suggests that economic growth is mainly related to the transition dynamics of the economic system rather than identifiable endogenously derived equilibrium growth. It appears that actual economic growth at the frontier occurs as a consequence of discontinuous waves of growth overlapping to some extent, thereby accounting for the persistence of growth in the very long run (see the earlier discussion on *discontinuous growth*).

Convergence vs. Divergence

The importance of this question

Convergence is the rule among a fairly stable group of advanced economies, and greatly diverging trends among the other economies. The question is: Why is this so?

The achievements of endogenous models

Existing endowments of human capital shape the responses of economies to growth opportunities over the short-to-medium term. Institutions and institutional change are thought also to be very important; however, these need to be more explicitly modelled.

A critique of endogenous models
Transition dynamics are more important than steady-state results in determining actual growth rates. These dynamics can exacerbate differences in economic performance compared with steady-state results.

The Innovation System

The importance of this question
The nature of the innovation system is important not only to trends in aggregate economic growth and the dispersion of growth across different groups of countries, but also to broader questions of economic development and environmental economics.

The achievements of endogenous models
The broader parameters of the endogenous growth models give a rough guide to the potential growth in the stock of knowledge and the links with the stock of human capital. The benefits of these developments flow to the advanced economies and some of the developing economies.

A critique of endogenous models
Growth as a microeconomic phenomenon may be discontinuous. We can see this more closely be focusing on the details of the innovation system. The knowledge frontier is lumpy. Aggregate growth reflects a mixture of divergent micro-economic trends.

BEYOND ENDOGENOUS GROWTH MODELS

In concluding this introduction to the economics of growth, it is useful to consider a number of issues that, taken together, go beyond current endogenous growth models. These issues are:

1. Creative destruction;
2. Endogenous versus exogenous elements in growth;
3. An engineering approach to growth;
4. The role of empirical research.

CREATIVE DESTRUCTION

Schumpeter’s notion of creative destruction is pertinent to an understanding of economic growth. In this section of the paper, I wish to draw attention to its relevance to the analysis of growth at the frontier.

Schumpeter

Schumpeter (1942) argued that the main agents of growth are entrepreneurs, who see that improvements, change, and progress are made. They are distinguished from capitalists, who bear risks; inventors, who have the ideas; and managers, who are concerned with routine matters of production and distribution.

Schumpeter's phrase, 'creative destruction', is most closely associated with his work on the determinants of growth. It refers to the never-ending change of the economic structure from within arising from the search by entrepreneurs for new goods and new methods of production to increase profits. In his framework, competition is about more than just prices. It is concerned with supply side factors such as new products, methods of production and forms of organisation, which can be described generally as innovation and technological progress.

Economic development is considered to be a dynamic process, occurring discontinuously over time. This is because the introduction of an innovation by one entrepreneur leads to a diffusion of the knowledge and makes it easier for other entrepreneurs to make decisions about their own production possibilities. Eventually, however, the pace of diffusion associated with that particular innovation will slacken and, with it, so will the rate of economic development. Because of the search for profits, another innovation is sure to come along after a period of time, allowing the development process to pick up pace again. In this way the cycle keeps repeating itself.

Creative Destruction and Economic Growth

Schumpeter's writings have inspired a branch of endogenous growth models that focus on quality-improving innovations (note Aghion and Howitt, 2005). Growth increases with the productivity of innovations. However, the dynamic element in Schumpeter's picture of economic development has not ben fully reflected in these models. This dynamism could be described in the following fashion.

1. The increase in the stock of knowledge is discontinuous, as indicated in the previous sub-section of this paper. Surges in the growth of knowledge give rise to breakthrough innovations in general purpose technologies. This is the first stage of a creative cycle, but it will have little direct impact on aggregate economic growth initially.
2. The second stage will be a surge in incremental technological innovations extending the general purpose technologies as well as complementary technologies. This will be accompanied by the beginning of the diffusion of these technologies. Aggregate economic growth will begin to be affected.
3. The third stage will be taken up with complementary investments in organisational innovation and in human capital. The biggest impacts on growth will be felt in this stage. These changes will require a degree of trial and error, so the length of the third stage will be fairly considerable.
4. A slow-down in the growth in the stock of knowledge could co-exist with the third stage accompanying an earlier surge in the growth of the stock of knowledge. At any time, the average rate of economic growth could reflect a mixture of impacts associated with lagged trends in the stock of knowledge and breakthrough innovations, incremental innovations of different vintages, and contemporary complementary innovations in organisation and human capital. These average growth rates could be fairly stable in the very long term if the first stage of the knowledge growth cycle is periodically renewed.

The notion of creative destruction provides a framework for addressing many of the criticisms of endogenous growth models. With respect to the *linearity critique*, the creative destruction framework allows for a multi-faceted economy. In part of the system, depending on which stage of the growth cycle they are at, key parameters in an endogenous growth model could be consistent with zero or declining growth, or exploding growth; the system as a whole (human capital, physical capital and organisational issues) would moderate the pace of growth in the latter.

Transitional dynamics in knowledge development and innovation rates and in the structure of the capital stock will tend to be the dominating influence on growth rather than long-run stable equilibria. The underlying components of growth are *discontinuous*. The persistence of growth is not necessarily a consequence of a continuous endogenous process; it may reflect an averaging out of distinctive and at least partially separable and discontinuous processes.

Concepts in Economic Growth

A greater understanding of the above approach to analysing economic growth can be gleaned by a consideration of a number of concepts (note Jolley 2007a).

The concept of *General Purpose Technologies* (GPTs) is a key feature of creative destruction. Bresnahan and Trajtenberg (1996) and, subsequently, Lipsey, Bekar and Carlaw (1998) and Helpman (1998) state that a GPT is a technology that initially has much scope for improvement and eventually becomes pervasive (in the sense of being widely used and having many uses) as well as having many technological complementarities. Each of these attributes is a necessary condition for a technology to be a GPT, but the necessary and sufficient condition for overall GPT status is for the technology to possess all of these attributes.

The impact of GPTs on economic growth depends, to a considerable extent, on complementarities with other technologies, human capital, and organisational capital. These complementarities form part of the overall process of knowledge creation. The investment process related to these complementarities involves adding to the stock of intangible capital in the economy.

Intangible capital consists of all forms of capital not immediately manifest in tangible matter. Enterprise intangible capital is all such capital that exists within the boundaries of the firm: that is, it captures all outlays by firms made in the expectation of future profit other than those for plant, equipment and infrastructure. Ideas, skills and creative potential are the essence of intangible capital (Webster and Jensen, 2006).

Knowledge is defined as “the ability of individuals or groups of individuals to undertake, or instruct, or induce others to undertake, procedures resulting in predictable transformations of material objects” (Aghion et al, 2000). The characteristics of knowledge as a factor of production are discussed in World Bank (1999) and Society for Knowledge Economics (2005).

The relationship between the stock of knowledge and the stock of intangible capital can be summarised by three points:

1. The stock of knowledge is capital, but intangible not tangible.
2. Business intangible capital in the form of production capital, human capital and organisational capital is part of the stock of knowledge. Only a part of the marketing capital that is included in business intangible capital could be classified as knowledge.
3. Many aspects of non-business intangible capital are part of the stock of knowledge. They include the broader training and education infrastructure, public R&D, the science and technology infrastructure, and the development of financial markets.

There is also a substantial literature on the *economics of technology*. We can divide this literature into three components.

1. The diffusion of new technologies (Jaffe et al, 2003; Hall (2004).
2. The economics of induced innovation (Jaffe et al, 2003; Ruttan, 2001).
3. The economics of science and technology (Ruttan, 2001; Lipsey, Carlaw and Bekar, 2005).

Finally, institutions have been identified in recent research as being the most fundamental factor shaping economic growth in the long run. The literature on institutions and growth embraces the following topics:

1. The characteristics of institutions (North, 1991; International Monetary Fund, 2005).
2. The impact of institutions on growth (OECD, 2004; Mokyr, 2002).
3. Are institutions endogenous or exogenous? (Engerman and Sokoloff, 2003).
4. The determinants of institutional quality (International Monetary Fund, 2005; OECD, 2004).

ENDOGENOUS VERSUS EXOGENOUS ELEMENTS IN GROWTH

The paper *General Purpose Technologies and the Knowledge Economy: Concepts in Economic Growth* (Jolley, 2007b) was based on the premise that an understanding of the interaction of General Purpose Technologies (henceforth GPTs) with other economic concepts (specifically, the knowledge economy, the economics of innovation, and the interface between economic institutions and growth) enables a greater understanding of the determinants of economic growth and economic development. The resulting synthesis was termed GPTKE (General Purpose Technologies and the Knowledge Economy).

The overall analytical framework attempts to clarify the endogenous aspects of the development of General Purpose Technologies. It does so by incorporating factors that determine:

- Rates of investment in GPTs, with feedbacks via the realisation of learning economies;
- The diffusion of advanced technologies within the GPT sector and of complementary technologies;
- Incremental innovation within the GPT sector and in complementary technologies;
- Breakthrough innovation for GPT and complements; and

- Science and technology impacting on GPTs and complements.

While the technological characteristics of each GPT are unique, and provide an exogenous blueprint for development, this blueprint can only be activated through the influence of an endogenous process of innovation, diffusion and investment.

The exogenous factors in this model can be divided into four categories:

- Existing endowments;
- Investment in intangible capital (which can be broken down into investment by businesses and investment by other entities, including the public sector);
- Characteristics of the policy-influenced facilitating structure; and
- Miscellaneous influences.

These factors are listed below.

Existing Endowments

Existing endowments are factors that influence economic growth that cannot be rapidly changed. In the very long run they might be treated as being endogenous if we could identify how they might be changed. But in the medium-term they represent more in the nature of fixed factors.

These existing endowments are:

- Management skills;
- Adaptability and flexibility of organisations, management and workforce;
- Human capital;
- Education and training infrastructure;
- Research infrastructure; and
- Financial markets.

The level of these endowments would determine the capacity of individual economies to take advantage of growth at the frontier. The frontier itself would exhibit strength in these endowments.

Investments in Intangible Capital

Business investment in intangible capital comprises R&D, the development of managerial skills, organisational innovation and restructuring, work force training, and the development of relationships with suppliers and customers. Investments in many of these areas could be modelled as being endogenous (this is particularly the case with respect to R&D) although exogenous drivers can also be identified (e.g., overcoming barriers to R&D).

Investments in intangible capital in the public and the not-for-profit sectors is also an important driver of growth, and is more likely to be exogenous than is the case for investments in business intangible capital. Key areas of other intangible capital are:

- Public R&D and its diffusion.

- Science and technology - growth in pure and applied sciences, reducing constraints on the productivity of scientific resources, and the diffusion of basic science to the private sector.
- Training, education and the development of its infrastructure; education for innovation.
- Development of financial markets with particular reference to financing innovation.

Policy Infrastructure

The policy infrastructure is a potentially enabling factor for the development of intangible capital and hence the generation of growth. The key features of the policy infrastructure are briefly summarised below.

1. R&D enabling factors such as developing relevant human capital skills, strengthening the science and technology base, incentives for private R&D, and cooperative arrangements between public and private R&D.
2. Education and training infrastructure.
3. Science policy.
4. Competition policy and regulation of product and labour markets.
5. Government procurement.
6. Physical infrastructure.
7. Other institutional factors, such as the nature of property rights, the system of commercial law, and the general rule of law as it discourages corruption and other forms of criminal activity.

Other Exogenous Influences

The Challenge of Bottlenecks

In Jolley (2007a) reference was made to research that demonstrated that innovation responded to demand signals in the market. A prime example given was the response of energy-related innovations to the boom in oil prices of the 1970s. In more general terms, resource scarcity has prompted innovations in the energy sector and synthetic rubber and fibres. Public policies aimed at local environmental problems have led to innovation in pollution control, water and waste treatment. In addition, an uneven pattern of change in technology stimulates innovation in the lagging areas – examples include the progressive spread of mechanisation through individual facets of textiles production, and the improvement of peripheral equipment to match major innovations in engine technologies and semiconductors.

R&D Productivity and Skills

While the level and distribution of private sector R&D can be taken as being endogenous, there are exogenous elements influencing R&D productivity. For example, research skills can be enhanced through advances in education and training. Improvements in research infrastructure are a further source of increased R&D productivity. Investments in particular areas of technology may give rise to spillover effects on other areas, producing increasing returns to R&D. On the other hand, bottlenecks in technology in particular areas could put a brake on the advance of technology in many other areas.

Increasing or Decreasing Returns to Knowledge Investment

The productivity of R&D will also be influenced by the course of developments in public science and technology. Of fundamental importance in the longer term is the question of whether increasing or decreasing returns characterise the process of knowledge creation.

Decreasing returns, i.e. diminishing returns from greater investments in knowledge creation, may reflect the deadweight burden of the accumulated volume of knowledge over time. This burden would show up in the increasing time taken to educate would-be knowledge creators in the existing knowledge corpus. Benjamin Jones (2005) investigates, theoretically and empirically, a possibly fundamental aspect of technological progress. If knowledge accumulates as technology progresses, then successive generations of innovators may face an increasing educational burden. Innovators can compensate in their education by seeking narrower expertise, but narrowing expertise will reduce their individual capacities, with implications for the organisation of innovative activity – a greater reliance on teamwork – and negative implications for growth.

On the other hand, *increasing returns* to knowledge could result from developments in one or other of two areas. The first is the possibility of spillovers across different fields of study, which provide a major boost to the total stock of knowledge. The second would be increases in the efficiency of educating potential knowledge creators. This could occur as a result of a conscious attempt to exploit knowledge spillovers through appropriate interdisciplinary education. The second could reflect attempts to streamline the content of education in existing knowledge while fostering the capacity for creative approaches to knowledge enhancement.

Exogenous Technological Characteristics of GPTs

The previous analysis points to the way in which features of the economic system can influence the level and growth of development and investment in GPTs. However the development path of GPTs is not readily forecastable in its early and middle stages because of the complex myriad of possible interactions it has with the economic system.

The development of GPTs tend to have varying ramifications for different parts of the economic system – energy systems, ICTs, transportation, materials, and organisational technologies. The size, nature and timing of impacts in each of these areas could vary considerably. The nature of the impacts will also depend on complementary investments in technology, workforce and organisational changes in each area, and these too can vary considerably. Moreover, the sequence of these myriad changes is not readily forecastable or pre-determined, so there are possibilities of widely varying outcomes depending on different assumptions about reactions and the timing of reactions along with the possibility of path dependence and technological lock-ins under different scenarios.

AN ENGINEERING APPROACH TO ANALYSING GROWTH

An engineering approach to economic growth has advantages over the conventional approach based on the usual production function analysis. Once we take into account GPTs we are led in this direction. Moreover, the importance of growth modelling for the long-term issues associated with environmental sustainability also encourages a use of this analysis.

An engineering approach to economic growth has its analogy in the economics of climate change. Climate change economics can use endogenous growth models to estimate a possible top-down innovation function in which policy interventions like carbon pricing lead to increased competitiveness of low-emission economic options. An alternative approach is the bottoms-up option of estimating future cost functions for particular technologies on the basis of engineering analyses.

The conventional economic growth theory uses a production function in which output is a function of labour and capital inputs with an additional variable denoting knowledge and/or human capital. Output is the sum of valued added in each area of production. Growth occurs through the substitution of capital for labour in the medium term (growth dynamics), or through the expansion in the stock of knowledge (long term equilibrium growth). The price relativity of labour to capital may play a part in the way productivity evolves.

From a managerial and engineering point of view output can be conceived of as materials/intermediate goods * labour * capital. A significant part of the productivity challenge to management is the maximisation of the output to materials/intermediate goods ratio. The prices of key inputs of materials relative to labour can play an important role in the evolution of technology.[3] The chain of materials/intermediate goods contains production functions with terms for labour and capital that can be summarised within an aggregate production function of the conventional form, with capital and labour and no material inputs. However, at the base of the production process are the untransformed materials of agriculture and mining.

In the original classical analysis, a factor of production, land, was also included in the production analysis. We can today represent land as a combination of resource inputs – non-renewable resources available to the mining sector, and the resource base of agriculture – soil, climate, water. By the explicit recognition of these factors of production we can handle the interplay between the potential for diminishing returns from resource depletion, the role of relative prices, and the role of knowledge growth in averting productivity shocks from resource depletion. Just as the tangible capital stock is subject to depreciation, the natural resource stock can be run down, and the long-term capacity for economic growth needs to take into account net rather than gross productive capacity.

The wider interpretation of the production process is that of a number of inputs being drawn upon to produce certain outcomes. The inputs are materials/goods in progress, energy, water, information/communications, intangible capital, tangible capital, and labour. The outcomes are output for sale, and waste. This represents a picture of how

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[3] For example, Allen (2009) stresses the role that high wages and low coal prices played in promoting the technological changes that led to the British industrial revolution.

business would see things, and it separates out the specific areas of technical and engineering focus. It also aligns with particular areas of economic and environmental interest (e.g. energy economics and technology; water policy issues; the information and communications technology (ICT) revolution; the economics of intangible capital; and the economics and technology of waste). Finally, it corresponds to areas in which GPTs arise.

With this interpretation of the production process we can focus on the differing concepts of productivity: minimising inputs of materials to final output; minimising energy inputs to output, water use per final output, ICT purchases per unit of final output; returns to intangible capital and tangible capital, and labour productivity, as well as the minimisation of waste per unit of final output. They can then highlight the way in which relative prices can impact on the evolution of the production process, including induced innovation. They are also useful in relation to environmental sustainability issues because they focus on non-renewable resources, energy, water and waste as separate aspects of the production process.

The history of economic growth and its relationship to the development of new GPTs fits comfortably into a production analysis like the above.

EMPIRICAL STUDIES AND GROWTH ECONOMICS

The researches of national statistical agencies, the data sets embodied in the Penn World Tables (Heston et al, 2009), the work of Angus Maddison on historical statistics (Maddison, 2007) and that of Jorgenson and his collaborators (Jorgenson et al, 2005) in addition to the KLEMS project (Koszerek et al, 2007) has given us a rich data base for growth economics. This has represented a considerable achievement. However, the typical econometric research in growth economics as summarised by Mankiw (1995) is subject to the major criticisms outlined in an earlier section of this paper.

There is, however a rich vein of descriptive and analytical studies on a broad range of sub-disciplines within economics that can provide a firmer empirical base for growth economics and facilitate the further developments of theoretical growth models. Listed below are some twenty headings for relevant areas of study.

1. The economics of technology and General Purpose Technologies.
2. Complementaries – between technologies, organisational innovation, and investments in human capital.
3. Knowledge economy – the characteristics of knowledge, knowledge and growth, the determinants of the growth of knowledge, barriers to the growth of knowledge. Knowledge management in the business sector, intangible capital in the business sector.
4. The economics of innovation: the science and technology sector, invention, innovation, R&D, diffusion of new technologies, spillovers across the economy.
5. Organisational innovation. Management skills, innovations in management, management methods and technological innovations, investments in management methods and skills, international diffusion of managerial innovations, corporate culture.

6. Human Capital. Impact on growth, complementarities with technology and organisational innovation. The economics of education, training, learning. International movements of labour. Labour market regulation.
7. Investment in tangible capital and growth. Complementarities with innovation.
8. Finance and growth.
9. Institutions and growth – property rights and the law, tackling crime and corruption; political regimes and growth.
10. International economics – the impacts of globalisation, trade and growth, international capital movements, migration.
11. Geography and growth – cities and urban development, clusters, infrastructure, population density.
12. Population and growth. Unified theories.
13. Inequality and growth.
14. Social Capital and growth.
15. Resources and growth.
16. Health and growth
17. The environment and growth.
18. Shocks and growth: natural disasters, political disruptions, macroeconomic shocks.
19. Policies and growth – macroeconomic policies, micro reforms, other policies.
20. Growth in economic history.

CONCLUSIONS

Growth economics is an important area of study, not just because growth is widely desired for its own sake, but also because it is a pre-condition for social progress. Moreover, because innovation is the key to understanding growth and innovation is also the key to addressing major environmental problems, the study of growth economics is also vital to analysing policy options for environmentally sustainable growth.

Economic growth is usually defined as the growth in GDP/GNP per capita. In growth economics, different groups of economies can be analysed (the where of growth), different time periods covered (the when of growth), and attempts made to understand the causes of growth (the how of growth). With respect to the latter, there is an abundance of possible explanations of the possible causes of growth, the difficulty being to distinguish between them.

The endogenous growth models developed over the past twenty years have been a great improvement on the previous generation of growth models but are subject to a number of important criticisms. A similar point can be made about the large number of cross-sectional econometric studies of national economic growth.

Growth economics needs to embrace some of the issues discussed in the fourth section of this paper - creative destruction, endogenous versus exogenous elements in economic growth, and what might be termed and engineering approach to analysing growth. In addition, there is a wide range of empirical studies that should be utilised in growth economics, as noted in the fifth section of the paper.

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