SUSTAINABLE DEVELOPMENT, GROWTH THEORY, ENVIRONMENTAL KUZNETS CURVES, AND DISCOUNTING

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Summary

Economists have examined the relationships between environmental quality and economic production and growth at an economy-wide level from both theoretical and empirical perspectives.

This chapter reviews some of the key results of economic growth theory in which production uses an environmental resource. Attention focuses on how the presence of environmental pollution affects the optimal investment in different forms of capital and on the role of discounting. The theory of resource scarcity and its possible consequences

for economic growth and sustainable economic development are considered. The chapter then considers the empirical literature on the relation between economic growth and development and the level of, and change in, various forms of environmental degradation. The environmental Kuznets curve (EKC) concept at the center of this literature is discussed and criticized and some of the more important results are surveyed. Finally, the chapter suggests some future directions for research in these areas.

1. Introduction and Overview

Human welfare depends on a supply of goods and services that provide both necessities and luxuries and also on an environment that provides for a healthy life and contributes to aesthetic or spiritual satisfaction. The economic activity that provides those goods and services ultimately depends on a supply of natural resources and inevitably leads to some disruption of the natural environment. The resulting disruption may threaten economic activity itself or detract from the environmental quality that people appreciate or benefit from directly. Additionally, extraction of non-renewable natural resources, such as minerals, directly reduces the future supply of those resources and may also cause the costs of extraction to rise in the future as the most accessible resources are used first.

Economists have examined these relationships at the economy-wide or macro-economic level from both theoretical and empirical perspectives. The first part of the chapter outlines the two dominant theories of economic growth - the neoclassical and endogenous growth models. It then reviews some of the key results of growth theory when an environmental resource is used in production. Attention focuses on how the presence of environmental pollution affects the optimal solution and the role of discounting. This leads to some conclusions regarding optimal environmental taxes. The theory of resource scarcity and its possible consequences are examined, and the implications of growth theory for sustainable economic development considered.

Empirical research on the relation between economic growth and development and the level of, and change in, various forms of environmental degradation has developed rapidly in recent years in what has come to be known as the environmental Kuznets curve (EKC) literature. Proponents of the EKC argue that, while environmental degradation tends to increase with economic growth at low levels of income *per capita*, at high levels of income per capita, degradation falls as income increases. The EKC concept and the empirical evidence for and against it have been at the center of recent debates in the academic literature and in media, such as *The Economist* magazine, on the relation between economic growth and the environment. The second part of the chapter reviews the EKC literature.

2. Theory of Economic Growth, Natural Resources and Environment Quality

In the first two subsections below, we review the standard theory of economic growth that does not include natural resources in order to set the stage for the discussion of growth models including natural resources in the following sections.

2.1. Neoclassical Growth Models

Economic growth models examine the evolution of a hypothetical economy over time as the quantities and/or the qualities of various inputs into the production process change. In the simplest model, a constant-sized labor force using manufactured capital produces output, which is equal to the national income. The neoclassical model assumes that output increases at a decreasing rate as the amount of capital employed rises. The uppermost curve in Figure 1 shows this relationship between output (Y) and capital (K).

Now suppose that the population, assumed to be some constant multiple of the labor force, saves a constant proportion of its income. Savings are used to build new capital goods. A constant proportion of the existing capital stock depreciates (and becomes productively useless) in each period of time.

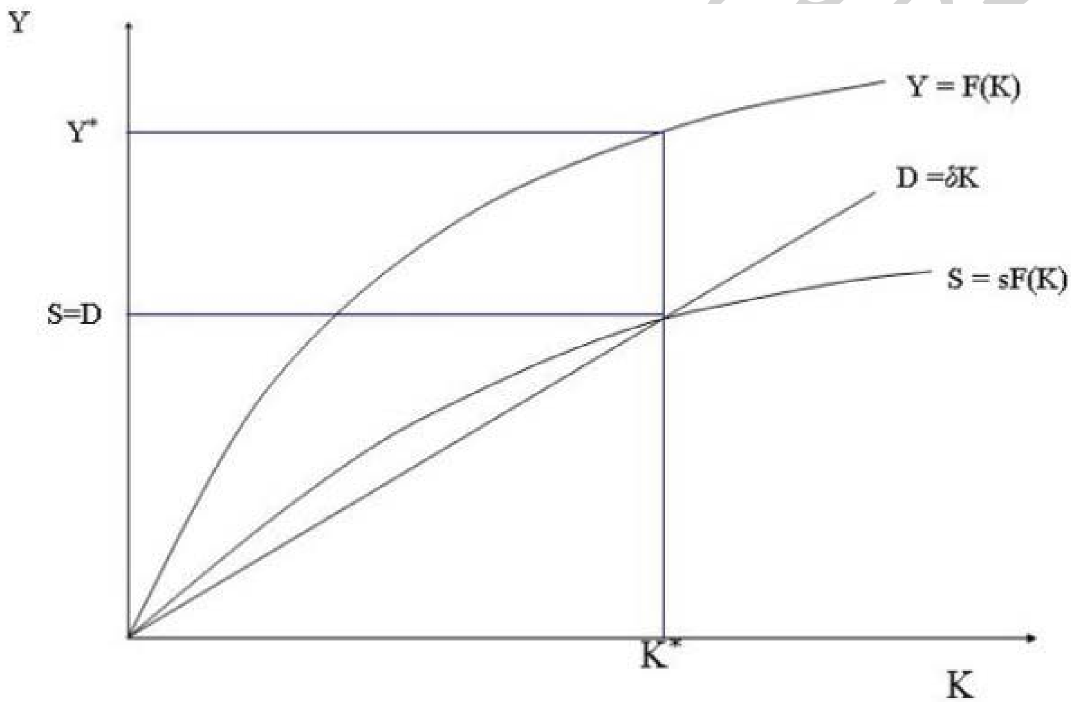

Figure1. The neo classical growth model

The capital stock is in equilibrium (and so unchanging in size) when saving equals depreciation. This is also shown in Figure 1. Note that the savings curve has the same shape as the output curve, but is lower for every value of K. This is because savings are a constant proportion, s, of income. The dynamics implied by Figure 1 are very simple. To the left of K^*, where capital per worker is scarce, capital investment generates a relatively large increase in future income, and so will offer a high rate of return. Moreover, it is clear from the relative positions of the S and D curves to the left of K^* that the addition to the capital stock (S) is greater than depreciation (D) and so capital rises.

However, diminishing returns to capital (shown by the decreasing rate of increase of the output curve) imply that successive increments of capital generate decreasing additions to future income, and so a falling rate of return on investment. Hence the incentive to accumulate capital weakens. When the capital stock has reached K^*, it will be at a stationary, or equilibrium, state. Additions to capital due to saving are exactly offset by reductions in capital from depreciation and the rate of return on investment will have fallen to a point at which there is no incentive to accumulate more capital.

This simple neoclassical model has startling implications. The economy must sooner or later reach a stationary state in which there is no net (additional) investment. Economic growth must eventually halt. In a transition process, while a country is moving towards this stationary state, growth can and will occur. An underdeveloped economy, with a small capital stock per worker, can achieve fast growth while it is building up its capital stock. But all economies will eventually settle into a zero growth equilibrium.
An economy could experience a further temporary period of growth once a steady state is reached if the savings ratio increases. To see this, look again at Figure 1. A higher savings rate means that the S curve is higher for every value of K, leading to a higher equilibrium capital stock and a higher level of income *per capita*. During the transition to this new equilibrium, growth will be positive. Much the same happens if an economy could reduce the rate at which its capital depreciates. But the key point we noted above remains true: no country can grow in perpetuity merely by accumulating capital.

This result is problematic. Table 1 presents *per capita* output growth rates over three decades in a selection of developed, OECD economies. These countries have succeeded in achieving positive growth rates in the neighborhood of 1.75% per year over fairly long periods of time. At this rate, real standards of living double in about 40 years. Furthermore, most of these countries achieved similar rates of growth for lengthy periods prior to 1970. Despite the fact that the average growth rate for this sample fell over the three decades shown here, it seems difficult to believe that these data reflect nothing more than transient periods of adjustment to an ultimate zero growth steady state.

So what mechanism can generate continuous growth, and account for the growth statistics in Table 1? A growing population is not a solution. If the labor force were to grow at a fixed rate over time, the total capital stock and the total quantity of output will rise but capital per worker and output per worker will remain constant once an economy has developed to its equilibrium. The only adjustment necessary to Figure 1 is that all units are now measured in *per capita* terms.

	1970-79	1980-89	1990-98
Australia	1.70	1.51	2.30
Austria	3.78	1.93	1.30
Belgium	3.15	1.85	1.30
Canada	2.87	1.82	0.80
Denmark	1.84	1.59	2.40

Finland	3.10	3.12	1.50
France	3.06	1.71	1.00
Greece	4.26	0.65	1.50
Ireland	2.68	1.56	6.80
Italy	3.36	2.25	1.00
Japan	4.08	3.21	1.00
Netherlands	2.43	1.37	1.90
New Zealand	0.79	0.79	1.50
Norway	3.52	2.52	3.30
Portugal	4.44	2.85	2.20
Sweden	2.02	1.58	0.70
Switzerland	1.22	1.96	-0.40
United Kingdom	2.29	2.10	1.80
United States	1.71	1.43	1.80
Average for the 19 selected	2.75	1.88	1.77
Countries.			

Source: World Bank (World Development Report, various issues, and World Development Indicators, 1997 CD Rom)

Table 1. GNP per capita growth rates for a selection of OECD economies

According to neoclassical growth theory, the cause of continuing economic growth is continuing technological progress. As the level of technological knowledge rises, the functional relationship between productive inputs and output changes. Greater quantities or better qualities of output can be produced from the same quantity of inputs. In the simple model we are examining, technological progress continually shifts the output function upwards, and so raises the equilibrium *per capita* capital stock and output levels. Intuitively, increases in the state of technological knowledge raise the rate of return to capital, thereby offsetting the diminishing returns to capital that would otherwise apply a brake to growth.

One important implication of the neoclassical growth model is the convergence of economic performance over time. If countries have equal access to technological progress, then their equilibrium growth rates should be identical. Moreover, the actual growth rates of poorer nations should be faster than those of richer nations, as the poor countries can achieve growth greater than the shared rate of technological progress during the “catching up” phase. We would expect to find an inverse relationship between growth rates and the level of income. However, if for some reason technology growth rates are uneven across countries, then equilibrium growth rates will differ.

If countries are identical in terms of their “fundamentals” (savings and depreciation rates, technological progress, and population growth) they will converge to a common level of output per person. Differences in real living standards cannot persist indefinitely in these circumstances. However, if any of these fundamentals do vary among countries, then there can be permanent differences in the equilibrium levels of output per person. A form of convergence known as “conditional convergence” occurs in this case. The growth rate of each country will converge towards its own equilibrium level, equal to its underlying rate of technological progress. Equilibrium levels of income *per capita* will differ because of differences in other fundamentals, such as savings and depreciation rates.

In Table 2, we present some information that might show whether economies converge in terms of growth rates or levels of *per capita* income. If absolute or unconditional convergence were taking place this would be reflected in the data. But without data on the conditioning variables, we cannot tell from this data alone whether conditional convergence is happening, or whether convergence is to equilibria with different growth rates. Nevertheless, the support for convergence in this data is weak. The high-income countries - the ones that are supposedly closest to their steady states - have consistently outgrown the world as whole. The East Asia and Pacific group appears to be outperforming all others by a large amount. But overall, the data do not suggest that the lower income economies are consistently catching up the high-income group. In the next section, we discuss another class of growth model that does not typically predict this sort of convergence. On the contrary, a property of these models is that relative success can be self-perpetuating.

	1965-73	**1973-80**	**1980-90**	**1965-90**	**1990-98**
Low income	2.5	2.6	4.0	2.9	5.3
Excl. China and India				1.7	1.0
Middle income	4.6	3.1	0.5	2.2	0.4
Lower middle income			-0.1	1.5	-2.7
Upper middle income			0.6	2.8	2.3
Low and middle income	4.3	2.7	1.2	2.5	1.5
East Asia and Pacific	5.0	4.8	6.2	5.3	6.6
Europe and Central Asia			1.4		-4.5
Latin America & Carib.	4.6	2.2	-0.4	1.8	1.8
Middle East & N. Africa	6.0	1.7	-2.5	1.8	0.4
South Asia	1.2	1.7	3.2	1.9	3.6
Sub-Saharan Africa	1.7	0.9	-1.3	0.2	-0.8
High income World	3.7	2.1	2.3	2.4	1.4
	2.8	1.3	1.2	1.5	0.8

Source: World Bank (World Development Report, various issues, and World Development Indicators, 1997 CD Rom)

Table 2. Growth of GNP per capita for selected country groupings

2.2. Endogenous Growth Models

The neoclassical growth model has two major limitations. First, the predicted convergence results do not match the evidence. Secondly, the models can only account for continuing economic growth by invoking the existence of exogenous technical progress. The model does not explain improvements in technology, nor is there any explanation of why the rate of technological progress may differ from one country to another. These facts led to attempts to endogenize technological change - explaining technological progress within the growth model as the outcome of decisions taken by firms and individuals. The resulting body of work has become known as endogenous growth theory.

In endogenous growth models the relationship between capital and output can be written in the form $Y = AK$. Capital, K, is defined more broadly than in the neoclassical model. It is a composite of manufactured and knowledge-based capital. Endogenous growth theorists have been able to show that, under reasonable assumptions, the A term in the expression above is a constant, and so growth can continue indefinitely as capital is accumulated.

In the neoclassical model, growth is eventually brought to an end by diminishing returns to capital. But suppose that the process of accumulating capital itself generates technological progress and offsets those diminishing returns. The key point is that technological knowledge can be thought of as a form of capital. It is accumulated through research and development (R&D) and other knowledge creating processes. Technological knowledge has two special properties. First it is a public good: the stock of this form of capital is not depleted with use. This is important as it implies that the knowledge stock can be stored over time, even when it is being used. Second, it generates positive externalities in production: whilst the firm doing R&D obtains benefits from the knowledge acquired, others benefit too - the benefits that the firm accrues when it learns and innovates are only partly appropriated by itself. There are beneficial spillovers to the economy from the R&D process so that the social benefits of innovation exceed the private benefits to the original innovator.

These externalities create momentum in the growth process. As firms install new capital, this tends to be associated with process and product innovations. The incentive to devote resources to innovation comes from the prospect of temporary monopoly profits for successful innovations. The growth of K thus means the growth of a composite stock of capital and disembodied technological knowledge. Therefore, output is able to rise as a constant proportion (A) of the composite capital stock, and is not subject to the diminishing returns shown in Figure 1.

So in an endogenous growth model, the economy can sustain a constant growth rate in which the diminishing returns to manufactured capital are exactly offset by the technological growth external effect that we described earlier. The growth rate is permanently influenced by the savings rate; a higher savings rate increases the economy's growth rate, not merely its equilibrium level of income.

In some variants of the endogenous growth model, the rate of economic growth is positively related to the scale of the economy. The larger is the number of firms, the greater will be the magnitude of the technological knowledge externality, and so the higher the growth rate will be. Two interesting implications follow. As more firms cluster in some location, so the generation and transmission of knowledge increases, increasing the potential economic growth rate. Second, trade liberalization and increased trade volume can boost growth rates. In this kind of world, success is self-perpetuating and convergence need never occur. However, as technological progress is now endogenous to the growth process, governments can manipulate the business environment in ways that will increase its pace of knowledge growth. This may support trade liberalization or greater openness; it may warrant investment in education or training; and matters such as intellectual property rights regimes (giving incentives to innovate, yet possibly restricting its speed of transfer) become of great significance.

2.3. Growth Models including Environmental Resources

The growth models we have examined so far have had nothing to say about economy-environment interactions. There are two main aspects to this relationship. First, production necessarily has a material basis. The production of goods and services draws upon and exploits environmental resources. Second, economic processes generate material flows into environmental media. These flows may have direct or indirect adverse effects on human welfare, and could interfere with the attainability of positive growth, or even the sustainability of a constant level of output.

The inclusion of environmental resources as additional productive inputs has potentially profound implications for the properties of growth models. All environmental resources exist in finite quantities though some such as sunlight or deuterium are available in very large quantities. Some environmental resources are non-reproducible; and many renewable resources are potentially exhaustible. Finiteness and exhaustibility of resources make the notion of indefinite economic growth problematic. Even sustainable development - i.e. at least no decline in output - may not be feasible.

In the next section, we examine how growth models may be augmented to include the use of environmental resources as productive inputs. The following two sections consider the feedback effects of economic activity on the natural environment. In each case, we shall focus largely on neoclassical models. Where results differ in the case of endogenous growth models, we draw attention to this in the text.

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Biographical Sketches

Roger Perman is a Reader in Economics in the Department of Economics, University of Strathclyde, Glasgow. A graduate of Manchester, Leicester and London (Birkbeck College) Universities, he was formerly Lecturer at Dundee Institute of Technology and Visiting Research Fellow in the Fraser of Allander Institute. His major research interests and publications are in the fields of applied econometrics and environmental economics. Roger Perman teaches, undertakes research and does economic consultancy work in a variety of countries, including Albania, France, Iraq, Russia, and the Ukraine. Current research includes structural convergence of European economies and applied cointegration analysis. He has recently jointly written texts in Environmental Economics, Business Economics, and the Economics of Strategy. His personal home page can be found at http://personal.strath.ac.uk/r.perman/

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