Endogenous Growth Theory and the Relation to Hartwick's Rule

Introduction

The availability of natural resources and the possibilities to secure social welfare have always played a role in economics. T. R. Maltus wrote "Essays on the Principles of Population" that secured him a place in the history of economic theory with a hypothesis saying that welfare per capita cannot be maintained for a society where population grows. Natural resources, in particular non-renewable resources, reoccurred again in the "Limits to Growth" debate in the 1970s. Most likely as a consequence of the oil price chocks. In the more recent years, fisheries constitute an example of problems concerning renewable resources.

The questions typically investigated in the literature concern: optimal growth paths given limited natural resources, pricing of natural resources, intergenerational equity, and economic policies that can contribute to realization of an optimal growth path. It is important to investigate if it is possible to have a strictly positive per capita consumption level in all future. For the case of renewable resources it is somewhat trivial, that situations exist where the choice of a right moderation in the utilization of the resource secures the existence of positive per capita consumption in future periods.

Growth Theory and Resources

In 1977 Hartwick developed, what is referred to by himself, a *savings investment rule* (Hartwick, 1977). This rule has since been referred to as *Hartwick's Rule*. In brief, Hartwick's Rule suggests how society, by reinvesting the rent from exhaustible natural resources in reproducible capital can sustain a strictly positive constant consumption over time. Hartwick's results are based on the following framework: (i) a constant population, (ii) no technical progress, (iii) no depreciation of reproducible capital, (iv) the production function is a Cobb-Douglas function with constant returns to scale with respect to capital and the resource taken together, and (v) it is assumed that there is full employment of labor. As a feature of the Cobb-Douglas function every input is essential for the production, which means that production cannot happen without both natural

resources and capital. The important problem is that input of the naturel resource must converge towards zero, and must be substituted by input of capital. This is possible if: (i) the natural resource rents are reinvested and (ii) if the output elasticity with respect to natural resources is less then the output elasticity with respect to capital.

Hartwick's Rule has its origin in neoclassical growth theory, and if exogenous technological progress is introduced the assumption about the substitutability possibilities between the two kinds of capital can be somewhat relaxed. On the other hand, it is not satisfactory to base the judgements of problems regarding the availability of resources on factors being exogenous to the model. The new growth theory endogenises technological progress.

Important features in economic growth are saving, investment and accumulation of reproducible capital. A continuously increasing stock of reproducible capital cannot keep pace with population growth due to decreasing marginal productivity. One idea behind one type of endogenous growth models is that it is likely that various types of positive externalities are nested in the accumulation of reproducible capital. If this idea proves correct, it means that growth rates for productivity will be affected permanently. Another stand of the new growth theory is the so-called R&D-based growth models. The idea behind my project, is to study natural resources in relation to these strands of new growth theory.

Ideas

Hartwick's Rule may be presented as a surprisingly simple answer to a complex question. The answer has some implications. The result has created the foundation for a series of contributions about "green" GNP measures. Hartwick's Rule is based on constant returns to scale with respect to reproducible capital and natural resources taken together. It will be interesting to examine the role of exhaustible natural resources in case of increasing returns to scale. Will Hartwick's Rule imply increasing consumption? Is the shadow value of natural resources exaggerated and thus the "green" GNP measures too pessimistic? Pollution from reproducible capital affects the returns to scale. When will pollution erode the production possibilities so that the increasing returns to scale effect will be offset? And what type of economic policy will be relevant?

Hartwick's Rule is pointed towards exhaustible resources. In the later years renewable resources, like fisheries and forestry, and agriculture in the developing countries, have played a central role in the debate. It is relevant to study the use of this type of resources within the model of increasing returns to scale.

Literature related to the problems outlined above include: Aghion and Howitt (1998), Asheim (1994, 2000), Asheim *et al.* (2002), Dasgupta and Heal (1979), Dixit *et al*. (1980), Hartwick (1977), Schou (2000), Stokey (1998), Withagen and Asheim (1997), and Vellinga and Withagen (1996), just to mention some of the contributions.

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