MODELING RESOURCE USE WITH ENDOGENOUS TIME PREFERENCE AND MINIMUM CONSUMPTION REQUIREMENT

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Overview

Hotelling's well-known rule is that scarcity rents for exhaustible resources increase at the rate of interest. Although there are many variations of the rule that derive similar rules, the implication remains the same. The dynamics of exhaustible resource use is driven by interest rates. Consequently, we face the following question: in what way are these interest rates determined? This question has never been answered in the framework of Hotelling and his successors.

Unlike in resource economics, debates about interest rates and time preferences have been intense in other fields of economics. In particular, in welfare economics, specifying discount factors falls under the topic of moral philosophy (e.g., Arrow and Kurz, 1970). Recent studies within this topic include those on hyperbolic discounting (e.g., Weitzman, 2001).

In macroeconomic theory, many studies have been conducted on models in which time preference depends on endogenous economic variables. Among those, habit formation models in which a history of consumption determines the time preference have recently become popular (e.g., Obstfeld, 1990). A classical topic in this category includes the Uzawa-Epstein formulation of time preference (Uzawa, 1968; Epstein and Hynes, 1983; Epstein, 1987).

This paper revisits a classical economic topic of exhaustible resource use on the basis of recent developments in time preference and discount factor models. An analysis of the effects of endogenous time preferences on the dynamic properties of resource use is conducted, contrasting the classical Hotelling results. More specifically, we develop an analytical model that incorporates endogenous time preference into the decision framework of resource consumption. The model structure consists of three parts: cake-eating economy, availability of a backstop technology, and the Uzawa-Epstein formulation of time preference. As a continuation of Maeda and Nagaya (2011), we highlight the effects of minimum consumption requirement. This is done by introducing a simplified version of the Stone-Geary utility. By modeling in this way, we can describe a more realistic situation that energy and resource use is indispensable.

Methods

In our previous study, Maeda and Nagaya (2011), we developed an analytical model that incorporates endogenous time preference into the decision framework of resource consumption. The model structure had the following features:

- cake-eating economy,
- availability of a backstop technology, and
- the Uzawa-Epstein formulation of time preference.

In this study, we add another feature, minimum consumption requirement. That is, we formulate the following problem.

$$\max_{\{E(t)\}} \int_0^T u\left(E\left(t\right)\right)\cdot e^{-\Delta(t)}dt + e^{-\Delta(T)}V$$

where

$$u\left(E\right) = \frac{\left(E-m\right)^{1-\eta}}{1-\eta}, \quad \eta > 0, \quad \eta \neq 1, \quad m \geq 0$$

$$\Delta\left(t\right) = \int_0^t r\left(E\left(s\right)\right)ds \qquad r\left(E\left(t\right)\right) > 0, \quad r'\left(E\left(t\right)\right) > 0, \quad r''\left(E\left(t\right)\right) \leq 0$$

E(*t*): Exhaustible resource use at *t*.
m: Minimum consumption requirement.
u(*): Representative agent's instantaneous utility.
Δ(*t*): Cumulative discount rate at *t*.
r(*): Instantaneous discount rate.

T: The time of switch to the backstop technology.
V: Value of the use of backstop technology.

The above form of utility function indicates the following limit:

$$u'(E) = \frac{1}{(E-m)^{\eta}} \to \infty \text{ as } E \to m .$$

This means that $E > m$ must hold true. Thus, m represents minimum consumption requirement.

Results

We investigated a classical model of the optimal use of exhaustible resource with the availability of backstop technology. The new ingredients added are endogenous time preference that is determined by the history of resource consumption and habit formation with minimum consumption requirement.

Our previous study corresponds to the case that the minimum consumption requirement, m is set as null. In this case, we have found that the reciprocal of the intertemporal elasticity of substitution (η) for the instantaneous utility plays a significant role in indentifying the shapes of the optimal paths of the exhaustible resource consumption: When $1<\eta$ ($0<\eta<1$), the consumption of the exhaustible resource at each time is declining (growing, resp.) in time t. For any η, however, these consumption paths turn out to be monotonous in time.

Introducing minimum consumption requirement, m in this study, we found that positive m has significant effects on both resource consumption path and the time of switch to the backstop technology. That is, the increase in the minimum consumption requirement, m, in the neighborhood of zero leads to the early arrival in the time to switch from the exhaustible resource use to the use of the backstop technology, T.

Conclusions

The effects of time preference and discounting factors on the properties of the economic dynamics have been a central issue in economic policy debates, in particular, in policies for climate change. The study report by Stern (2007), known as the "Stern Review," suggested that a prompt action for climate change is needed. The report created strong pros and cons in not only the policy arena but also the academia. One of the most debatable issues was the treatment of discount factors: Nordhaus (2007), for example, criticized the Review, stating that the Review was assuming very low discount rates, and that the setting helps to explain most parts of its unusual conclusions. We expect that the results obtained in this paper contribute not only to the literature of pure economic theory, but also to such recent climate policy debates on discounting factors.

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