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Exhaustible resources, technology choice and industrialization of developing countries☆

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ABSTRACT

How should the world economy adapt to the increased demand for exhaustible resources from countries like China and India? To address that issue, this paper presents a dynamic model of the world economy with two technologies for production; a resource technology, which uses an exhaustible resource as an input and an alternative technology, which does not. I find that both the time path of resource extraction and the adoption of the alternative technology depend on the optimal allocation of capital across the technologies, and on the size of the capital stock in relation to the resource stock. In particular, if the capital stock is low, only the resource technology is used initially and the alternative technology is adopted with a delay. Next, I use the model to analyze the effects of industrialization of developing countries on the extraction of oil and technology choice for energy production. As a result of industrialization, the alternative technology for energy production is adopted earlier.

1. Introduction

In recent years, the industrialization of large developing countries such as China and India has generated a considerable increase in demand for exhaustible resources, for example, copper, aluminum, iron ore and oil. ABARE (2008) reports that China and India accounted for about 35 percent of global steel consumption in 2007 and China alone accounted for about one third of world

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consumption of aluminum. Between 1990 and 2006, China's and India's total oil consumption increased by about 180 percent.[1] The increase in resource use has resulted in increases in the extraction of resources and through higher resource prices it has had an impact on resource-importing countries in the rest of the world.

> "China's hunger for natural resources has set off a global commodity boom. Developed countries worry about being left high and dry "
>
> *The Economist, March 13th 2008*

A study by Gordon et al. (2006) estimates that the global stock of copper is insufficient to make the standard of developed countries available to the total world population. Using data on per person copper use in countries such as the US, the authors find that extending that use to the world population requires more copper than even the most generous estimate of available resources. They find that the same holds for zinc, and possibly aluminum. Several studies of this kind have contributed to a renewed interest in the management of exhaustible resources from academics as well as from policymakers. In light of the possibility that demand exceeds total supply, at what rate should these exhaustible resources be extracted? When will exhaustible resources be substituted for renewable resources and how will the transition take place? In an attempt to address such issues from an optimal policy perspective, this paper constructs a dynamic model of the world economy that exhibits two production technologies; a resource technology which uses an exhaustible resource as input, and an alternative technology which captures the use of renewable resources. The motivation for modeling two production technologies is that in many real-world applications, a substitute to an exhaustible resource does require a different production technology or production method. For example, one use of tin is tin-plated steel containers for food packaging and preservation, commonly referred to as tin cans. In 2003, a new type of carton package was developed from coated paperboard, and it has become an important substitute for tin cans.[2] The production of food containers from paperboard is quite distinct from production of tin cans and requires an entirely different technology. Hence, both capital and labor must be separately allocated to each of the technologies. Similarly, in the case of fossil fuels, production of energy from solar or hydro power requires a production technology which is quite different from production of energy from oil. This model feature is important, because given that production factors are scarce, the decision of how to allocate capital and labor across technologies could play an important role in determining the equilibrium paths of the use of exhaustible as well as renewable resources.

The main finding of this paper is that both the time path of extraction and technology adoption do depend on the size of the capital stock in relation to the resource stock, and on the optimal allocation of capital across the two technologies. More specifically, if the capital stock is high in relation to the resource stock, the alternative technology is immediately adopted. The two technologies coexist until the resource is abandoned, and there is a complete switch to the alternative technology. If, instead, the capital stock is low, only the resource technology is used initially and the alternative technology is adopted with a delay. The intuition for this result is that if the resource technology is used it is optimal to allocate capital to that technology first, in order to operate it at a constant resource–capital ratio. If the capital stock is initially low in relation to the resource stock, all capital will be allocated to the resource technology until, over time, capital accumulation yields a sufficiently high level of the capital stock that the alternative technology is adopted. Similarly, the time path of resource extraction depends on the relative sizes of capital and resource stocks. If the capital stock is high in relation to the resource stock, resource extraction is decreasing over time. If, instead, the capital stock is low, resource extraction has the shape of an inverse U; it is first increasing and then decreasing. With a low capital stock, part of the resource extraction is deferred to the future when the capital stock is higher and consequently, more capital can be allocated to the resource technology.

The paper also analyzes the effects of industrialization of developing countries on one of our most important exhaustible resources: oil. The term industrialization in this context refers to the process by

[1] Energy Information Administration, www.eia.doe.gov.
[2] The carton package was developed by the company Tetra Pak. For more information, see www.tetrapak.com.