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Research and development and sustainable growth over alternative types of natural resources

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ABSTRACT

This paper develops an endogenous growth model to study how different types of natural resources - namely renewable versus non-renewable - affect sustainable growth and welfare. In a decentralized equilibrium setting, we find that negative growth may occur in an economy endowed with non-renewable resources. To escape from this stagnant growth, the research sector must be highly productive. However, non-renewable resources are not necessarily dominated by their renewable counterparts in terms of resulting output growth and welfare. We also characterize analytically and quantitatively equilibrium paths to evaluate growth and welfare implications resulting from a resource type switch that is caused by an adverse environmental shock.

1. Introduction

Prior to the twentieth century, natural resources, usually comprising primary commodities, played a pivotal role in world trade. Many countries, such as Australia, the United States, and Canada, benefited greatly from significant primary commodity exports in the early stages of their economic development (North and Thomas, 1973; Auty and Mikesell, 1998). However, since the turn to the twentieth century, natural resources have often been treated as less important than labor and capital in generating economic growth and development. Many researchers (e.g. Nankani, 1979; Sachs and Warner, 1997, 2001) even find a harmful impact of natural resource abundance on the economic development path of low and middle income countries. Despite the potential harmful impact of natural resources on growth, Jones (2002) indicates that having very few natural resources does not alleviate this harmful impact of the resource depletion rate on economic performance. In another facet, other researchers (e.g., Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992) point to technological change as the main driver of global output growth in the last century. Observing these perspectives, an important question arising is whether positive growth can be sustained in an economy where there is ongoing technological progress mingled with natural resources (as an essential input) in production.[1] In that respect, it will be interesting to distinguish two cases: when the stock of resources is finite (non-renewable resources) and when the stock of resources can be regenerated (renewable resources). Hence, throughout this article we will try to find a concrete answer to the following questions: (i) Do resource dynamics influence growth in presence of R&D? (ii) What are conditions for having sustained positive balanced growth when natural resources matter? (iii) Which type of resources (renewable or non-renewable) is superior in generating more growth and welfare?

In an attempt to answer these questions, we construct a model of endogenous growth with creative destruction and natural resources. Upon attaining balanced growth paths, we analyze key properties of these equilibrium paths and derive conditions under which the economy obtains permanent positive growth. We also compare the rates of growth and welfare levels across different types of resources. Despite

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[1] Traditional research and development (R&D)-based endogenous growth models such as Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992), Le (2008, 2011) do not offer a satisfactory answer to this question due to the absence of natural resources. In particular, in their models, long-run growth will never go below zero as soon as there exists some form of R&D investment.

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having no transitional dynamics,[2] our model is suitable for our objective due to its simplicity and ease of use which allows us to focus on the performance of resource-rich developed economies and their outcome in the long-run, the period over which sustainability is a highly relevant issue.

In greater details, the model under consideration has two factors of production, labor and natural resources, and four sectors, primary (or resource production), research, intermediate good production, and final consumption good production. The primary sector uses labor to process raw natural resources into materials. Here, both types of resources are considered. Unlike non-renewable resources, those of renewable type have the capacity to grow in size over time to provide productive input to the intermediate good sector. However, the size of the resource stock cannot be enlarged without bound. Specifically, it is endogenously determined by the rate of extraction and the intrinsic growth of the resources themselves. The R&D sector hires labor to improve the efficiency of production inputs. The intermediate good sector purchases designs created in the R&D sector and employs labor together with processed materials obtained from the primary sector to produce intermediate products which are essential for the production of a final consumption good in the final good sector. The analysis is conducted for both cases of renewable and non-renewable resources.

Our main results obtained from the model are as follows. For each type of resources, there exists an optimal balanced growth path. Along these balanced growth paths, while the dynamics of renewable resources do not affect output growth, those of non-renewable resources decelerate it. This is because renewable resources will be optimally extracted to their maximum yield at which the extraction rate is equal to the natural growth of resources resulting in a zero growth of resources at optimal. This process, hence, does not affect output growth. By contrast, the extraction of non-renewable resources functions like a form of disinvestment that reduces the economy's resource wealth. This is the source of potential negative growth in the economy. In order to escape from this possible long-run negative growth, the research sector must be sufficiently productive to make up for the fall in the resource wealth.

Furthermore, long-run output growth is found to be increasing in productivity of the research sector but decreasing in the rate of time preference. While an increase in productivity of resource extraction is always growth enhancing under renewable resources, this is not immediately clear under non-renewable resources. These results can be explained as follows. Because the research sector is the engine of growth in this economy, output growth depends largely on the performance of this sector. Specifically, any improvement in research productivity will lead to a corresponding improvement in output growth. By contrast, a higher rate of time preference makes household value current consumption relatively more than future consumption and, hence, invest less in R&D, resulting in lower output growth. Households will also extract resources faster and, thus, dampen the resource stock more quickly. In the mean time, due to resource firms' optimization, an improvement in resource extraction productivity has the effect of relocating labor from the resource sector to other parts of the economy, including the research activity. Under renewable resources, resource extraction is fully offset by their natural growth so output growth will be higher. However, under non-renewable resources, whether output growth is higher or not depending on whether higher technological progress (due to higher labor allocation) is able to generate enough growth to make up for the amount of more resources depleted (due to improvement of resource extraction technology). This is also the factor causing an ambiguity on the orderings of growth rates and welfare levels under these two alternative resources.

To better visualize the theoretical predictions of the model, we illustrate some of our results with a simple numerical example. This quantitative evaluation suggests that under assumptions on parameter values plausible for a group of resource-rich industrialized countries such as Australia, Canada and the United States, renewable resources seem to be the dominant source of both growth and welfare creation. This welfare result is robust to different values of productivity in the research sector and the resource sector. To accommodate a possible claim that renewable resources may become non-renewable if at some point in time their self-regenerating capacity falls too low, possibly close to zero, we also experiment a hypothetical switch of resource type from renewable to non-renewable that is caused by an environmentally disastrous shock that drives the intrinsic growth rate of resources down to zero, and explore its implications on growth and welfare. We find that with the range of chosen values such a switch is always growth and welfare reducing.

Recently, Business Insider (2012) provides a list of most resource-rich countries in the world. Among the Top Ten, many countries, such as Australia, Brazil, Canada, Russia, and the United States, are shown to have a large reserve of renewable resources (e.g. timber) as well as non-renewable resources (e.g. gold, copper, iron ore). Making the best use of these resources to raise citizens' standard of living and welfare has long been an important item in the agenda of the governments in these countries. The model in this paper is timely and very much in line with that policy goal. Its results certainly help the countries not only forecast more accurately the economic impacts of natural resources and innovation but also choose a right economic policy and pursue every opportunity to increase benefits of their large natural resource reserves. They will also provide significant guidance in terms of assessing the role of natural resources and R&D in promoting an innovation culture, productivity and growth performance of the economy. Despite being mathematically rigorous, several theoretical predictions of the model are readily testable using data.

Linking to the relevant literature, the question of whether natural resources actually play a significant role in enhancing or inhibiting standards of living over time and to what extent and what direction, technological improvement could affect this process has been studied previously by other researchers. In particular, Dasgupta and Heal (1974), Solow (1974) and Stiglitz (1974a, b), among others, examine this issue using a neoclassical framework. They find that in the presence of non-renewable resources, output growth is positive under certain technological conditions. More recently, Grimaud and Rouge (2003), Lafforgue (2008), Stamford da Silva (2008), Peretto and Valente (2011), Acemoglu et al. (2012), Peretto (2012), and Silva et al. (2013) attempt to address the issue based on an endogenous growth setting with R&D. However, these models only focus on non-renewable resources. By extending its investigation to renewable resources as well, this paper is able to consider how the economy behaves differently under different resource types and whether a specific type of resources can generate higher growth than its counterpart.[3]

In a recent paper, Le and Le Van (2016) investigate both renewable and non-renewable resources using a similar R&D-based growth framework. In comparison, this paper differs from Le and Le Van (2016) in several important aspects including our main focus. *Firstly*, while Le and Le Van (2016) focuses more on the issue of social planner's problem and transitional dynamics to the optimal path, this paper pays more atten-

[2] For analytical transitional dynamics in a similar set-up, see Le and Le Van (2016).

[3] To our knowledge, other growth papers study renewable resources include Tahvonen and Kuuluvainen (1991, 1993), Ayong Le Kama (2001) and Suphaphiphat et al. (2015). However, while Tahvonen and Kuuluvainen (1991, 1993) and Ayong Le Kama (2001) employ a neoclassical setting with pollution, Suphaphiphat et al. (2015), despite examining the issue of natural resources in an R&D-based endogenous growth framework, do not consider non-renewable resources. In addition, they focus on the difference between regimes of resource management: open access versus property rights over resources. In our paper, we abstract from pollution externalities and management regimes and provide, instead, a detailed comparison of growth and welfare under alternative forms of resources.