The Quarterly Review of Economics and Finance 59 (2016) 15–24

Contents lists available at ScienceDirect

The Quarterly Review of Economics and Finance

journal homepage: www.elsevier.com/locate/qref

Long-term economic growth under environmental pressure: An optimal path

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ARTICLE INFO

Article history:
Received 9 July 2014
Accepted 27 March 2015
Available online 4 April 2015

JEL classification:
C53
E17
O47

Keywords:
Long-term economic growth
Environmental pressure
Optimal path
Convergence
Divergence

ABSTRACT

This paper presents a model, based on the advance-retreat course (ARC) model (Dai, Liang, & Wu, 2013; Dai, Liu, & Liang, 2013), of long-term economic growth under environmental pressure. The model is used to explain economic convergence and divergence; construct an optimal long-term growth model for basic, emerging and real total output; derive an optimal growth accounting equation; indicate the optimal paths of long-term growth and economic structure change; analyze empirically the growth for U.S. and China. Among the findings are that emerging industries contribute significantly to real output in the long term; that economic diversification can increase real output and promote long-term growth. The paper suggests policy orientations that are needed to avoid economic collapse.

1. Introduction

The economic growth process embodies the economic state and influences the quality of human life. Economists hope to understand and grasp the process and character of economic development through their research on long-term economic growth and then to control any economic fluctuations and ensure long-term economic growth.

There has been much outstanding research in economic growth, such as the real business cycle theory (Kydland & Prescott, 1982; Plosser, 1989), the new economics of growth (Lucas, 1988; Romer, 1986, 1990), the R&D-Based Theory in Economic Growth (Jones, 1995, 1998; Solow, 1956, 1957), long-term convergence and long-term regional economic growth (Barro and Sala-i-Martin, 1992, 1995). In addition, Phelps (1966a, 1966b, 1972) proposes the "Golden Rules of Economic Growth", analyze the relationship among money, public expenditure and labor supply and explains the problems of economic stagflation and the growing unemployment. Pasinetti (1983) presents an original theoretical treatment of the problems of maintaining full employment in a multisector economic system with a growing population and different rates of technical progress in different sectors. Mowery and Rosenberg (1991) demonstrate the importance of a historical perspective in understanding the role of technological innovation in the economy. De La Croix and Michel (2002) provide an in-depth treatment of the overlapping generations model in economics, and they incorporate production into the model. De La Grandville (2009) provides a fascinating introduction to the theory of economic growth and shows how many of the results from this field are of paramount importance for society.

In recent years, economists have become more concerned with the influence of economic environmental factors, such as economic policy, natural resources and labor, on long-term growth and convergence. Maarten (2007) notes that the convergence rate is affected when the intraregional aspects of agglomeration are taken into account. Maasoumi and Wang (2008) investigate economic convergence in China and find that the policies, reforms and other differences in the region will influence the convergence.

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http://dx.doi.org/10.1016/j.qref.2015.03.008
1062-9769/

Dimitrios (2008) discusses how the interactions between capital accumulation, endogenous longevity and environmental quality determine both the long-run growth rate of the economy and the pattern of convergence toward the balanced growth path. Myers (2009) believes that the labor market is interacting with changes in output and production. Fung (2009) tests for convergence in financial development and economic growth; the results show strong evidence for conditional convergence and show that some low-income countries with a relatively under-developed financial sector are more likely to be trapped in poverty. This finding explains the observed "great divergence" between the poor and the rich countries.

The above studies show that environmental factors, including economic structure, policy, natural resources, and capital and labor, can foster both economic convergence and divergence. Indeed, pressure (or resistance) from environmental factors – pollution caused by industrial production, competitive pressures arising from merchandize trade, resource depletion associated with energy consumption, capital and financial risk, etc. – can change the economic growth process. Thus, environmental pressure must be considered when analyzing long-term economic growth.

In another hand, the study of Hill (1997) shows that the concerns about environmental issues and pressure on manufacturing firms to decrease their environmental impact have both intensified since the early 1980s. Lorek (2001) thinks that growing resource consumption goes together with growing environmental pressures and vice versa, although not necessarily proportionally. Azad and Ancev (2010) point out that growing public concern about the health of rivers and wetlands, and the ecosystems they support, puts pressure on large water users-such as the irrigation industry-to find ways to use less water. Erdem (2012) indicates that rapid growth in energy consumption influences on the one hand energy prices and endangers energy supply security; on the other hand, it distresses ecological balances. This means that the challenge for long-growth is increasing, and can also be taken as the increase of environmental pressure. In fact, environmental pressure arises mainly from physical factors, such as environmental disruption and lack of natural resources. However, social factors, such as cultural background, political instability, damage due to war, economic systems, laws and regulations, market structure, financial events, and financial order, also have important effects on economic growth that cannot be ignored. Although some social factors can sometimes play a positive role in promoting growth, over time they may become not apply to economy and create environmental pressures that impede social progress and economic growth and cause reduced output. Social and economic change can not only improve the efficient use of natural resources and the natural environment but also perfect or improve social factors, and the more that social factors and resources accumulate, the more complex they become. Therefore, a consideration of the economic effects of environmental pressure should include both natural and social environmental pressure. The existing literature has focused on the former.

Concerning environmental pressure and its impact on the economy and combining both types of environmental pressure in a model of economic growth, this paper discusses long-term economic growth under environmental pressure; presents an optimal growth model and uses it to illustrate optimal economic structure and show the optimal path of long-term growth; analyzes convergence and divergence in long-term growth; and studies empirically the U.S. and China's economic growth. Most importantly, the paper shows that emerging industries contribute significantly to real output, that economic diversification leads to increased real output and long-term growth, and that divergence ultimately arises in response to environmental pressure.

2. Foundation

2.1. Categorized production function

Industries can generally be divided into two categories: *traditional* and *emerging*. Traditional industries are those that mostly involve labor and basic manufacturing, while emerging industries are those that mostly involve new science and technology. Traditional industries require large quantities of labor and equipment – resources that constitute the foundation of traditional industry. In a traditional industry, capital often takes a material form (e.g., equipment or buildings), while labor involves the efforts of workers with standardized skills. Technological progress is measured by the technologies embodied in capital equipment, final goods and services. Traditional industries usually employ advanced processing techniques and complete equipment systems and enjoy stable product markets. Traditional industries often require a higher cost of capital and better technology. In addition, technology levels in traditional industries tend to remain stable for long periods of time. In contrast, powerful technology is fundamental to emerging industries. In an emerging industry, capital may take a material or immaterial form; it may include equipment, patents, software, intangible assets and workers with standardized professional skills. Technology develops rapidly in emerging industries; thus, overall technological levels tend to evolve quickly.

For the sake of convenience, capital inputs will be expressed as the value of capital required in production, labor inputs as the number of workers required in production and technology inputs as the cost of research and development. Thus, the production function (Barro & Sala-i-Martin, 1995; Solow, 1956, 1957) for an economy can be expressed as $Y = A \cdot F(K, L)$, where Y is GDP, K is capital, L is labor, and A is multifactor productivity. For given quantities of capital and labor, improvements in technology will yield increased output. Thus, economies with more advanced technology exhibit greater productive efficiency.

Because capital, labor and technology change over time ($K = K(t)$, $L = L(t)$, $A = A(t)$), the technology level $A(t)$, assuming differentiability, can also be expressed as $dA(t)/h(t)$; thus, $A(t) = \int h(t)dt = H(t) + a$, where a is a constant. Therefore, output can be expressed as:

$$Y = Y_1 + Y_2 \tag{1}$$

where $Y_1 = a \cdot F[K(t), L(t)]$ and $Y_2 = H(t) \cdot F[K(t), L(t)]$. In Model (1), the technology level associated with output $Y_1 = a \cdot F[K(t), L(t)]$, a, is a constant, signifying a stable technology level, which is a characteristic of traditional industries. Therefore, Y_1, the output of traditional industries, is referred to as basic output. The technology level associated with output $Y_2 = H(t) \cdot F[K(t), L(t)]$, $H(t)$, is a function of time, signifying that the level of technology is variable, which is a feature of emerging industries. Therefore, Y_2, the output of emerging industries, is referred to as emerging output. We refer to model (1) as the *categorized production function* (CPF) for traditional and emerging industries, where $A(t) = H(t) + a$ is categorized total factor productivity. Model (1) indicates that traditional industries have two inputs, capital and labor, whereas emerging industries have three inputs, capital, labor and technology. Model (1) can be concisely expressed as:

$$Y = \mu + \sigma$$

where $\mu = a \cdot F[K(t), L(t)]$ is the production function for traditional industries, $\sigma = \mu \cdot q(t)$ is the production function for emerging industries, and $q(t) = H(t)/a$ is the ratio of the technology level of emerging industries to that of traditional industries, indicating the degree of innovation, or *innovation efficiency*, of the former. Innovation efficiency is a dimensionless quantity that expresses the advantage in productive efficiency of emerging over traditional industries. Here,