Energy 67 (2014) 213–222

Contents lists available at ScienceDirect

Energy

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

Energy substitution effect on transport industry of China-based on trans-log production function

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ARTICLE INFO

Article history:
Received 10 August 2013
Received in revised form
15 December 2013
Accepted 18 December 2013
Available online 22 January 2014

Keywords:
Transport industry
Trans-log production function
Elasticity of substitution

ABSTRACT

China is currently in the stage of industrialization and urbanization, which is characterized by rigid energy demand and rapid growth of energy consumption. China's transport industry is of high energy consumption and high pollution. Therefore, energy issues in the industry are particularly of concern to all parties. In this paper, a trans-log production function model for China's transport industry is established and input factors of capital, energy and labor are included. Output elasticity of each factor and substitution elasticity between the variables are analyzed. Results show that: during the period 1980–2010, there is a relatively high elasticity of substitution (the value is around 1.05–1.07) between energy factor and labor factor in China's transport sector; significant elasticity of substitution between capital factor and energy factor exists as well (the value is about 0.98–1.00). It suggests that the substitution between energy and labor could be achieved by continuously upgrading technology. Through allocating more capital into transport industry, relevant energy saving technology could be continuously promoted and the substitution between capital and energy will also be realized. The transition of Chinese transport industry from labor-intensive to capital-intensive is a significant trend.

1. Introduction

Transport industry is an important sector of China's economy. It is notable that China's current transport industry is of high energy consumption and heavy pollution. Transport is one of the most challenging sectors when addressing energy security and climate change due to its heavy reliance on oil products and lack of alternative fuels [34]. Globally, the transport industry accounts for 61% of world oil consumption and about 28% of total final energy consumption in 2007 [25]. Particularly, energy use in transport industry is growing rapidly in emerging countries, such as China and some parts of Latin America [53]. The transport sector, a major oil consumer and greenhouse gas (GHG) emitter worldwide, is the most rapidly growing sector in terms of energy, particularly oil demand, and GHG emissions in China. Petroleum consumption in China's transport industry reached 98 Mtoe (million tons of oil equivalents) in 2005, 21 times that of 1980 [2]. Rapid growth of road vehicles, private vehicles in particular, has resulted in continuing growth in China's oil demand and imports, which has been widely accepted as a major factor affecting future oil availability and prices, and a major contributor to China's GHG emission increase [54].

In the 1980s, transport was a constraint to China's economic development. From the beginning of the 90s, China began to build transport infrastructure vigorously, and since 1998, the newly introduced fiscal policy facilitated the development of all kinds of transport infrastructure even further. After ten years of continuous development, China's transport infrastructure and economic growth start to develop in a coordinated way. As a matter of fact, energy demand in China's transport industry increased from 25.2 Mtoe in 1980 to 191.2 Mtoe in 2007, indicating an average annual growth rate of 7%, and making transport the fastest growing energy consuming sector in China. Rapid growth in energy use has resulted in rising proportion of transport's energy consumption in the country's total energy consumption [19]. According to the results of Wang [48]; energy consumption in transport accounted for 6.1% of the country's total energy consumption in 1980; while the figure rose to 10.2% in 2007.

Asia Pacific Energy Research Centre (APERC) provides the total consumption of oil products (unit: kilo-tons of oil equivalent, hereinafter referred to as KTOE) in transport industry of China over 1980–2010. Oil consumption in transport industry and its share in total oil consumption of China are shown in Fig. 1. From the figure,

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0360-5442/$ – see front matter
http://dx.doi.org/10.1016/j.energy.2013.12.045

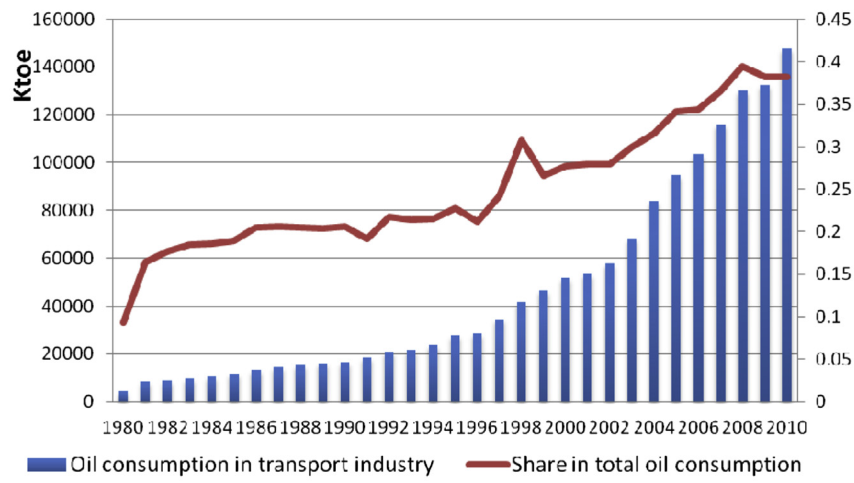

Fig. 1. Oil consumption in transport industry and its share in total oil consumption of China (1980–2010).

it is clear that the share of oil consumption in transport industry in total oil consumption of China was no more than 10% in 1980, but rose rapidly to about 40% in 2010.

With the deepening of the urbanization and industrialization process, the rising income of urban and rural residents has brought the 'motorization phenomenon' into daily life [7]. Based on the history and present status, a basic judgment is made on the developing trend of Chinese transport sector: energy consumption in China's transport industry may probably still maintain a rapid growth for quite a long time. According to the '*Twelfth Five-Year Plan*', China's GDP will maintain an average annual growth rate of 7% and urbanization rate will increase from 47.5% to 51.5%; [32] accordingly, the traffic demand of passenger and freight will experience sustained growth. Toward the end of the '*Twelfth Five-Year Plan*', passenger and freight transport of highway are planned to reach 40 billion people and 30 billion tons, respectively; and transport of passenger and freight of civil aviation will reach 450 million people and 9 million tons, respectively. Freight handling capacity along the east coast and inland waterway will reach 7.8 billion tons and 3.85 billion tons, respectively. Meanwhile, transport safety is pushed to a higher level due to the improvement of people's livelihood, social stability and national security.

Therefore, the optimization of transport structure, the setting up of a comprehensive transport system and the construction of transport support capacity become especially important. In addition, it is also important to note that China's transport industry currently has a big problem: it is labor-intensive, high energy consuming and produces heavy pollution. Thus, the development of transport industry means a lot for the transition of China's economic development model.

Substitutability between energy and the other factors (i.e., labor and capital) is important to energy policy in industries, planning and analysis. Estimating the degree of substitution between production factors such as energy and non-energy inputs is crucial for a host of issues, including environmental and energy policies such as trading greenhouse gas emission allowances, recycling energy tax revenues to reduce output or non-energy factor taxes, and the step-by-step increase of fuel taxes [14].

The literature on the substitutions between energy and other factors in China is limited. However, for policy purposes, it is useful to have an indication of energy-other factor substitution, substitution possibilities for specific industries and, in particular, industries that are large consumers of energy, such as the transport industry. As a result, in this paper, we adopt the trans-log production function model to study the input factors of China's transport industry. The trans-log production function model was first introduced by Christensen et al. [9]; but energy was not regarded as an input factor until recent years. An improvement was made by introducing energy factor into this classical economics model and analyzing energy issues in specific industries. In this paper, output elasticity of each input factor is calculated. Most important of all, substitution elasticities of these factors are also provided. Understanding of the substitutional relationship between the factor pairs is crucial for optimizing the development model of transport industry and improving its development quality.

This paper is structured as follows. The second part introduces relevant literatures. The third part introduces research methods, describing the trans-log production function model, deducing and describing output elasticity of input factors and the substitution elasticity of these factors. In the fourth part, all the selected indicators and their data sources and processing procedure are described in detail. In the fifth part, the ridge regression results of each variable in the transcendental logarithmic production function are provided, and the output elasticity and substitution elasticity between the variables are also calculated. The sixth part is a conclusion of the article and provides some policy suggestions for the development of China's transport industry.

2. Literature review

Since the seminal study by Berndt and Wood [5]; the substitutability between energy and capital has been a consistent topic of discussion and research. Berndt and Wood [5] asserted that energy and capital complement one another in US manufacturing. However, Griffin and Gregory [17] refuted the conclusion and posited the energy–capital hypothesis, suggesting that inherently there exists substitutability between energy and capital. Pindyck [39], Griffin [16], Truong [47], Thompson and Taylor [46], Christopoulos [10], Bentzen [3], and Koetse et al. [27] offered support for this energy–capital hypothesis. However, Fuss [15], Berndt and Khaled [4], Berndt and Wood [6], Anderson [1], Denny et al. [11], and Prywes [40] attempted to refute these positions, siding with the position held by Berndt and Wood [5]. Currently, there is still no