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Estimation of inter-fuel substitution possibilities in China's transport industry using ridge regression

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ABSTRACT

The transport industry is a key driver of the rapid growth of oil demand in China. It accounted for 38.2% of total Chinese oil consumption in 2010, and is consequently a major contributor to greenhouse gas emissions and other pollutants. In order to estimate the potential to lower Chinese dependence on oil and reduce carbon dioxide emission, this study has investigated the potential for inter-fuel substitution between coal, oil, natural gas and electricity in China's transport industry over the period 1980–2010, by employing a log linear translog production and cost function. A ridge regression procedure was adopted to estimate the parameters of the function. Estimation results show that all energy inputs are substitutes, and indicate higher substitution possibilities between oil and natural gas relative to other energy input pairs. Furthermore, the substitution elasticity between oil and electricity in the transport sector is increasing significantly over time. Understanding of the substitution relationship among different fuels is crucial for making relevant policies for optimizing the development mode of Chinese transport industry.

1. Introduction

The transport industry is an essential sector in the operation of a market economy and also plays a significant role in shaping income distribution [14]. However, the transportation sector is also responsible for a large share of energy use [20] and is one of the most challenging sectors when considering energy security and climate change due to its high reliance on oil products and lack of credible alternative fuels [17]. Furthermore, energy use in the transport industry is growing particularly quickly in the fastest developing countries such as China [37]. It is also the most significant sector in expediting environmental degradation among all other economic sectors [23] and has become great challenge to global climate change [7]. Overall, despite its economic importance, transport is one of the major contributors to the depletion of fossil fuels, the degradation of the environment and the deterioration of human health [2].

Though it contributed merely 4.8% of the whole country's GDP in 2010, it accounted for 38.2% of total oil consumption in the same year. The APERC (Asia Pacific Energy Research Center) provides the total consumption of oil products (unit: kilo-tons of oil equivalent, hereinafter referred to as KTOE) in the Chinese transport industry from 1980 to 2010, as shown in Fig. 1, presenting the growth of the transport share of oil consumption from less than 10% in 1980 to almost 40% in 2010. Rapid uptake of road vehicles, particularly private vehicles, has driven this growth.

Based on the history and present status it seems likely that Chinese transport sector energy consumption will maintain grow rapidly for quite a long time [3]. According to the '*Twelfth Five-Year Plan*', Chinese central planners are now aiming to 'rein in' the economy to an average annual growth rate of 7% for the period 2011 to 2015 – still a very high rate compared to western levels (According to World Bank, GDP growth rate of China in 2013 was 7.7%. In the same year, this number was merely 1.9% for United State; 1.7% for United Kingdom; 0.1% for European Union.). Accordingly, the demand for passenger and freight transport is likely to maintain sustained growth. As this growth continues it will be a major factor effecting future global oil demand and prices [38].

This large and increasing oil consumption also has important climate change implications. Based on CO_2 emission coefficients of different kinds of fossil energies (oil products, coal and gas) provided by the Intergovernmental Panel on Climate Change (IPCC, 2006), CO_2 emissions from fossil energy used in China's transport industry during the period over 1986-2010 are obtained. An

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Nomenclature

Y_t	output at time t
α_0	the state of technical knowledge
X_{it}	input i at time t
X_{jt}	input j at time t
α_i, α_{ij}	technologically determined parameters
L_t	input of labor at time t
K_t	input of capital at time t
C_t	input of coal at time t
O_t	input of oil at time t
NG_t	input of natural gas at time t
E_t	input of electricity at time t
η_{it}	output elasticity of the ith input at time t
σ_{ij}	substitution elasticities between inputs i and j

overview on total energy consumption and CO_2 emissions in transport industry is given in Fig. 2.

Both total energy consumption and CO_2 emissions have experienced rapid growth during the period over 1986–2010, with an annual growth rate of 7.8% and 7.2%, respectively. As of 2010, total CO_2 emissions from transport in China are as large as the entire CO_2 emissions of the UK economy [11]. This makes efficiency improvement and control of emissions in the transport industry a high priority. An initial trend in Fig. 2 is encouraging; the growth rate of CO_2 emission is bit lower than that of energy consumption, indicating an improvement (in climate change mitigation terms) of the energy structure over time.

In this context of the economic and environmental importance of China's transport sector, the potential for inter-fuel substitution between coal, oil, natural gas and electricity in China's transport industry is a worthy research topic. This paper presents such an analysis over the period of 1980–2010, and is structured as follows: Section 2 introduces relevant literature. Section 3 introduces research methods, presenting a discussion of the model. Section 4 gives a description of the dataset used in this study. All the selected indicators and their data sources and processing procedure are described in detail. Section 5 presents the empirical results and discussion. Section 6 draws the conclusion and draws insights on the development of China's transport industry.

2. Literature review

The literature on energy-other factor substitution in China is limited, and the possibility of substitution between energy and

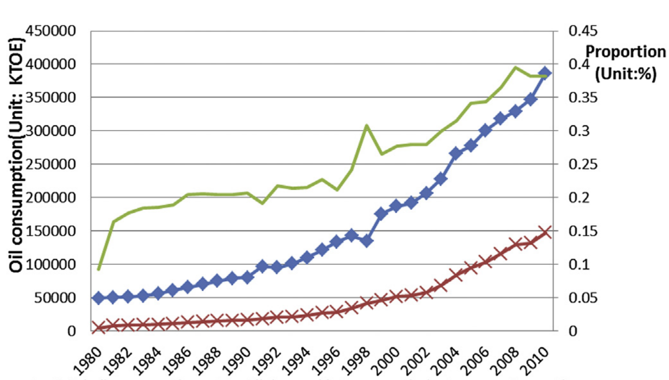

Fig. 1. Oil consumption in the transport industry and its share in the total oil consumption of China from 1980 to 2010 (Unit: KTOE).

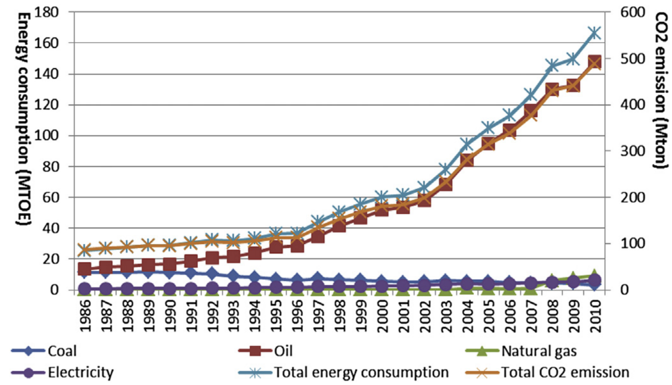

Fig. 2. Total energy consumption and CO2 emission in transport industry.

other factors have been ignored by most Chinese scholars of energy economics [29]. The literature on estimates of inter-factor and inter-fuel substitution possibilities of energy demand for China is almost non-existent [19]. The few papers that do exist (e.g. [8]) say little about factor substitution between energy and non-energy factors and rarely consider technological effects on change in energy intensity. Also, studies on inter-fuel substitution in China have received limited attention.

Worldwide, more attention has been paid to this topic. For example, [27] used the locally flexible translog functional form to investigate the demand for energy and inter-fuel substitution in the United States and revealed the limited ability to substitute one source of energy for another, suggesting that fossil fuels will continue to maintain their major role as a source of energy in the near future. [28] also investigated inter-fuel substitution for a number of OECD (Organization for Economic Co-operation and Development) and non-OECD countries by taking a flexible functional form approach. [1] examined fuel substitution possibilities in industrial energy demand using data on eight of the OECD countries for the period 1978–2008. Energy substitution in particular sectors is also starting to draw attention. Ref. [6] focused on substitution in the electric power industry of the eastern US, and Ref. [15] investigated the potential substitution among energy, capital, and labor in Chinese transport industry by employing a translog production and cost function.

Elasticities of substitution among different inputs (energy, capital and labor for instance) have been investigated by a considerable number of authors employing various empirical methods. The empirical production function literature is large, but early studies generally did not include energy as an input factor. This has changed considerably since the first oil crisis, and the number of studies that provide empirical evidence on capital-energy substitutability has grown rapidly. Empirical studies that include both capital and energy as input factors apply either a CES (constant elasticity of substitution) or a flexible production function to estimate a substitution parameter [13]. In contrast to a CES production function, flexible production functions make no restrictive assumptions on the estimated substitution elasticities. Due to flexibility of the specification, a tractable methodology, satisfaction of desired properties of production and cost functions, the most used method of estimating these elasticities in the field of energy economics studies has been the use of transcendental logarithmic cost functions (translog), introduced by Ref. [5], and then developed by Ref. [22] and many others.

Generally, as Ref. [25] suggested, the evidence on inter-fuel substitution from existing studies is mixed, and it should be noted that there are many methods which have been used to estimate inter-fuel elasticities of substitution (e.g. [26]). In Ref. [32]