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Economic growth with coal, oil and renewable energy consumption in China: Prospects for fuel substitution

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ABSTRACT

We examine the relationship between Chinese aggregate production and consumption of three main energy commodities: coal, oil and renewable energy. Both autoregressive distributed lag (ARDL) and vector error correction modeling (VECM) show that Chinese growth is led by all three energy sources. Economic growth also causes coal, oil and renewables consumption, but with negative own-price effects for coal and oil and a strong possibility of fuel substitution through positive cross-price effects. The results further show coal consumption causing pollution, while renewable energy consumption reduces emissions. No significant causation on emissions is found for oil. Hence, making coal both absolutely and relatively expensive compared to oil and renewable energy encourages shifting from coal to oil and renewable energy, thereby improving economic and environmental sustainability.

1. Introduction

Climate change, geopolitical tensions and recent nuclear accidents have increased concerns about energy supply security and environmental impacts associated with energy production and consumption. As a result, several countries are currently proposing strong energy substitution policies and radical energy conservation measures. In this setting, it is important to assess the prospects for the success of those policies, including potential impacts on economic growth (Goldemberg and Lucon, 2010).

Despite the emergence of a bourgeoning literature on the nexus between energy consumption and economic growth, consensus remains elusive. Some of the probable reasons for not having any consensus in this area are using different data sets, alternative econometric methodologies and different countries' diverse characteristics (Ozturk, 2010).

Studies identifying the relationship between energy consumption (both at aggregate and disaggregate levels) and output primarily take two different approaches. The *supply-side* approach analyzes the contribution of energy consumption in economic activities within the traditional production function framework (see, Oh and Lee, 2004; Stern, 2000). The *demand-side* approach analyses the relationship between energy consumption, gross domestic product (GDP) and energy prices in a tri-variate energy demand model (see, Asafu-Adjaye, 2000; Rafiq & Salim, 2009). All previous studies in this field follow one or the other of these two approaches and, on that basis, devise energy conservation policies. Application of both models concurrently potentially provides more robust estimates and more meaningful policy implications.

Fuel substitution is an energy policy instrument that can enhance sustainable development. To reduce global warming many countries are considering substituting oil, natural gas or renewable energy for coal, as coal exerts the most detrimental impact on environment. Hence, an empirical study analyzing this substitution prospect is warranted. To undertake meaningful policy insights in this regard this paper includes coal, oil and renewable energy in applying a combined *supply-side* and *demand-side* approach to Chinese data. We then discuss the possibilities for energy conservation and fuel substitution between coal, oil and renewable energy. Coal and oil have been selected as they are two major energy sources for the Chinese economy right at this moment and both have good price data available. Although prices of renewables are not available, we have included renewables consumption data and endeavor to infer the substitution possibilities.

Why is China a suitable case study? China has been on the 'news' for its spectacular GDP growth as well as high energy demand (particularly crude oil and coal) in recent years. China is the largest producer and consumer of coal in the world, and accounts for almost half of the world's coal consumption. Oil consumption in China is growing very fast in recent years and China is the second-largest consumer of oil behind the United States (EIA, 2014). Also China is widely blamed for its high pollutant emission by media and civil societies all around the world. Based on the amount and growth potential of demand for energy

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in the Chinese economy, it is now time to search for causal relationships between various forms of energy consumption and national output (GDP) in China and also for possible substitutability among the three major energy sources for environmental sustainability, coal, oil and renewables.

This paper adds two distinctive contributions to the existing literature. First, this is one of the very first papers to investigate the growth, energy and emission linkage in China by including oil, coal and renewable energy consumption to reach to robust energy conservation policy implications. Second, we examine fuel substitution relationships in China using advances in time-series methodology.

The rest of the paper is structured as follows. The next section presents an overview of the energy consumption profile of China. The third section provides a summary of findings on the relationship between energy consumption and economic growth in the last decade, Section 4 introduces the theoretical framework used in this paper, while a description of data sources and methodologies is presented in Section 5. Section 6 presents the empirical results. Conclusions and policy implications are given in the final section.

2. Energy consumption in China: an overview

The Chinese economy has experienced phenomenal growth over the last three decades. Since the initiation of market reforms in 1978, China's growth has been about 10% per annum (World Bank, 2013). Being the world's most populous country with a population of over 1.3 billion, this rapid economic growth has enabled China to lift more than 600 million people above the absolute poverty level. However, with strong economic growth, China's demand for energy, particularly for coal and oil has been surging, as has China's pollutant emission (Fig. 1). According to British Petroleum [BP] (2013), in 2012, China is the largest consumer of coal in the world and also the second largest consumer of crude oil with 50.3% and 12.1% of the world total, respectively (see Table 1).

Crompton and Wu (2005) show that China consumed 31.0% of the world's coal, 7.6% of oil, 10.7% of hydroelectricity and 1.2% of world's total gas in 2003. More recent data reveal that the consumption figures for all these types of fuels have increased dramatically. For example, China accounted for 50.3% of the world's coal consumption, 12.1% of oil consumption, 24.1% of hydroelectricity consumption and 4.8% of gas consumption in 2013 (Appendix Table 1). The growth of output and energy consumption has environmental consequences, with enormous increases during this period in pollutant emission.

According to Fig. 2, China's coal production and consumption have been pretty much equal over the years. However, the gap between China's oil consumption and production is increasing, resulting in an increasing trend in oil imports since 1993. With respect to pollutant emission, oil is a better alternative source of energy than coal. Hence,

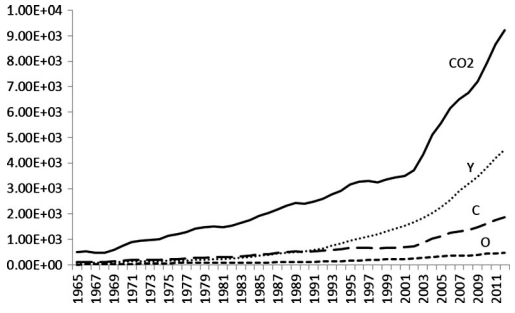

Fig. 1. Real GDP, coal, oil and renewable energy consumptions, and carbon emission scenario in China. Note: Real GDP is in billion US 2005$; coal, oil and renewables consumptions are in tonnes of oil equivalent; carbon emission is in million tonnes of carbon dioxide. Real GDP data is taken from World Development indicator; coal, oil, renewables consumption and emission are from BP.

Table 1
Socio-economic and oil consumption fact sheet (2013) of China.
Source: Data of all the indicators except energy consumption is found from World Development Indicator by World Bank while coal, oil and renewable energy consumption data are from BP Statistical Review, 2014.

Indicator(s)	Quantity
Population, total (millions)	1357.38
Percentage of world population	19.05%
GDP (constant 2005 billion US$)	4864.00
Percentage of World GDP	8.69%
GDP growth (annual %)	7.67%
Coal consumption (million tonnes of oil equivalent)	1925.3
Percentage of world coal consumption	50.3%
Growth in coal consumption	4.0%
Oil consumption (million tonnes)	507.4
Percentage of world oil consumption	12.1%
Growth in oil consumption	3.8%
Renewable electricity generation (quadrillion BTU)	7.782
Percentage of world renewable electricity generation	18.13%
Growth in renewable electricity generation	3.47%

substitution between coal and oil may help reduce the rate of increase in pollution emissions. Further, any substitution from both of these fossil fuels to renewable energy is truly welcome for its positive influence on pollution and exhaustion of non-renewable energy sources.

China substantially subsidizes energy prices to end users (Haley and Haley, 2008). Chinese retail prices for energy products are regulated according to location and the type of consumers. The government maintains domestic price ceilings on finished energy products that are not consistent with the soaring international energy prices over the past decade. In particular, oil refineries get government subsidies to ease the gulf between low domestic prices compared to international energy prices.

The Chinese government has prioritized the expansion of natural gas-fired and renewable power plants as well as the electricity transmission system to connect more remote power sources to population centers (EIA, 2014). For example, the Three Gorges Dam hydroelectric

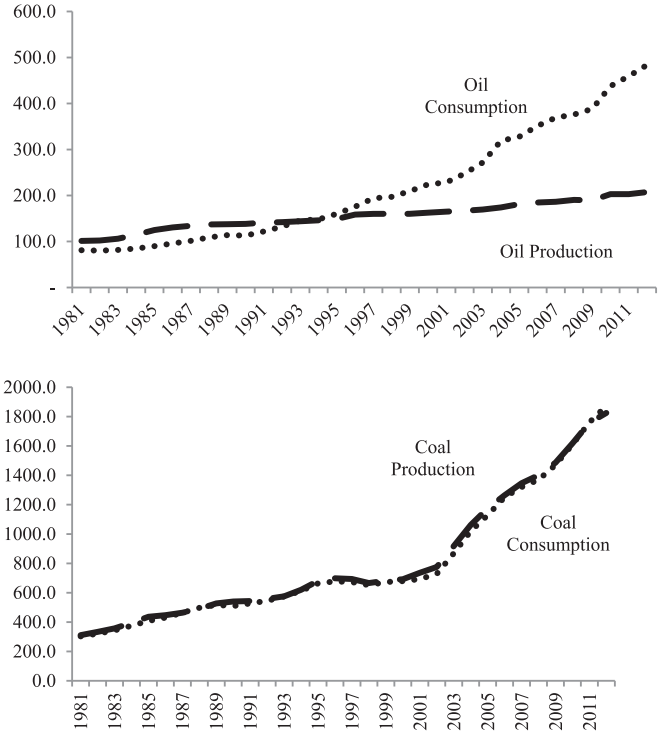

Fig. 2. Coal and oil production and consumption scenario of China, 1981–2012. Source: BP (2013).