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Structural decompositions of energy consumption between 1995 and 2009: Evidence from WIOD☆

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ABSTRACT

Energy is key to achieving sustainable development. This paper explicitly distinguishes between the supply side of energy consumption and demand side of energy consumption, and investigates the factors that affect the energy consumption across economies. Using data from the World Input-Output Database (WIOD), this paper decomposes the relative changes of energy consumption into intensity effect, production structure, structural change in final demand, total final demand effect and household consumption. Then it further decomposes production structure into inter-industry structural effect, and trade effect in intermediate inputs. Overall, energy consumption growth is mainly driven by total final demand (55.04% increase at the world level), but can be significantly reduced by intensity effect due to technological change (21.02% decrease at the world level). There is heterogeneity of structure related effects across economies and within the same economy in both aspects of energy consumption. In addition, the trade effect and household effect are relatively small. This paper provides an empirical framework for analyzing energy consumption in a globalizing world, and suggests tailored and integrated energy policies.

1. Introduction

Development faces a fundamental dilemma. The development initiative proposed by many governments and international organizations has pledged to provide better living standards to people without discrimination or exclusion, for instance, the United Nations MDGs and SDGs (United Nations, 2000, 2015). The process of improving living standards is closely associated with material well-being, which in turn necessitates continuous improvements and expansion in industrial production, resulting in increasing energy consumption and high externalities such as harm to human health and climate change (Allcott and Greenstone, 2012), particularly in developing countries. Global energy use (kg of oil equivalent per capita) and CO2 emissions (kt) rose by 17.4% and 46.4% from 2000 to 2014, respectively. Meanwhile, the growth in China was 148.8% and 202.2%, respectively.[1] There has been an increasing concern about whether consumption is excessive (Arrow et al., 2004). If – given the heavy dependence on fossil fuels and the context of climate change – the relationship we currently observe between energy consumption, emissions and material well-being persists, developing less developed countries implies a trend in energy demand that is unsustainable.

Notable efforts have been made by policymakers across the world in this regard, for example, the EU 2020 strategy (European Commission, 2010) and the Paris Agreement. Since 2004 the Chinese government has launched a series of national programs to reverse the rising trend of energy intensity at that time, e.g., China's 11th Five Year Plan (2006–2010) and the 12th Five Year Plan (2011–2015). Through the national programs, China has made substantial progress in energy efficiency, but challenges, institutional constraints and implementation deficiencies remain, which will require great policy efforts (Andrews-Speed, 2009; Price et al., 2011; Wu et al., 2017). Also, the existing policies should be revised or strengthened to suit the changing socio-economic circumstances. When designing or revising energy policy, it is of primary importance to have a good understanding of energy consumption dynamics, namely, understanding the influencing factors that drive changes in energy consumption (Ang, 2004). This is the goal of

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[1] Data source: World Development Indicators, the World Bank.

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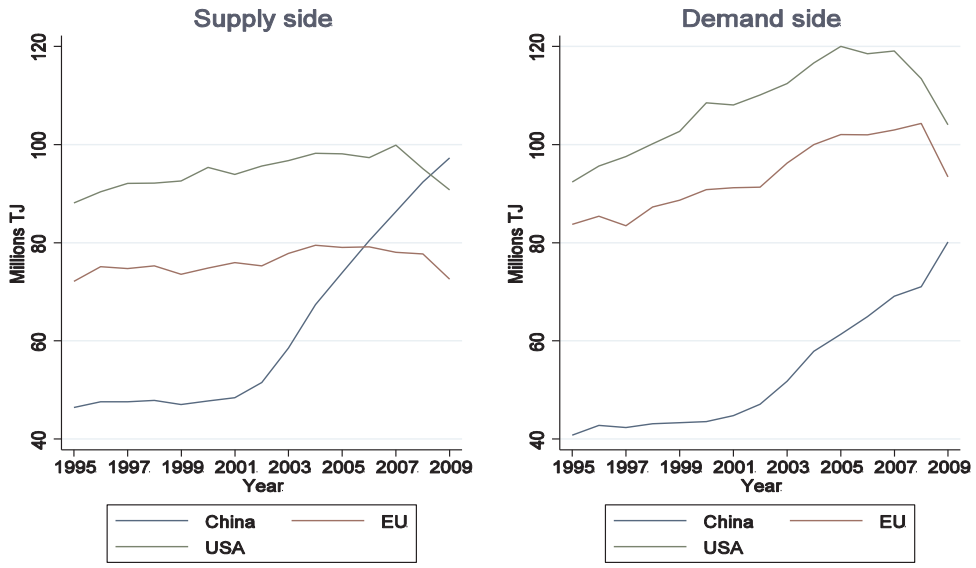

Fig. 1. Supply side and demand side energy consumption of selected economies, 1995–2009.
Source: Own elaboration using WIOD data

the current paper.

This paper investigates a number of major economies in a globalizing world where production, consumption and emissions may happen across sectoral and national borders. This is done by integrating the complex trade relations between sectors and economies in the analysis, namely, the Structural Decomposition Analysis (SDA), which makes this paper depart from the extensive literature on energy consumption factors that focuses on a certain sector or economy.

Due to international fragmentation and offshoring of production across borders (Grossman and Rossi-Hansberg, 2008; Timmer et al., 2014), a certain economy may consume more products than it can produce. The implication is that the energy embodied in the products the economy consumes may exceed the amount used in its own production. Therefore, it makes sense to consider two different perspectives about where energy consumption should be attributed: (1) supply side of energy consumption (production-based accounting) and (2) demand side of energy consumption (consumption-based accounting).

The first perspective, which is the easiest to apply given the way in which international statistics are collected, is to allocate energy to production. In this view, energy consumption is attributed to the country where energy is actually used, either in the production of goods and services, or directly by end-users. The second perspective is to allocate energy embedded in the products consumed by sectors and households. This is a perspective that is taken in the calculation of "energy footprints", which is similar to the concept of emissions embodied in trade.[2] Here, it does not matter where a good is produced, and hence where the energy is actually used, but it matters where the goods (or services) that use energy are consumed. A simple example illustrates the difference between these two perspectives in Fig. 1. As China has become "the factory of the world", it seems likely that an important part of the energy that is used in manufacturing in China actually leaves a footprint in many other countries, to which China exports goods.[3] Although China's supply side energy consumption started to accelerate in 2001 and had already overtaken that of the EU and USA, China still consumed much less energy on the demand side.

The distinction is captured here by distinguishing between supply side of energy consumption and demand side of energy consumption. In the input-output framework, the relative changes of supply side and demand side energy consumption are decomposed into six contributing factors separately: intensity effect, inter-industry structural effect, trade effect in intermediate inputs, structural change effect in final demand, total final demand effect and household consumption effect. These factors describe different stages of economic activities in the economy. A certain factor may affect the two dimensions of energy consumption differently. This paper investigates how the aforementioned six factors affect both dimensions.

The current paper wants to contribute to a better understanding of energy consumption dynamics by outlining the salient trends, over the last decade and a half. The backward-looking perspective is not intended to be used for extrapolation, or prediction of future trends for any specific sector or economy. Instead, the analysis looks at past trends and reveals the stylized facts, in order to identify which trend-breaks are necessary for policymakers to focus on. The results in this paper can provide useful information for tailored and integrated energy policy concerning technological change and structural change (inter-industry, trade and consumption).

2. Factors driving energy consumption and intensity

There is extensive literature on the factors driving energy consumption and intensity using different decomposition approaches. One strand of literature has been applying production function with various inputs to decompose the dynamics of energy (Wang et al., 2017c) or emissions, e.g., sulfur (Stern, 2002, 2006). Wang et al. (2017c) decompose China's provincial energy productivity into effects due to technical progress, technical efficiency, scale, factor substitution and random differences. Though the magnitude of effects varies, they emphasize the overwhelming influence of

[2] For example, Hertwich and Peters (2009), Kanemoto et al. (2012, 2014), Wiedmann et al. (2007), Xu and Dietzenbacher (2014).

[3] These two perspectives are similar to the production- and consumption-based accounting in CO_2 emissions presented by Chang (2013).

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