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Drivers of rising global energy demand: The importance of spatial lag and error dependence

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ABSTRACT

This paper analyzes key factors that led to rising global energy demand in recent decades. In addition to income and price elasticities traditionally examined, this research takes into account the effects of structural, demographic, technological and temperature changes on energy demand. Using newly developed panel data techniques allowing for spatial error and/or spatial lag dependence, this research finds evidence for the existence of spatial lag dependence, a positive but declining income elasticity, a negative price elasticity, and the significant effects of industry/service value added, urbanization and technical innovations on energy demand. This research has important implications for public policies that aim to encourage energy savings, develop service sector and promote energy-efficient technologies towards a sustainable energy future.

1. Introduction

Over the past decades, rapid economic growth in the world economy, especially emerging economies, has spurred energy consumption considerably, putting unprecedented pressure on achieving energy-saving. This research aims to identify the key drivers of rising global energy demand in the past decades.

Increases in per capita income and changes in lifestyles have fueled consumption of cars, refrigerators and other heating and cooling, lighting appliances, and intensive uses of transportation services nationally and internationally in recent years, for which more energy is undoubtedly required. Businesses need more energy for their production and delivery in each country to meet growing demand for goods and services. Developed countries still need huge amounts of energy to maintain their existing lifestyle. Middle income countries such as China rely on enormous amounts of affordable energy provision for their growing economies. The 2010 World Energy Outlook [16] predicts that world primary energy demand will increase by 36% between 2008 and 2035, or 1.15% per year on average, and world demand for oil, often used to proxy the world demand for energy, will increase from 2000 Mtoe(million tons of oil equivalent) to 17,000 Mtoe in 2035.

Substantial research has been undertaken to examine the relationships between energy demand and some key economic factors such as income level and energy price. However, not enough consideration has been given to the influence of demographic, structural, technological and temperature changes on energy demand. Does urbanization exert a distinctive and empirically verifiable impact on energy consumption? How important is technological progress for the levels of energy consumption? How significant is temperature for the rising energy consumption? This research examines the effects on energy demand of energy price, income per capita as well as structural, demographic, technological and temperature changes, mainly using annual data between 1980 and 2009 for an OECD sample of 24 countries.

This research makes use of the CCE (Common Correlated Effect) approach due to [33]; further developed by Refs. [6,19] and [37]. The CCE approach is to estimate the heterogeneous panels with a multifactor structure that assumes that the cross section error dependence can be caused by a finite number of unobserved common factors. This research uses the CCE approach to estimate an extended model that allows for spatial lag dependence, in additional to spatial error dependence. This research provides evidence for the existence of spatial lag dependence, and a positive but declining income elasticity, and a negative price elasticity of energy demand. It also finds that more industry value added and urbanization raise energy demand, while the developments of service economies and technical innovations tend to reduce energy demand.

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As economies continue to grow, energy needs will be increasing. This has raised a long-term concern over energy security by many governments around the world given the limited ecological capacity of our ecosystem. This research contributes to a better understanding of the dynamics and trends in energy markets. The findings of this research have important implications for public policies in terms of inducing energy savings, encouraging expansion of the service sector and promoting energy-efficient technologies that enable a switch from fossil fuels to renewable energy sources towards a sustainable future.

This paper is organized as follows: Section 2 provides a review of relevant literature, Section 3 describes the sample and data, Section 4 outlines the methodology employed, Section 5 conducts cross section dependence testing, panel unit root testing, panel cointegration testing and estimation, and Section 6 concludes.

2. Energy demand studies

The energy demand studies across countries have flourished recently. Ref. [24] study the inter-linkages between energy consumption, economic growth and energy prices for 20 net energy importers and exporters from 1971 to 2002 where the consumer price index of base year 2000 is used to proxy energy prices.[1] [7] examine the causality between energy consumption and economic growth for a large sample of developed and developing countries with four energy sectors. Two papers make use of similar approaches and reach similar conclusions; however, both of them do not allow for cross country correlation, which is especially relevant when energy exporters, importers or global economy are targeted. Ref. [41] examine the relationships between energy demand, economic growth and prices in 24 non-OECD countries for three sectors over the period 1978–2003. With linear and nonlinear income and price elasticities, [41] lead to similar results in terms of a positive income elasticity and a negative price elasticity. While Ref. [41] use fixed time effects to control for unobserved dynamic effects, it fails to control for the heterogeneous common effects and spatial correlation. Ref. [22] conduct a cross-country analysis for 11 OECD countries. They find that the price responsiveness was very strong while income responsiveness was very weak.

A number of specific country studies have also been conducted. Ref. [25] suggest a positive income elasticity and a negative price elasticity of residential demand of electricity and natural gas in the United States based on 49 states over 21 years using shrinkage estimators. Ref. [36] study the long-run income and price elasticity of energy demand for 10 Asian developing economies over the period of 1974–1990 at aggregate, sectoral and industrial levels. In general, they find a positive elasticity with respect to per-capita GDP and a negative elasticity with respect to energy prices, with substantial heterogeneity across countries. By using unit root and cointegration tests and error correction model, Ref. [5] find a positive income elasticity and a negative price elasticity of energy demand in Thailand. Ref. [10], using annual log-linear econometric models of the electricity demand, show that the overall price elasticity ranges from −0.363 to −0.428 in South Australia. Ref. [8] find that the long run price and income elasticities are more price elastic than the short run both in industrial and residential consumption in the Italian electricity market.

The majority of existing energy demand research restricts their attention to income and price elasticities. However, numerous factors have been found important for the recent increases of energy use, including demographic, structural, technological and weather/climate (i.e. temperature) changes.

Historically, economic growth has been achieved with a large scale shift of labor force from primary agriculture to urban-based industries. Urban lifestyles and urban economic activities are expected to directly and indirectly exert an excessive pressure on the levels of resource consumption, especially energy usage. Significant movements of population from rural to urban areas necessitate the increased provision of public infrastructure including transportation, communication, energy, water supply and sanitation and drainage systems, resulting in greater energy use. Population growth is also related to energy use as population growth leads to increases in demand for goods and services, residential and commercial housing, and transportation, which drive the rises of energy use. Ref. [26], in examining the climate/non-climate factors of electricity demand, demonstrates that demographic factors such as population growth and response during holiday and working days are among the main factors affecting the electricity consumption pattern in Jordan.

Ref. [27] show that structural change in terms of shifts in employment shares (or values added) in the economy, from agriculture to industry to services, has important implications for the growth rates of total factor productivity, which is closely related to energy use. [40] suggests, based on 11 world regions for the period of 1971–1998, that structural change in the economy causes similar structural change in final energy use, and for higher-income regions most of the reduction in final energy intensity is firstly attributed to the industry sector and secondly the service sector. Ref. [14] find that a sectoral shift towards industry in the majority of provinces in China leads to the recent rebound in energy intensity in its economy, which is partly offset by the intra-sectoral energy savings in industry and other sectors. Ref. [5] find a positive impact of changing industrial structure on Thailand energy demand.

Technological change has been a central issue in global energy-environment-economy modeling. There is overwhelming evidence that technological change is endogenous and induced by needs and pressures. Research and development expenditure, spillovers from research and development and technology learning have been the major approaches to model induced technological change. These approaches capture the process of new energy-saving technical advances and replace the inefficient technologies with energy-saving techniques. The induced technological change tends to reduce the costs of abatement and speed up abatement process [43]. But technological innovation might lead to higher energy uses due to a “rebound effect”. Ref. [26] confirms that some technological factors, for example introducing new electric apparatus, are key factors affecting the electricity consumption pattern in Jordan. Ref. [42] finds evidence that technological progress contributed to the decline of energy intensity for 100 countries over 1980–2010.

The temperature effect on energy demand has received considerable attention. Ref. [29] study the electricity demand in the UK and find that the relationship between electricity load and air temperature has an important dynamic component. Ref. [28] examine the relationship between electricity demand and weather in Spain and find weather to be significant and important in the model. Ref. [38] find that energy use goes down with the rising temperature due to a reduction of energy demand for heating purposes, based on an unbalanced panel of 137 countries over three decades. Ref. [4] argue that sunshine duration should be taken into account when modeling electricity consumption.

With recent data and newly-developed method, this research will be a comprehensive and renewed study of energy demand, aiming to provide new evidence and insights into this crucial issue.

[1] A core consumer price index typically excludes food and energy prices, and therefore might fail to proxy energy prices.

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