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Dynamics of energy use, technological innovation, economic growth and trade openness in Malaysia

Kazi Sohag [a, b, *], Rawshan Ara Begum [a, **], Sharifah Mastura Syed Abdullah [a], Mokhtar Jaafar [b]

[a] Institute of Climate Change (IPI), Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia
[b] Faculty of Social Science and Humanities, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia

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ABSTRACT

This study extends the Marshallian demand framework to investigate the effects of TI (technological innovation) on energy use in Malaysia. This extended theoretical frameworks predicts that TI, an exogenous element in the energy demand function, increases energy efficiency and, correspondingly, reduces energy consumption at a given level of economic output. Using an ARDL (autoregressive distributed lag) bounds testing approach for the sample period 1985–2012, this study confirms both short- and log-run theoretical predictions. However, controlling for the effect of TI, this study finds that increasing GDP per capita and trade openness produce a rebound effect of TI on energy use.

1. Introduction

Globally, both economic and population growth continue to be the most important drivers of increases in CO_2 emissions from fossil fuel combustion. Despite the UNFCCC (United Nations Framework Convention on Climate Change) and the Kyoto Protocol, GHG emissions grew more rapidly between 2001 and 2010 than during the previous decade. The main contributors to this trend were higher energy demand associated with rapid economic and population growth as well as increased use of fossil fuels (IPCC, WG3, 5AR). Thus, energy efficiency improvements and fugitive emissions reductions during fuel extraction and within energy conversion, transmission, and distribution systems; fossil fuel switching; and low carbon technologies, such as RE (renewable energy) sources, are important to reducing energy sector emissions while addressing the dilemmas of economic growth, energy security, and environmental sustainability. Implementation of energy efficiency measures varies greatly by country as well as by sector and industry, especially if developing countries are taken into account [64]. The scale of economic activity is strongly associated with energy use [9,55] however, the elasticity of economic growth to energy use is heterogeneous among countries because a country's growth pattern depends on its economic activities. Al-Mamun et al. [3] also stressed that energy use is quite sensitive to sectoral domination in the economy because industrialized and sophisticated service-oriented economies consume higher shares of the global energy supply compared to countries with primary sector–based (agricultural) economies, which consume relatively less energy. Since the early 1980s, the economy of Malaysia has, to a great extent, transformed from an agricultural to a sophisticated industrial and service economy [11] whose industrial and service sectors contribute 40.2% and 50.2% of total GDP, respectively. This change increased per capita energy use from 660.32 units to 2639.43 units between 1980 and 2012.

Like economic growth, trade influences domestic energy use through several channels, such as economies of scale, composite effects of production factors, and technological effects [52,57]. For instance, export demand augments the scale of economic activities, which consequently increases energy usage in the domestic country [15]. However, the composite effects of production factors can either promote or hinder the use of energy, depending on three main processes. First, trade may foster specialisation in the local

* Corresponding author. Faculty of Social Science and Humanities, and Institute of Climate Change (IPI), Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia.
** Corresponding author.

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economy by changing the factors of production (such as capital, labour, and energy) as the economy transitions from agriculture to industry and services. Thus, energy dynamics (patterns of energy use) change through specialization of the economy [25]. Second, trade increases local market competitiveness through international market competition [57] and thus improves the efficiency of production factors. Finally, trade liberalization promotes the diffusion of technology, which is often characterized as energy efficient, from developed countries to less developed countries [60], helping to reduce the energy consumption required to produce a given level of output. Although trade has continuously accounted more than 100% of GDP in Malaysia since the early 1980s, the impact of trade on energy use in Malaysia has not been studied; hence, this article incorporates trade openness into an energy function to explore this nexus.

TI (technological innovation) is crucial for improving energy efficiency [20,26,61,28]. Although there are other methods of promoting energy efficiency, such as market-based approaches, policies and controls, the magnitude of the impact of technological innovation is larger due to its direct association with the energy efficiency function. In this case, advanced technologies allow the economy to produce a given level of output using a lower level of energy. Moreover, technological innovation provides opportunities for the economy to switch from depletable sources to renewable sources of energy to meet energy demands. However, technological innovation reduces energy consumption marginally; hence, it may not reduce a great share of the energy used. For instance, if the price of energy falls due to gains in energy efficiency, the reduced price might encourage economic agents to use more energy [1]. Malaysia has experienced considerable technological innovation with its rapid economic growth, moving towards achieving developed nation status by 2020. There is a trend of increasing technological innovation (as measured by the number of patents) in Malaysia from 1980 to 2012, as shown in Fig. 4. Thus, this study investigates the effects of TI (technological innovation) on energy use in Malaysia based on an extended Marshallian demand framework, as it is important to assess the dynamic effects of economic growth and trade openness as well as the effects of TI on energy use in Malaysia.

No previous studies have focused on estimating the dynamic impacts of technical innovation on energy use exclusively for the Malaysian economy. This study assesses the impact of technological innovation on energy use by controlling for several important variables, i.e., GDP per capita, trade openness, and price. Employing time series data from the World Development Indicators (1980–2012), this study applies ARDL (autoregressive distributed lag) and dynamic OLS frameworks to explore the short- and long-run impacts of particular variables on energy use. There are few techniques for measuring the long-run relationships among the variables of interest: [65] and Johansen [66,67] are the most extensively applied approaches. The present study applied an ARDL bounds testing approach to the energy, growth, trade and technological nexus due to its favourable characteristics compared to other standard approaches, as highlighted in the methodology section. This study also investigates a possible structural break during the sample years by applying a [63] unit root test and a [24] residual-based test for co-integration in models with regime shifts. Moreover, we address the possibility of an endogeneity problem using simultaneous equations to analyse an energy demand-supply setup. The findings of this study should facilitate the adoption of energy policies to address the dilemmas of economic growth, energy security, and environmental sustainability in Malaysia.

The remainder of this article is organized as follows. Section 2 provides the empirical model derived from demand and technological progress theory, the data and the methodology. Section 3 focuses on the empirical findings. Finally, Section 4 concludes and highlights some policy implications.

2. Review of the literature

Numerous studies have investigated the energy, economic growth and technology nexus in the context of various countries. Each of these studies is a worthy exploration of these issues. For instance [33], investigated the causal relationship between energy use and economic growth by applying a heterogeneous panel co-integration approach in the context of ASEAN economies over the period 1971–2002. They found a unidirectional causal relationship from energy use to economic growth over the long run but an insignificant causal relationship over the short run. Asafu-Adjaye [8] found unidirectional causality from energy use to economic growth for India and Indonesia, whereas energy use influences economic growth in a bidirectional manner for Thailand and Philippines. Some studies have also found a unidirectional causal relationship between energy use and economic growth in oil exporting economies [37,47]. However, like economic growth, energy prices also help explain the energy demand function. By applying static and dynamic panel techniques [2], revealed that energy prices are negatively associated with natural gas and electricity demand in the US economy, while this relationship is positive for income. In Pakistan, there is a shortage of electricity supply, but electricity demand is elastic with respect to its price and income [27] hence, income taxes and rigid pricing policies would promote energy efficiency. However, in technologically advanced economies, energy becomes an important factor of production with no close substitutes; hence, energy prices and economic growth might not respond to energy demand. For instance [34], revealed that energy is an essential good with no close substitute; hence, economic growth and energy prices are inelastic in OECD economies. Similarly, [62] found that energy is an inelastic good in China due to its massive industrialization. Dahl [16] also revealed that energy sources, particularly gasoline and diesel, are essential products, and hence, the elasticities of price and income are insignificant in explaining energy use in 120 developing and developed countries. Except for domestic energy demand [4], concluded that neither the energy price nor economic growth is responsive to the import demand function for oil in the Turkish economy.

Like economic growth, trade helps explain domestic energy dynamics. Sadorsky [46] observed that the volume of imports and exports increases domestic local energy use in Middle Eastern countries. However, trade also has a non-linear impact on energy use. For instance [52], revealed that trade and energy exhibit a U-shaped relationship in high-income countries and an inverted U-shaped relationship in middle- and low-income countries. Yanikkaya [60] highlighted that trade openness facilitates the penetration of technology from developed countries into developing countries. In line with this finding [57], argued that technological diffusion promotes energy efficiency when the diffusion takes place through trade openness in the context of European Union member countries. However, measures of trade openness, economic growth and human development influence energy use in the economies of Thailand, Indonesia and Malaysia [10].

Regarding the nexus between technological innovation and energy efficiency, technological innovation increases the quality of production by augmenting energy efficiency [13]. In fact, OECD countries experience greater energy efficiency gains due to their sizeable technological innovation compared to other developing countries [59]. Outside the OECD found an inverted U-shaped relationship between household final consumption and residential CO_2 emissions due to the use of advanced household technologies