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Energy prices and economic growth in the long run: Theory and evidence

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ABSTRACT

In this paper, we attempt to derive and test the role of energy prices on economic growth. We first developed a two-sector endogenous growth model, based on J Polit Economy 1991; 99:500–521. We modified the model such that consumption goods sector uses energy as an input along with capital. The model allows us to show that the growth rate of energy price has a negative effect on the growth rates of energy use and real GDP. Following this, derived theoretical relationships between energy prices and economic growth and energy consumption were tested empirically using error-correction based panel cointegration tests and panel Autoregressive Distributed Lag (ARDL) approach. We applied this methodology on data of composite energy prices, GDP per capita and energy consumption per capita for sixteen countries for the period between 1978 and 2011. We found significant cointegration between energy prices and real GDP per capita, as well as between energy prices and energy consumption per capita. Moreover, long-run estimates reveal negative and significant effects of composite energy prices on both GDP per capita and energy consumption per capita. We suggest that increasing the share of renewable energy sources in energy consumption would help policy-makers to control permanent long-term increases in consumer energy prices, in turn leading to an increase in economic growth, and hence in welfare. This paper contributes to the literature by highlighting the existence of a previously neglected welfare-improving channel of renewable energy.

Contents

1. Introduction

There has been a plethora of empirical studies on short- or medium-term interactions between energy (especially oil) prices and macroeconomic indicators following the pioneering study of [1]. Although there has been debate over the nature of the relationship, such as non-linearities [2–5] and asymmetries, i.e. differences in response to positive and negative shocks [6–9], there seems to be a consensus on the fact that oil price changes would at least have a particular, if not pivotal, effect on macro-economic variables.[1]

On the other hand, the impact of (rising) energy prices has never received substantial attention from growth economists, possibly because this has been perceived as a short run issue. The main concentration of the mainstream economic growth

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[1] Please additionally see: [10–19].

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literature has been on the optimal depletion and the price path of exhaustible resources, following the original study of [20].[2] More recently, the "new" growth economics, i.e. the endogenous economic growth literature, has focused on transition/substitution between energy sources [30–33], directed technical change in an economy with energy sources [34–39] and induced energy-saving technologies and environmental issues [40–42]. Therefore, the issue of effects of energy prices on economic growth seems to be an unexplored area in the theoretical economic growth literature.

For this purpose, we study a stylized model of an economy, in which an energy price-economic growth nexus is developed and tested. In the theoretical part of the paper, we showed that energy price growth has a negative effect on the growth rates of GDP per capita and energy demand by developing a two-sector market economy à la [43]. In our setup, the source of endogenous growth in the economy, i.e. the investment goods sector, uses only physical capital, while the consumption goods sector uses both energy and capital as inputs. Using energy as an input in consumption function has been supported by relatively recent empirical literature (e.g. [18,44,45]). Additionally, it is known that the consumption goods sector has been responsible for the majority of world energy consumption. According to IEA's 2012 World Energy Outlook [46], the combined shares of transportation and residential sectors in total primary energy consumption increased slightly from 60.8% in 1990 to 60.9% in 2008. The report also forecasts that these two sectors combined will remain dominant in energy demand, with a total share varying between 59.4% and 59.8% until 2035.

Our model, further, presumes that the price of energy input is growing at an exogenous rate.[3] Exogeneity in energy, especially oil, prices has recently become a debated issue in the literature. [47] was the first study to stress the bidirectional causality between oil prices and US macroeconomic performance. This reverse causality issue was later empirically quantified by [48], who proposed a methodology to disentangle major oil price movements with respect to three determinant forces: (1) oil supply shocks, (2) demand shocks specific to oil market and (3) shocks due to the global demand for all industrial commodities. The author found evidence that global macroeconomic conditions have been the dominant factor in oil price movements for the post-1973 period. Similarly, more recent studies have suggested that the increase in oil prices between 2003 and 2008 was due to the global business cycle rather than to supply shortfall [49,50]. Therefore, there seems to be a consensus in the literature that endogeneity is a problem in the empirical study of the relationship between oil prices and US macroeconomic indicators. Here, we propose a closed economy and use a broader definition of energy price, i.e. the price of energy services used in the consumption goods sector. While it is clearly possible to endogenize the energy prices in the model, with regards to our research objective, it is more convenient to keep it as an exogenous variable.[4]

The relationships derived in the theoretical part were tested empirically using an error-correction-based panel cointegration test and a panel Autoregressive Distributed Lag (ARDL hereafter) estimation for a group of countries, comprising Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Luxemburg, the Netherlands, New Zealand, Portugal, Spain and Sweden.[5]The data on real GDP per capita, energy consumption per capita and composite energy prices cover the period from 1978 to 2011. The test reveals that energy prices have a significant cointegration relationship with real GDP per capita, as well as with energy consumption per capita. Moreover, we found that energy prices have negative and significant long-run effect on both variables. These results provide clear support for the derived theoretical relationships.

The contribution of this paper to the literature is two-fold. First, there exist few studies on energy price-economic growth nexus in endogenous economic growth literature. For example, [34] considering a three-sector model and embedding energy as an input in the intermediate goods sector, have already shown the negative impact of rising energy prices on economic growth.[6] In another study, [52] shows that decrease in energy consumption due to rise in energy prices would promote capital accumulation if the investment effect dominates the lower energy use effect. Thus, higher energy prices do not necessarily hamper the growth process. Second, to the best of the authors' knowledge, although a number of studies analyze the long-term relationship between energy consumption and economic growth, only few studies test the empirical regularity on the long-term relationship between energy price and economic growth. The majority of existing studies use error-correction based models (VECM or VAR) along with the cointegration tests to interpret the relationships for different countries (e.g. [53–56]).[7] Thus, this study explores an untapped area of potential research by applying panel cointegration tests and panel ARDL methodologies to the analysis of the long-term effects of energy prices on economic growth and energy consumption.

The set-up of this paper is as follows. In Section 2 we present the basic model showing that endogenous growth is inversely affected by energy price growth. Section 3 presents the empirical analysis. A summary and some concluding remarks are provided in Section 4.

2. A two-sector endogenous growth model

The model developed in this article is based on a closed economy with no government. We define overall utility of the representative consumer in the economy as $U(C_t)=\int_0^{\infty} e^{-\rho\times t}\,u(C_t)\,dt$, where felicity function is $u(C)=(C^{1-\theta}-1)/(1-\theta)$, C is the consumption level, ρ is the subjective rate of discount and $1/\theta$ represents intertemporal elasticity of substitution. We presume that there are two types of factor of production in the model: broader interpretation of physical capital, K, and energy, E. We further presume that there are also two sectors in the economy, namely investment goods sector and consumption goods sector. Following [43], we define production technology of the investment goods sector as follows:

$$Y_I = A \times K_I \tag{1}$$

In (1), Y_I represents output in investment goods sector, A is overall factor productivity, and K_I, a flow variable, is a broader interpretation of physical capital used in investment good production.

[2] Seminal works in this stream are as follows: [21–29].

[3] Here we implicitly assumed that the energy source is non-renewable, because until recently global energy prices are driven mostly by fossil fuels such as oil, gas, and coal and the renewable energy sources still constitutes smaller portion of global primary energy supply/demand. For instance, in 2011, the share of fossil fuels and renewable energy sources in primary energy demand was 82% and 18%, respectively [46]. Moreover, according to the Hotelling-based reasoning following [20], it is natural to expect that the price of nonrenewable energy sources would increase gradually in the long run due to the scarcity or depletion of resources, although the short-term verification of the rule may not be applicable.

[4] In the Annex, we present the results of the model when energy price is a non-renewable and endogenous.

[5] Please see Section 3 for the rationale for country selection.

[6] [34], which is in fact based on [51], uses energy in intermediate goods sector. Yet, as commonly known, intermediate goods are capital good varieties, thus intermediate goods sector can be considered as investment goods sector.

[7] [57] provides an extensive survey of the literature on energy consumption-economic growth nexus since the seminal study of [58]. Most recent studies mentioned in this survey either use ARDL approach to individual countries (e.g. [59–64]), or panel data error-correction models (e.g. [65–69]).