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Energy consumption and energy R&D in OECD: Perspectives from oil prices and economic growth



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HIGHLIGHTS

- Economic growth encourages the use of cleaner forms of energy.
- Economic growth promotes renewable energy R&D.
- Subsidies for renewable energy R&D promote renewable energy consumption.
- Fossil fuel R&D promotes fossil fuel consumption in countries with oil reserves.
- Oil consumption reduces significantly with higher oil prices.

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ABSTRACT

We estimate the short-run and long-run elasticities of various types of energy consumption and energy R&D to changes in oil prices and income of the 20 OECD countries over the period of 1980–2010 using the Nerlove partial adjustment model (NPAM). We find negative income elasticity for coal consumption but positive income elasticity for oil and gas consumption suggesting the importance of economic growth in encouraging the usage of cleaner energy from coal to oil and gas. By introducing time dummies into the regressions, we show that climatic mitigation policies are able to promote the usage of cleaner energies. Through the dynamic linkages between energy consumption and energy R&D, we find that fossil fuel consumption promotes fossil fuel R&D and fossil fuel R&D in turn drives its own consumption. Renewable energy R&D which is more responsive to economic growth reduces fossil fuel consumption and hence fossil fuel R&D.

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1. Introduction

As one of the most important sources of energy, crude oil continues to occupy a key position in the heart of many economies. To macroeconomists, oil price changes are significant source of economic fluctuations that affect many economies simultaneously. Oil price shocks have indeed occurred several times since World War II. For instance, the 1973–1974 oil price shock triggered by the Yom Kippur and the 1979–1980 oil price shock as a result of Iranian revolution are the primary explanation of the stagflation of the 1970s. Interestingly, since the late 1990s, the global economy has experienced similar magnitude of oil shocks, but its impacts on output and inflation are relatively stable to many industrialized economies. To energy economists, oil price shocks should provide incentive to many economies, especially those without oil reserves, to use oil more efficiently either

through more cautious oil consumption or the development of new technology that uses alternative sources of energy. While oil price shocks encourage more efficient use of oil and promote substitution away from oil to other alternative energy resources, economic growth during economic boom stimulates oil consumption. In light of this contradiction and its crucial policy relevance, this study is motivated to investigate how various types of energy consumption, including renewable energy, respond to oil price changes and income changes.

As oil holds a prominent position as the principal of energy source, accounting for 36.3% of OECD primary energy consumption in 2010, much interest has been devoted to investigate the responses of oil consumption towards changes in oil prices and real output. Most recent studies include Ramanathan (1999), Cooper (2003), Ramanathan and Subramanian (2003), Narayan and Wong (2009) and Wadud et al. (2009). Cooper (2003) and Narayan and Wong (2009) find relatively inelastic oil consumption to changes in oil prices. Goodwin et al. (2004) show that elasticity of oil consumption to changes in oil prices ranges from 0.25 in the short-run to 0.64 in the long-run. As for the responsiveness of oil

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consumption to the changes in real output, Narayan and Wong (2009) document that oil consumption is more responsive, in terms of both magnitude and statistical significance in Australia. Narayan and Smyth (2007), however, document that the same coefficient is statistically insignificant in the Middle East. On the contrary, Wadud et al. (2009) show no meaningful relationship in the long-run between oil consumption, oil prices and real output before introducing the structural break during the oil shock.

A new strand of recent literature has moved on to examine the elasticity of oil consumption using disaggregated data such as various gasoline products (see Huntington, 2010; Iwayemi et al., 2010; Ramberg and Parsons, 2012). Own price elasticity of natural gas is also quite well-studied (see Cornillie and Fankhauser, 2004; Erdogdu, 2010). As the existing studies tend to focus only on the own price elasticities of oil consumption and gas consumption, findings from these studies though useful could not be used to address the issue of how other forms of energy can be used as substitutes to oil. This study attempts to fill such a gap. This study is interested in finding out not only how countries change their energy consumption and energy R&D behavior during periods of soaring oil prices and income growth but also the dynamic linkage between energy consumption and energy R&D. While past studies did not seem to clearly distinguish the difference between energy consumption and energy R&D, they are indeed distinct and should be treated differently as energy consumption reflects the economy's demand for energy while energy R&D reflects the economy's supply of energy. Potential influence from one to the other could also arise. As a result, to differentiate the two, this study examines distinctly two different sets of relationships: (1) the impact of energy R&D, economic growth, oil and gas prices on energy consumption and (2) the impact of energy consumption, economic growth, oil and gas prices on energy R&D.

Nerlove partial adjustment model (NPAM) is used to study the responses of various forms of energy consumption and energy R&D (including renewable energy consumption and R&D) to changes in oil prices and real output, using data from 20 OECD countries for the period 1980–2010. The purpose of this study is to assess the reliance of countries on oil and the potential to substitute away from oil to other energy sources. Similar studies which seek to determine the effects of oil consumption to the changes in oil prices or changes in income usually use either the NPAM method (e.g. Cooper, 2003) or the error-correction model (e.g. Wadud et al., 2009). Prior to the estimations of energy consumption or energy R&D to changes in oil prices and real output, this study conducts a two-stage-least-squares (2SLS) regression first to prevent the potential presence of endogeneity in the estimations. Time dummies are also included in the regressions to account for potential structural breaks.

This study adds to the current literature in three dimensions. First, we examine not only the own price and income elasticities of oil consumption but also the responsiveness of other forms of energy consumption and energy R&D to the changes in oil prices and real output where energy consumption portrays energy demand, energy R&D portrays energy supply. Second, instead of examining solely the effects of oil price and income on energy, we include other variables such as the various energy consumption and accumulated energy R&D to reduce the problem of omitted variable bias. Third, we also clearly distinguish the responses of energy consumption and energy R&D to changes in oil prices and real output in two different groups of countries, with oil reserves and without oil reserves. Using group-country panel regressions, we analyze whether differences in oil endowments could potentially influence the willingness of countries to switch from one form of energy to another. Existing studies such as Wadud et al. (2009), Eltony and Al-Mutairi (1995), Cheung and Thomson (2004), and Narayan and Wong (2009) look at individual countries

instead of groups of countries. The countries examined are the US, Kuwait, China, and Australia.

There are several main findings in this study. First, growth in real output per labor plays a key role in promoting the usage of cleaner forms of energy. While negative income elasticity is found in coal consumption, positive income elasticities are found in oil, gas and renewable energy consumption. This finding suggests the importance of economic growth in promoting the usage of cleaner forms of energy from coal consumption to oil, gas, and renewable energy consumption. The regression results also show countries adopting more renewable energy technologies with economic growth. Second, economic growth has both direct and indirect effects on fossil fuel consumption. The direct effect suggests that higher economic growth leads to higher fossil fuel consumption. The indirect effect of higher economic growth on fossil fuel consumption works through renewable energy R&D. Higher economic growth promotes renewable energy R&D and renewable energy R&D in turn reduces fossil fuel consumption as renewable energy R&D has negative and significant effect on fossil fuel consumption.

The remaining of the paper is organized as follows. Section 2 outlines the empirical framework that is used in the estimation of elasticities of energy consumption and energy R&D to changes in oil prices and income in the 20 OECD countries. It explains the importance of oil price, gas price, and energy consumption or energy R&D in the regressions. Section 3 describes the data and methodology used in this paper. Tests for endogeneity and selection of structural breaks are also discussed. Section 4 discusses the empirical findings of the elasticities of energy consumption and energy R&D to changes in oil price and income. Section 5 concludes.

2. Empirical model

We use a system of GMM estimator derived from Nerlove's partial adjustment model (NPAM) to estimate the short-run and long-run elasticities of (1) various types of energy consumption to changes in oil prices and income and (2) various types of energy R&D to changes in oil prices and income of the 20 OECD countries. As countries with different oil endowments may respond differently to changes in oil prices and income, besides running panel regressions for all the 20 OECD countries, we also conduct group-country panel regressions for OECD countries with and without oil reserves so that between country-group heterogeneity can be captured. A basic model with GDP per labor and oil prices as the main independent variables is first tested. An extended model including other key variables such as energy R&D and gas prices is then introduced. The regression estimations from the extended model can also be used as a robustness check on the significance of changes in oil prices and income on various types of energy consumption and energy R&D.

2.1. Basic model

In the basic model, to investigate the relationship between the oil consumption, oil prices and income per labor, it is assumed that demand is a function of price and income. The classical demand theory postulates that price will have a negative effect and income will have a positive effect on demand. As oil is one of the most important sources of energy, fluctuations in oil prices could potentially influence the usage of oil and other forms of energy. Therefore, the basic model is used to investigate the effect of oil prices not only on oil consumption but also on the consumption and R&D of other forms of energy such as coal, gas, and renewable energy. Based on this theoretical foundation, long run oil

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