Energy Economics 49 (2015) 669–675

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

# Oil prices and the global economy: A general equilibrium analysis

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ARTICLE INFO

*Article history:*
Received 15 August 2014
Received in revised form 16 January 2015
Accepted 15 March 2015
Available online 23 March 2015

*JEL classification:*
Q43

*Keywords:*
Oil price
CGE model
Global economy
International trade

ABSTRACT

A global computable general equilibrium model is used to analyze the economic impacts of rising oil prices with endogenously determined availability of biofuels to mitigate those impacts. The negative effects on the global economy are comparable to those found in other studies, but the impacts are unevenly distributed across countries/regions or sectors. The agricultural sectors of high-income countries, which are relatively energy intensive, would suffer more from a rising oil prices than that in lower-income countries, whereas the reverse is true for the impacts across manufacturing sectors. The impacts are especially strong for oil importers with relatively energy-intensive manufacturing and trade, such as India and China. While the availability of biofuels does mitigate some of the negative impacts of rising oil prices, the benefit is small because capacity of biofuels to economically substitute for fossil fuels on a large scale remains limited.



## 1. Introduction

A good understanding of adverse impacts of oil price rise in an economy is essential to design policy responses to reduce those impacts. However, the impact of oil price shocks on global economy is debated in the literature. Several studies, such as Hamilton (1983, 1996, 2008), Barsky and Kilian (2004), Kilian (2009), Morana (2013), present a good account of this debate. Using data since World War II until the first oil crisis in 1973, Hamilton (1983) finds that oil shocks contributed to some of the US recession prior to 1972. Similarly, analyzing data since the first oil crisis until 2000, Barsky and Kilian (2004) show that oil price increases contributed to US recessions although the impacts were not as large as commonly thought. Recently, Morana (2013) shows that oil prices increases exacerbated economic recessions during the Gulf wars and also financial crisis in 2008. Other key studies investigating the impacts of oil price increases on macroeconomy includes Hamilton (2011), Kilian and Vigfusson (2011), Blanchard and Riggi (2013), Herrera and Pesavento (2009), Jimenez-Rodrıguez and Sanchez (2005), Lee and Ni (2002), Lee et al. (1995) and Mork (1989). Most of these studies use econometric approach to establish the relationship between changes in oil prices and GDP based on historical data. One limitation of this approach is that the correlation between oil prices and GDP could be just a statistical coincidence (Hamilton, 1983). Kilian (2008) argues based on time series estimates that the GDP impacts of oil price shocks depend significantly on whether the observed oil price changes were exogenous or endogenously induced by other factors.

A few studies have examined the impacts of oil price rise on GDP using structural models, particularly the computable general equilibrium (CGE) models. For example, Sanchez (2011) shows, using a dynamic CGE model, that the oil price rise during 2002–2008 period would have caused 2% to 3% loss of GDP annually in six oil importing countries (Bangladesh, El Salvador, Kenya, Nicaragua, Tanzania, and Thailand). Using a CGE model, Aydın and Acar (2011) finds that higher oil prices would have a significant adverse impact on Turkish economy in the short run, though the economy would adjust in the long run and the impacts would be milder. A higher oil price path reaching to US$185 per barrel in 2020 would cause 1.3% of GDP annually as compared to the baseline where oil price was expected to reach US$108 per barrel in 2020. The analysis was carried out for the 2010–2020 period, and the GDP impacts in the short run (2011 and 2012) were 2.3% and 2.3, respectively. Using a stochastic dynamic general equilibrium model, Balke et al. (2008) find a relatively weaker impact of oil prices on US GDP since the 1990s compared to earlier years in the 1970s and 1980s. They conclude that domestic drivers rather than oil price shocks are primarily responsible for explaining US GDP fluctuations more recently.

This study intends to shed some lights on this debate. We use a multi-country, multi-sector, recursive dynamic, global CGE model to examine the impact of projected oil price increases on the global economy as well as specific regional/national economies. The model differs from existing ones in that it models the land-use sector in depth by disaggregating land supply in each country or region into 18 agro-ecological zones. It also explicitly represents major biofuels and their feedstock and explicitly models the tradeoff between fossil fuels and biofuels so that the indirect effects of oil price on the agricultural sector through

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http://dx.doi.org/10.1016/j.eneco.2015.03.005
0140-9883/

changes in biofuel production are captured.[1] The study first projects the price of crude oil up to year 2020 and posits alternative scenarios where that price is 25%, 50%, and 100% higher, then examines the impact of increased oil price on various economic indicators in 2020. Our study finds that GDP elasticity with respect to world oil price (i.e., ratio between percentage change in GDP and percentage change in world oil price) are roughly comparable with that of existing studies which also use CGE models to analyze macroeconomic impacts of oil price increases (e.g., Aydın and Acar, 2011; Sanchez, 2011). The effect of biofuels in mitigating the impacts of rising oil prices is relatively small because the capacity of biofuels to economically substitute for oil at a global scale remains limited.

The paper is organized is as follows. Section 2 briefly presents the CGE model developed for the study. This is followed by the presentation of key results in Section 3, particularly the assessment of the impact of increased oil prices on GDP, sectoral outputs, and international trade in Section 4. Finally, Section 5 concludes the paper.

## 2. Model and data

We developed a multi-country, multi-sector, recursive dynamic computable general equilibrium model for the purpose of this study. The model has 25 countries/regions with 28 sectors and commodities in each country and region (please see Table 1).

There are some distinct features of this model. First, it explicitly represents biofuels thereby allowing the substitution of petroleum products with biofuels when oil price increases. Most CGE model analyzing macroeconomic impacts of oil price shock do not have this feature and thus might have overestimated impacts of oil price on the economy. Second, to accommodate the interactions between the biofuels and petroleum fuels, the model also represent various land-use type that is not present in most existing CGE models analyzing energy issues. Third, it represents various petroleum products explicitly, whereas most existing models represent petroleum fuels as an aggregated output from petroleum refineries. This is very important as different biofuels (e.g., ethanol and biodiesel) compete with different petroleum fuels (e.g., gasoline and diesel).

The detailed structure of the model is illustrated in Fig. 1. As can be seen from the figure, economic sectors are divided into three groups: non-energy manufacturing and service industry, energy industry, and agriculture (land-use) industry. The production behaviors of non-agriculture industries are represented with constant elasticity of substitution (CES) production functions because it is more flexible compared to other commonly used functional firms such as Cobb–Douglas. Moreover, the nested structure of CES allows different substitution possibilities between factors of production, between aggregate factors of production and aggregate intermediate goods, and also between different types of intermediate goods. At the top of the nested structure in Fig. 1, gross output is the CES composite of non-energy manufacturing and service bundle (ND) and value-added energy bundle (VAE). Any good or service is supplied through domestic production and import. Value-added bundle includes land (for agriculture production specifically), capital, and labor. The model allows direct substitution between capital and energy.

Since the study is focused on the impacts of oil price shock on the economy, the energy sector is represented in detail. The total demand for energy is a CES composite of electricity and an aggregate of non-electric energy commodities. Non-electric energy bundle includes natural gas, petroleum products, and biofuels. The petroleum and biofuel bundle allows direct substitution between ethanol and gasoline and also between diesel and biodiesel.

[1] This paper however does not discuss the fuel-food controversy caused by biofuels. There exist a large number of studies on that topic. Interested readers could refer to Timilsina (2012), Timilsina and Shrestha (2011), Zilberman et al. (2013).

**Table 1**
Sector and countries/regions considered in the model.

| Sector/commodity | Country/region |
|---|---|
| 1. Paddy rice | 1. Australia and New Zealand |
| 2. Wheat | 2. Japan |
| 3. Corn | 3. Canada |
| 4. Other cereal grains | 4. United States |
| 5. Vegetables, fruit | 5. France |
| 6. Oilseeds | 6. Germany |
| 7. Sugar (cane and beet) | 7. Italy |
| 8. Livestock | 8. Spain |
| 9. Forestry | 9. UK |
| 10. Processed food | 10. Rest of EU and EFTA[a] |
| 11. Coal | 11. China |
| 12. Crude oil | 12. Indonesia |
| 13. Natural gas | 13. Malaysia |
| 14. Other mining | 14. Thailand |
| 15. Sugar ethanol | 15. Rest of East Asia and Pacific (EAP) |
| 16. Corn ethanol | 16. India |
| 17. Grains ethanol | 17. Rest of South Asia |
| 18. Biodiesel | 18. Argentina |
| 19. Gasoline | 19. Brazil |
| 20. Diesel | 20. Rest of LAC[b] |
| 21. Refined oil | 21. Russia |
| 22. Chemicals | 22. Rest of ECA[c] |
| 23. Other manufacturing | 23. MENA[d] |
| 24. Electricity | 24. South Africa |
| 25. Gas distribution | 25. Rest of Sub-Saharan Africa |
| 26. Construction | |
| 27. Transport services | |
| 28. Other services | |

[a] EFTA includes Norway, Switzerland, Iceland, and Liechtenstein.
[b] LAC refers to Latin America and Caribbean.
[c] ECA refers to Eastern Europe and Central Asia.

We followed Timilsina et al. (2012) while modeling the land use. We replaced the CES functional form with a constant elasticity of transformation (CET) function form because a land could be used to produce various crops, pasture, or forests. This is a standard approach in the literature (see, e.g., Banse et al., 2008; Huang et al., 2004; Birur et al., 2008; Hertel et al., 2010). The total land area is divided into 18 agro-ecological zones (AEZ) in every country/region so that economic substitution possibilities between different land-use type do not violate physical realities of such a substitution. In each of the CET nest of our land module, agents maximize payoffs by optimally allocating the fixed land area for this nest to various competing uses.

We assume that a representative household maximizes its utility, using a non-homothetic Constant Difference of Elasticities (CDE) function, subject to the budget constraint. The key advantage of using a CDE demand system is that it can be easily parameterized to better represent the policy scenarios. For the details of this functional form Surry (1993) could be a good reference.

As usual, the government revenue is collected through indirect taxes, tariffs, and a direct tax on households. Total government expenditure is exogenously determined keeping it as a fixed share of nominal GDP. The allocation of government expenditures across goods and services follows the same rule as was in the base year.

International trade is modeled following Armington assumption that states that same good or service might have different quality if it originates from different sources. Thus, the domestically produced and imported components of a good are aggregated through a CES functional form. Export supply is depicted by a two tier CET function, where, on the first tier, the total output of a sector is designated to the total exports and total domestic supply. In the second tier, total exports are partitioned to individual commodities according to their destinations.

The old and new stocks of capital build the total capital stocks, where new corresponds to the capital investments at the beginning of the period and old corresponds to the capital installed in previous periods. New capital is assumed to be perfectly mobile across sectors, whereas the old capital stock is not.