On the World Energy Price-GDP Relationship

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This paper analyzes the macroeconomic impact of high oil prices on each national economy. Using an analytical model, we show that oil price-real GDP elasticity can be estimated roughly from current oil prices, GDP, and oil imports and exports. In contrast to large-scale modeling, our approach is based on simple algebra and clear assumptions, and thus provides policy makers with a more transparent view of the vulnerability of economies to oil price increases, in terms of GDP; our model shows how this vulnerability declined sharply in the late-1980s and stayed low through the 1990s, and how the Euro-zone countries are becoming more vulnerable while Japan remains less so.

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Key words: world crude oil; price elasticity; GDP.

INTRODUCTION

This paper discusses the impact of changes in world crude oil prices on each national economy. Increases in crude oil prices impose higher production costs on industries for which crude oil and related products are inputs. This effect permeates into the economy through increases in factor prices, and causes recessions.

The International Energy Agency (IEA) conducted a study of this issue (IEA: 2004) by large-scale energy-economic model simulation to calculate decreases in GDP in developed

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and developing countries resulting from crude oil price increases. The large-scale model simulation showed that a hypothetical increase in world crude oil prices from twenty-five dollars per barrel to thirty-five dollars per barrel results in declines in GDP of 0.3 percent in the U.S., 0.4 percent in Japan, and 0.5 percent in the Euro zone. Frequently cited in the public media around the world, these results had been highly influential in those days as benchmarks in economic policy debates on how to cope with the recent oil price increases in a number of countries.

The IEA report does not provide a detailed description of the model structure. Explanations of the World Energy Model (WEM), which is a main part of the model employed, are found elsewhere in the IEA's publications, but important details of the WEM have not been disclosed to those outside of the IEA; the model thus remains a black box, even as the frequently-cited results it produces continue to be influential. These circumstances do not offer a sound basis for economic policy debate.

The economic literature offers many studies that examine the relationship between oil prices and the macroeconomy. The extensive literature reviews in studies such as Jones, Leiby and Paik (2004) and Brown and Yüncel (2002) indicate that most preceding studies of the issue can be divided into two groups: econometric analyses of existing economic data, and studies employing computational models. These literature reviews also indicate that no consensus has yet been reached on how, why, and to what degree economies are affected by changes in world oil prices.

This paper employs a simple, static general equilibrium model to examine the oil price-macroeconomy relationship. With our model, we can easily calculate the elasticity of the oil price-real GDP relationship. The model thus affords policy makers a clearer view of how oil-importing countries are affected by world oil prices.

The remainder of the paper is organized as follows. The next section presents a static general equilibrium model that represents a national economy importing or exporting crude oil. In Section 3, we derive a formula for estimating oil price-real GDP elasticity. In Section 4, we discuss how our approach is different from past studies. Section 5 provides examples of the use of the formula. The results are compared to those of the IEA study. Section 6 concludes our discussion.

2. THE MODEL

Consider a simple economy comprising final consumption, energy transformation (oil refineries), and crude oil production sectors. Crude oil is assumed to be the only good that is traded internationally. The final consumption good sector uses capital, labor, and energy
products as inputs, and produces a single consumer product. The energy transformation sector produces energy products from crude oil by refining processes, using capital and labor. The crude oil employed in the transformation sector is either produced domestically or imported. Domestic crude oil production requires capital and labor. Domestically produced crude oil is then either supplied to the domestic transformation sector or exported.¹ The elements of this economy are described as follows.

Final consumption good sector:

\[ \pi_f = Q - \left\{ rK_f + wL_f + p_e E \right\} \]  \hspace{1cm} (1)

Energy transformation sector:

\[ \pi_e = p_e E - \left\{ rK_e + wL_e + p_d D + p_m M \right\} \]  \hspace{1cm} (2)

Crude oil production sector:

\[ \pi_c = p_d D + p_e X - \left\{ rK_c + wL_c \right\} \]  \hspace{1cm} (3)

National income:

\[ \pi = rK + wL \quad \text{where} \quad K = \sum_{j=f,e,c} K_j, \quad L = \sum_{j=f,e,c} L_j \] \hspace{1cm} (4)

**Q**: final product  
**E**: intermediate energy products (refined oil products)  
**D**: domestic production of crude oil  
**M**: crude oil imports  
**X**: crude oil exports  
**r**: rental price  
**w**: wage  
**\pi_j**: profits  
**K_j**: capital input  
**L_j**: labor input  
**p_j**: good prices  
\((j=f, e, c, i): \text{suffixes representing each production sector}\)  
**p_k**: crude oil prices  
\((k=d, m, x): \text{suffixes representing domestic production, imports, or exports}\).

Let \(Y\) denote (real) GDP. Equations (1) to (4) sum up to \(Y\) as follows:

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¹ The Armington assumption, representing incomplete substitutions between domestic and imported crude oil as well as between domestic oil supply and export, is assumed. The assumption is usually represented by the Armington coefficients in transformation functions.
When all sectors in the economy are competitive, profit in each sector is zero as follows:
\[ \pi_f = \pi_c = \pi_e = 0 \]
This condition implies the following identity:
\[ Y = \pi_f = rK + wL \]

The system of equations (1) to (4) constitutes a general equilibrium when some additional conditions are assumed. Let us discuss this point below.

In economic theory in general, production with \( N \) inputs and one output is represented by a system of \( N+1 \) equations for \( N+1 \) unknowns, given \( N \) relative prices are provided.\(^2\) Similarly, production of \( N \) outputs with one input is represented by a system of \( N+1 \) equations for \( N+1 \) unknowns. (Such a case applies to the crude oil production sector.) Thus, it is easy to see that:
- The optimality conditions for Eq. (1) constitute a set of four equations for endogenous variables \( Q, K_f, L_f, E, r, w, \) and \( p_c. \)
- The optimality conditions for Eq. (2) constitute a set of five equations for endogenous variables \( E, K_e, L_e, D, M, r / p_e, w / p_e, p_d / p_e, \) and \( p_m / p_e. \)

For the conditions for Eq. (3), we need to introduce transformation function for \( D \) and \( X \) with a composite good \( ZX. \) If we let \( \varphi \) denote the price of the composite good, we have:
\[ \varphi Z_X = p_J D + p_X X. \]
Then, we know that:
- For the optimality conditions of the composite good as input, we have a set of three equations for endogenous variables \( Z_X, D, X, p_d / \varphi, \) and \( p_e / \varphi. \)
- For the optimality conditions of the composite good as output, we also have a set of three equations for endogenous variables \( Z_X, K_c, L_c, r / \varphi, \) and \( w / \varphi. \)

We have definitions of \( K \) and \( L \) as in (4). Thus, equilibrium conditions for the equations (1) to (4) comprise of 17 (= 4+5+3+3+2) equations in total with 21 endogenous variables, \( Q, E, K, L, K_f, L_f, K_e, L_e, K_c, L_c, D, M, X, r, w, p_e, p_d, p_m, p_e, Z_X, \) and \( \varphi. \)
When we fix crude oil import and export prices \( p_m \) and \( p_e \) as parameters, the number of

\[^2\] For instance, if we assume that production has a form of \( Z = F(X, Y) \) (note that it does not necessarily have the constant returns to scale property), and that relative prices of \( X \) and \( Y \) with respect to the price of \( Z \) are \( p_X, p_Y, \) then the optimality conditions are: \( \partial F / \partial X = p_X \) and \( \partial F / \partial Y = p_Y. \) Thus, we have a set of three equations, which solves for three unknowns \( Z, X, \) and \( Y \) as functions of \( p_X, p_Y. \)
endogenous variables reduces to 19. In the remainder of this paper, let us assume that the world crude oil market is competitive, and thus export and import prices coincide. Letting $p$ denote the world crude oil price, we assume:

$$p_s = p_w = p.$$ 

With this assumption, (5) simplifies itself to:

$$Y = Q - p(M - X). \tag{6}$$

Let us introduce the following assumption:

**Assumption 1.** The employment $L$ is fixed at a certain exogenous level as a natural employment rate or full employment.

With this assumption, the number of endogenous variables reduces to 18. To make the system a complete general equilibrium, we need one more equation (condition). Such a condition can be provided by the behavior of “representative household.” Let us write the condition as the following functional form: $K = \kappa(r, w, L)$.

With these assumptions above, the economy of (1) to (4) constitutes a static general equilibrium that is represented by the system of 18 equations and 18 endogenous variables. Each endogenous variable is a function of the world oil price $p$. This allows us to easily calculate the oil price-real GDP elasticity $\eta = \frac{dY/Y}{dp/p}$. The next section examines the detail.

### 3. ANALYSIS

We propose the following lemma.

**Lemma 1.** Assume that the economy is in a steady state. Then, per capita capital in the steady state is a function of wage $w$ only, that is:

$$K = \kappa(w) \cdot L \tag{7}$$

**Proof of Lemma 1:**

Let us consider a representative household optimizing its intertemporal utility.

$$\max_{\{c_i\}} \sum_{i=1}^{T} \beta^{T-i} u(c_i) \cdot L_i$$

s.t.  

$$c_i = r_i k_i + w_i - i_i,$$

$$k_i = K_i / L_i.$$
\[ k_{t+1} \cdot (L_{t+1}/L_t) = k_t - \delta k_t + i_t \]

\[ \beta^T g(k_{T,t}; r_{T,t}, w_{T,t}) \cdot L_{T,t} \geq 0 \quad \text{(terminal condition)} \]

\[ K_i \text{ given; } (L_i)_{t=1}^{T} \text{ given} \]

Introducing Lagrangian:
\[
\ell(k_{t=1}^T, \lambda) = \sum_{t=1}^{T} \beta^{t-1} u((1 + r_t - \delta)k_t - (L_{t+1}/L_t)k_{t+1} + w_t) \cdot L_t + \lambda \beta^T g(k_{T,t}; r_{T,t}, w_{T,t}) \cdot L_{T,t},
\]

we have optimality conditions as follows:
\[
u'(c_t) = \beta \cdot u'(c_{t+1}) \cdot (1 + r_{t+1} - \delta), \quad t = 1 \cdots T - 1
\]
\[
u'(c_T) = \beta \cdot \lambda \cdot \frac{dg}{dk_{T,t}}
\]
\[ g(k_{T,t}; r_{T,t}, w_{T,t}) = 0 \]

These conditions constitute a system of \( T+1 \) equations for \( T+1 \) unknowns (per capita capital \( (k_i)_{t=1}^{T} \) and shadow price \( \lambda \)). When the economy is in a steady state, \( \beta \cdot (1 + r_t - \delta) = 1, \quad \forall t \)

must hold. Thus, \( r \) is independent of capital and labor in a steady state, which means that \( k \)

is a function of \( w \) only. □

Let us introduce another assumption:

Assumption 2. In each production sector, capital and labor are used to produce a composite good. The composite good is separable from other production factors in the sector’s production function. Moreover, the production function that produces the composite good from capital and labor inputs is the same for all sectors.

Assumption 2 indicates for instance, that as for (1) we have:
\[ Q = F(K, L, E) = G(R, E); R = H(K, L) \]

and \( H \) is uniform to all sectors.

With the property of the composite goods, we have the following lemma.

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3 The functional form of \( g \) can take various forms. For example, (1) if we assume that the terminal condition is determined by the terminal income level, we have \( g(k_{T,t}; r_{T,t}, w_{T,t}) = g(r_{T,t}k_{T,t} + w_{T,t}) \); (2) if we assume that we need to have a lower bound for consumption, we have \( g(k_{T,t}; r_{T,t}, w_{T,t}) = u(c_{T,t}) - \underline{u}; \) (3) if we assume that we need to have a lower bound for capital, we have \( g(k_{T,t}; r_{T,t}, w_{T,t}) = k_{T,t} - \bar{k}; \) etc.
Lemma 2. Given Assumption 2, per capita capital is a function of \( r/w \), that is:

\[
K = \psi(r/w)L.
\]  

(8)

Proof of Lemma 2:

When \( R_j \) and \( \phi \) represent the composite good and its price, respectively, we always have:

\[
\phi R_j = rK_j + wL_j.
\]

This means \( H \), defined as \( R_j = H(K_j, L_j) \), must be a function of homogeneous of degree one.

Thus, in each production sector, \( K_j \) and \( L_j \) \((j = f, e, c)\) are determined such that the ratio of these inputs is a function of the ratio of prices. That is, \( K_j/L_j = \psi(r/w) \). Thus,

\[
K = \sum_{j=f,e,c} K_j = \psi(r/w) \sum_{j=f,e,c} L_j = \psi(r/w)L. \quad \Box
\]

Now we have the main proposition as follows:

Proposition (world oil price-real GDP elasticity). With Assumptions 1 and 2, for the static economy stated above, the oil price-real GDP elasticity in absolute value is estimated as the proportion of net import of crude oil to GDP. That is:

\[
\eta = \frac{dY/Y}{dp/p} = -\frac{p(M - X)}{Y}.
\]  

(9)

Proof of Proposition:

As discussed in the previous section, every endogenous variable is a function of the world oil price \( p \). From (1), we have:

\[
\pi_f = \pi_f(K_f(p), L_f(p), E(p), r(p), w(p), p_e(p)).
\]

Thus,

\[
\frac{d\pi_f(p)}{dp} = \frac{\partial \pi_f}{\partial K_f} K_f' + \frac{\partial \pi_f}{\partial L_f} L_f' + \frac{\partial \pi_f}{\partial E} E' + \frac{\partial \pi_f}{\partial r} r' + \frac{\partial \pi_f}{\partial w} w' + \frac{\partial \pi_f}{\partial p_e} p_e'.
\]

\[
= -r'K_f - w'L_f - p_e'E.
\]

Similarly,

\[
d\pi_f(p)/dp = p_e'E - \{r'K_e + w'L_e + D + M\},
\]

\[
d\pi_e(p)/dp = D + X - \{r'K_e + w'L_e\}, \text{ and}
\]

\[
d\pi_c(p)/dp = r'K + w'L + rK' + wL'.
\]

Thus, we have:

\[
\frac{dY}{dp} = \sum_{j=f,e,c} \frac{d\pi_j}{dp} = -(M - X) + rK' + wL'.
\]
Due to Assumption 1, the last term is zero. From Lemmas 1 and 2, (7) and (8) indicate that $\kappa(w) = \psi(r/w)$. Thus, $w$ is a function of $r$ only. However, as is discussed in the proof of Lemma 1, $r$ is independent of capital and labor in a steady state. Thus, so is $w$. Therefore, $K/L$ is constant in a steady state, meaning $K' = 0$. □

4. DISCUSSION

The Proposition may seem reductive or even obvious, but the economic literature offers no discussion of similar formulations. Rather, a great number of studies have employed time series analysis or vector autoregressive models to examine the oil price-GDP relationship. Another group of studies have employed computational models to simulate the economic effects of higher oil prices, including impact on GDP. Let us examine the approaches of these two groups of studies more closely.

The first group includes studies pursuing econometric analyses of the impact of oil prices on economies. One of most influential studies taking this approach, Hamilton (1983) employed vector autoregressive (VAR) models to examine the causal relationship between economic downturns and increases in oil prices in the U.S. after World War II. Following Hamilton, many econometricians undertook related investigations, including Burbidge and Harrison (1984), Mork (1989), Morry (1993), Balke, Brown and Yücel (2002), and others. Some of these studies examine asymmetric effects of oil price rises on GDP, investigating how and why the impact of oil price changes differ depending on whether the change is upward or downward. Lee, Ni and Ratti (1995) employed GARCH models to examine historical changes in the volatility of oil price movements; their results suggest that the oil price-GDP relationship is not a stable one. Hooker (1996a) argues that this relationship changed substantially for the U.S. economy around 1973. Debate on this issue has continued in Hamilton (1996), Hooker (1996b), and other studies.

A brief look at the long list of econometric studies on the relationship between oil prices and the macroeconomy reveals that no consensus has emerged among researchers on how, why, and to what degree oil prices influence economies. The relationship is not a simple causal one, and may even be time-variant. Morry (1993) provides in summary form estimated values for oil price-GDP elasticity for the U.S. economy from many preceding studies; the values vary widely, ranging from 0.006 to 0.203.

Several studies examine differences in the oil price-GDP relationship between different economies. Mork, Olsen and Mysen (1994) compare seven countries (the U.S., Canada, Japan, Germany, France, the U.K., and Norway); they observe a negative relationship between oil prices and GDP in all of these countries except for Norway, but they
find that the magnitude of the relationship varies. Bjørnland (2000) employs VAR models to compare Germany, Norway, the U.K., and the U.S., and in addition develops a Keynesian-type simulation model; the results indicate that with the exception of Norway, the economic slowdown in all of these countries in the mid-1970s was largely due to the oil shock of 1973-4, but that the slowdown of the early 1980s was not due to oil prices. Other comparative studies include Abeysinghe (2001), which examines four ASEAN countries, four NIEs in Asia, China, Japan, the U.S. and the OECD countries as a group. All of these comparative studies agree that a relationship between oil price and real GDP surely exists, and that the magnitude of the relationship varies both historically and regionally. However, they all fail to explain this variability fully.

Studies pursuing computational models tend to take two approaches, developing either Keynesian-type econometric models, or neo-classical-type models such as real business cycle models (RBC) or general equilibrium models. The IEA study takes the latter approach.

Keynesian-type models are in general developed for the purpose of economic policy analysis, not for the purpose of analyzing the impact of oil price changes. Due to this fundamental aspect of Keynesian-type models, researchers who use such models to analyze the oil price-GDP relationship encounter problems in incorporating oil prices into their model frameworks. The treatment of oil prices determines the behavior of the model; simulation results based on Keynesian econometric models are largely dependent on modeling techniques and parameter settings, and are thus subject to the discretion of the modelers.

A project by the Stanford Energy Modeling Forum, EMF7 (Hickman, Huntington and Sweeney, eds.: 1987) was intended to examine similarities and differences in fourteen models based on the renowned American economic policy models of the 1980s. Runs of the models based on a given set of parameters and economic conditions were compared; the researchers showed that the models were similar in basic behavior in general, but that the actual results they produced varied.

Other Keynesian-type models include Beenstock (1995), the OECD INTERLINK model (Dalsgaard, Andre and Richardson: 2001), and the MULTIMOD model (Hunt, Isard and Laxton: 2001), which treated the dynamic behavior of international trade and money transfers. The INTERLINK and MULTIMOD models produced estimated values of oil price-GDP elasticities for several countries ranging from −0.01 to −0.002. Again, the treatment of oil prices in these models entails ambiguity in that, being based on Keynesian structures, they treat production as a single sector, and do not distinguish oil from other domestic consumption goods. In the INTERLINK model, moreover, crude oil is treated as a part of international trade, and thus increases in oil prices affect economies only through changes in international trade.
Keynesian econometric modeling also has a few general problems apart from the issue of how crude oil is treated in Keynesian frameworks. In principle, standard Keynesian econometric policy models are subject to the Lucas critique. In addition, the mechanism of oil price-change impacts on the macroeconomy is dependant on a country’s energy policy, and thus parameters that link oil prices to economic performance are time-variant. In fact, econometric analyses based on VAR models such as those mentioned above show that the oil price-GDP relationship can change; the use of a Keynesian framework may work for short-term prediction, but cannot capture structural changes in an economy.

Alternatives to the Keynesian approach include real business cycle (RBC) models. Finn (2000) attempted to incorporate energy use into a standard RBC modeling framework. She added a capital working rate to the production function, and then related the working rate to energy use that is accompanied by the use of capital. Other studies that treat energy in the framework of RBC models include Rotemberg and Woodford (1996), Kim and Loungani (1992), and Miguel, Manzano and Marín-Moreno (2003).

Although RBC models may be attractive to theorists who are interested in the mechanism of economic fluctuations caused by oil price shocks, they have not succeeded in quantifying the oil price-GDP relationship, and specifically, oil price-GDP elasticity. This is partly because RBC models are intended more for conceptual analysis than for computation, and partly because parameters in such models are usually set by calibration, which means that the parameters employed in computation represent particular moments in an economy, and can thus hardly reflect its possibly time-variant nature.

The difficulty—that estimated or calibrated parameters fail to capture structural changes in economies—may arise not only in Keynesian and RBC models, as mentioned above, but in any computational modeling, including computable general equilibrium (CGE) modeling. If the purpose of modeling is to predict or evaluate short-term macroeconomic performance and/or policy, this difficulty is unimportant. However, the oil price-GDP relationship is closely related to long-term national energy policy in any economy. As far as energy-economic issues are concerned, this difficulty must be treated with special care.

Bohi (1991) took an approach similar to ours in the present study in his discussion of how the oil price-output relationship is determined in firms or at the national level. His theoretical analysis suggests that two effects are responsible for declines in firms’ output or in GDP resulting from increases in energy prices; one is indirect, and the other direct. The indirect effect is due to substitutions between capital and energy inputs as well as between labor and energy inputs. The direct effect is estimated as energy price multiplied by the amount of energy input, divided by net output of the economic entity. Although Bohi’s analysis represents a theoretical contribution to the understanding of an aspect of the oil
price-GDP relationship, his treatment has problems: first, his definitions of “output” and the entity that produces the output, as well as his distinction between gross and net outputs, are unclear; secondly, his mathematical treatment of production functions and the related behaviors of economic entities are also unclear.

5. ESTIMATES

5.1 Impact on Real GDP

Let us estimate the impact of representative oil-price changes on real GDP in a selection of economies using the Proposition. Data sources for these calculations include the OECD energy balances (2004) and the database offered by the Institute for Energy Economics of Japan.

As described in the introduction, the IEA study evaluates two cases: a baseline case in which the world oil price stays at twenty-five dollars per barrel for five years beginning in 2004, and a high-price case in which the world oil price increases from twenty-five to thirty-five dollars (a ten dollar increase), and stays at that level for five years. Comparing these two cases, the IEA study estimates the impact of the ten-dollar increase of oil prices on real GDP to be declines of 0.3% in the U.S., 0.4% in Japan, and 0.5% in the Euro zone. For ease of comparison, we employ the same condition of a ten-dollar increase in oil prices from twenty-five to thirty-five dollars per barrel, and use the Proposition to obtain the impact on real GDP for Japan, the U.S., the Euro zone, the U.K., China, and the OECD countries.

As shown in Figure 1, the ten-dollar increase in oil price (in real value) reduces the real GDPs of Japan and the U.S. by about 0.3 percent, that of the Euro zone by 0.6 percent, and that of the OECD countries as a group by 0.3 percent. These results are similar to the IEA estimates, with the estimate for Japan being slightly smaller, and that for the Euro zone slightly larger, than the IEA estimate. The decline in real GDP for China is about 0.5 percent. In contrast to the other countries investigated, the U.K. shows a 0.1 percent increase in real GDP. This is because the U.K. is a net oil exporter nowadays.

An issue meriting discussion is the treatment of changes in international trade. In the framework presented here, no international trade is considered except for that in crude oil. One of the assumptions underlying this simplification is that trade terms and conditions, especially exchange rates, do not change. In contrast, the IEA model includes international trade in its modeling framework. In fact, international trade can change with changes in GDPs resulting from oil-price changes, and then the new trade structures can in turn influence the GDPs of individual countries. Such interaction between GDP and international trade may be an indirect but important determinant of the oil price-GDP relationship. Thus, ignoring this
interaction may lead to underestimating the impact of oil-price increases. However, it is noteworthy that in the IEA model, exchange rates are treated as fixed, and this may make international trade in effect less sensitive to domestic economic conditions. In short, the treatment of international trade in the IEA model does not necessarily result in a better account than that rendered by our formula.

Our formula facilitates the examination of historical changes in oil price-real GDP elasticity. As stated above, the IEA estimates consider an oil-price increase from twenty-five to thirty-five dollars per barrel, a forty percent increase. For ease of comparison, we adopted the same condition, calculating the percentage changes in real GDP resulting from forty percent increases in oil price, that is, the oil price-real GDP elasticity multiplied by forty for each year. The results are shown in Figure 2.

The results in Figure 2 lead to several interesting observations. First, the GDPs of all of the countries investigated were highly sensitive to oil prices in the 1970s. However, the magnitude of elasticity started to decline in the mid-1970s in the U.K., and in the early 1980s in Japan, the Euro zone, and the U.S. From the late 1980s to the present, the magnitude has remained low for most countries. Secondly, the U.K. is slightly different from other OECD countries in that it became a net oil-exporter in 1981, and since then it has benefited from oil price increases. The magnitude of the benefits, however, has remained low since the late 1980s. Thirdly, the Euro zone and Japan show similar movements, but the Euro zone in recent years has become more vulnerable to oil price changes than it was before the end of the 1990s. Fourthly, China began to export oil in the mid-1970s in order to earn foreign currency. The economic growth that China has experienced since then has demanded the consumption of a great deal of oil; this changed the country into a net oil importer in 1996. In recent years, China has been about as vulnerable to oil-price changes as the OECD countries. Moreover, it is possible that China will become more vulnerable to oil-price changes in the future, due to the rapid increase in its dependence on oil imports.

Most OECD countries, however, have pursued energy policies since the oil shocks of the 1970s that attempt to reduce the dependency of their economies on oil through such measures as increasing energy efficiency and replacing oil with other resources including natural gas, coal, and nuclear energy. Figure 2 indicates that these efforts have been successful since the late 1980s in most OECD countries.

5.2 Comparison with Past Oil Shocks
Our formula can also be used to estimate in reverse the specific oil price rise necessary to cause a shock to an economy. In the era of the first oil shock, oil prices soared from two dollars per barrel in October 1973 to eleven dollars per barrel in January 1974. Under the
economic conditions of the time, these soaring oil prices had a significant impact on many
developed economies. Could an equivalent change in oil prices have a similar impact today?
The answer is no. The effect of such a change would not be just a matter of nominal price
levels. It would be a matter of the size of the economy versus oil imports and exports, as well
as of the current level of oil prices.

The Proposition facilitates this kind of comparison; let us employ them to estimate
how much of an oil price increase would be necessary to cause economic downturns similar
to those of the first and second oil shocks. Changes in real GDP at time $t$ can be expressed as:

$$\eta_i \frac{\Delta p_i}{p_i}.$$ 

The oil prices that would have the same impact on real GDP as those at the time of the first
oil shock can be estimated as follows:

$$p_i + \Delta p_i = \left( \eta_{73} \frac{\Delta p_{73}}{p_{73}} + 1 \right) p_i.$$ 

The same line of reasoning applies to the second oil shock. Assuming average recent world
oil prices of around twenty-five dollars per barrel, we obtained the results presented in
Table 1.

Table 1 shows that the Japanese economy in recent times has been much more
resistant to hypothetical oil price shocks than the U.S., Euro-zone, and Chinese economies.
China is of particular interest: the resistance of its economy to oil price shocks, in terms of
both real GDP and inflation, has been extremely low recently. This reflects the rapid growth
of the Chinese economy, as well as the soaring dependence of its economy on imported oil.

6. CONCLUSION

This paper provides an alternative approach for estimating the world oil price elasticity of
real GDPs. A simple, static general equilibrium model provides a simple formula for the
estimation: the real-oil price elasticity of real GDP in an economy is equalized to the ratio of
a country’s net import of crude oil to its GDP.\(^4\) The formula provides us an insight into how
and to what degree the vulnerability of these economies to oil price shocks is determined.

Compared to large-scale modeling, the approach may be too simple to account for
all effects of world oil price increase on a macroeconomy. However, such simplicity has the

\(^4\) While the present study highlights the effects of world oil prices, the basic idea that derives
these formulae may apply to any other goods as long as goods are only used for intermediate
production, not for final consumption, and are traded internationally. In reality, however,
there seems no pure-intermediate good other than crude oil that is internationally traded in
such a large volume. In this sense, the analytical framework here is most suitable to the crude
oil issue.
benefit of affording policy-makers a more transparent, clearer view of the effect of oil price increases. Specifically, the approach shows how the vulnerability of the economies of the OECD countries to increases in world oil prices, in terms of both real GDP and consumer prices, declined sharply in the late 1980s and stayed low through the 1990s; and how in recent years the Euro-zone countries are becoming more vulnerable than before, while Japan is not. The case of the Chinese economy is slightly different; the approach shows that China is becoming much more vulnerable than other countries as it grows and becomes more dependent on imported oil.

REFERENCES


International Monetary Fund, IMF Working Paper, WP/01/14.

(http://www.iea.org/Textbase/Papers/2004/High_Oil_Prices.pdf)


Figure 1. Changes in real GDPs w.r.t. World Oil Prices (under the same conditions as those of IEA estimates)

Figure 2. Historical Changes in Oil Price-Real GDP Elasticities (multiplied by 40)

Table 1. Oil Prices That Would Have The Same Economic Impact as Those of Past Oil Shocks

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>US</th>
<th>UK</th>
<th>Euro zone</th>
<th>China</th>
<th>OECD total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent to the First Oil Shock</td>
<td>127</td>
<td>40</td>
<td>(below zero)</td>
<td>67</td>
<td>24</td>
<td>66</td>
</tr>
<tr>
<td>Equivalent to the Second Oil Shock</td>
<td>129</td>
<td>81</td>
<td>(below zero)</td>
<td>77</td>
<td>12</td>
<td>102</td>
</tr>
</tbody>
</table>

(Note: Benchmark oil price is 25$/b for all countries.)

(Unit: $/Barrel)