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Reassessing the Oil Security Premium

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RESOURCES FOR THE FUTURE

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Abstract

World oil supply disruptions lead to U.S. economic losses. Because oil is fungible in an integrated world oil market, increased oil consumption, whether from domestic or imported sources, increases the economic losses associated with oil supply disruptions. Nevertheless, increased U.S. oil production expands stable supplies and dampens oil price shocks, whereas increased U.S. oil imports boosts the share of world oil supply that comes from unstable producers and exacerbates oil price shocks. Some of the economic losses associated with oil supply disruptions—gross domestic product losses and some transfers abroad—are externalities that can be quantified as oil security premiums. To estimate such premiums for domestic and imported oil, we take into account projected world oil market conditions, probable oil supply disruptions, the market response to oil supply disruptions, and the resulting U.S. economic losses. Our estimates quantify the security externalities associated with increased oil use, which derive from the expected U.S. economic losses resulting from potential disruptions in world oil supply.

Key Words: oil markets, energy security, oil prices, economic activity

JEL Classification Numbers: Q4, Q48

Contents

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Stephen P.A. Brown and Hillard G. Huntington*

1. Introduction

High oil prices and unstable foreign oil production have renewed concern about U.S. energy security. The United States draws its oil from an integrated world oil market that includes historically unstable suppliers. In addition, disruptions of world oil supply have led to episodes of sharply rising oil prices, which have resulted in reductions in U.S. gross domestic product (GDP) and large income transfers to foreign oil producers. In fact, 10 of the 11 U.S. recessions since World War II have been preceded by sharply rising oil prices (Figure 1).

A number of studies—such as those by the Council on Foreign Relations (2006) and Leiby (2007)—emphasize the costs of U.S. dependence on imported oil. But because oil is fungible, consumers cannot distinguish between domestic and imported sources of the oil they consume, and all oil prices move together with the consequence that no supply is secure from price shocks. At the same time, policy *can* distinguish between domestic and imported sources of oil, and these sources of supply differ in the instability they create in world oil markets.

To the extent that the U.S. economic losses associated with oil supply disruptions are externalities that are not taken into account in private actions, they become a concern for economic policy. Our assessment finds that the principal externalities associated with oil supply disruptions are GDP losses and some of the transfers abroad. Such losses are not confined to those who buy the marginal barrel of oil and are not likely to be taken into account in the purchase decision.

The oil security premium is an attempt to quantify the externality portions of the economic losses associated with the potential disruptions in world oil supply that result from the

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increased consumption of either domestic or imported oil. To estimate such oil security premiums, we employ a welfare–analytic approach, taking into account projected world oil market conditions, probable oil supply disruptions, the market response to oil supply disruptions, and the U.S. economic losses resulting from disruptions to the extent that they should be considered externalities. To make these estimates, we use a simulation model of world oil markets and draw on an Energy Modeling Forum (EMF) assessment of probable oil supply disruptions, recent studies of the elasticities of world oil supply and demand, and an extensive literature about the response of U.S. economic activity to world oil supply disruptions. Unlike previous analyses, we focus exclusively on the externalities directly associated with oil insecurity and ignore the oil wealth transfers associated with stable markets.

The components of these estimates are traditional elements of the oil security premium, but we depart from the literature that estimates security premiums for the substitution of a barrel of domestically produced oil for an imported barrel. We take a broader approach and provide estimates for three types of oil security premiums: one for increasing U.S. oil consumption with domestically produced oil, one for increasing U.S. oil consumption with imported oil, and one for displacing a barrel of imported oil with a barrel of domestically produced oil. The latter premium differs from the first two because it holds total oil consumption unchanged.

In the next section we examine the integration of the world oil market and reasons for distinguishing between secure and insecure supplies. In section 3, we examine the economic reasons for public policy to protect against oil insecurity by separating the private costs borne by each oil consumer from the external costs that could affect other consumers. In section 4, we build on Sections 2 and 3 to explain how the security premiums are estimated, what data is used, and the resulting estimates. The concluding section summarizes the findings and draws implications for U.S. oil security policy.

2. Domestic and Imported Oil

Domestic and imported oil are nearly indistinguishable to the consumer. In fact, fungibility and relatively low transportation costs have led to an integrated world oil market in which, as Nordhaus (2009) explains, prices move together (Figure 2). At the same time, domestic oil production is stable, whereas production outside the United States contains unstable elements. Consequently, policymakers may have a reason to differentiate between domestic and imported oil, and have some ability to do so via legislation or regulation even if consumers cannot.

Because oil is fungible and its price is determined in an integrated world market, domestically produced oil is subject to the same global oil price shocks as imported oil. A disruption of foreign oil supplies would mean higher oil prices in the United States, even if it were importing no oil from the country whose production was disrupted. Rising oil prices elsewhere in the world would divert secure supplies from the United States to other markets, and the United States would see the same oil price gains that prevail on world markets. Because no oil supplies are secure from price shocks, the increased consumption of either domestic or imported oil has the potential to increase the economy's exposure to oil supply shocks.

Nonetheless, the economy's exposure to oil price shocks differs for changes in domestically produced and imported oil. Our examination shows that oil production in countries that Beccue and Huntington (2005) identify as unstable suppliers varies with non-U.S. oil production, which motivates policy to distinguish between domestic and imported oil. An increase in U.S. oil imports reduces energy security by increasing the share of world oil supply that comes from unstable suppliers. In contrast, an increase in U.S. oil production or other close substitutes enhances energy security by increasing the share of world oil supply that comes from stable suppliers.

The same analysis applies to any liquid fuels—such as biofuels, coal-to-liquids, or gas-to-liquids—that are close substitutes for refined products. The prices for these fuels will move with the changes in market conditions that affect prices for refined products. A foreign oil supply disruption that boosts prices for refined products will also boost those for any liquid fuel that is a close substitute. For this reason, an increase in the domestic production of biofuels, coal-to-liquids, or gas-to-liquids has the same security implications as an increase in domestic oil production. The resulting change in security depends on the extent to which U.S. oil consumption is increased or oil imports are displaced.

3. Oil Security Externalities

To the extent that the economic losses associated with oil supply disruptions are negative externalities that are not taken into account in private actions, they become a concern for economic policy. A number of costs arise from potential oil price shocks, but not all such costs are externalities. And of course, oil use creates other externalities—such as air pollution and greenhouse gas emissions—that are not associated with energy security.

If oil consumers can correctly anticipate the size, risks, and societal impacts of an oil disruption and take them into account, there is little reason for government intervention.

Consumers will internalize all of the social costs of oil consumption, including the risk of disruptions, by holding inventories, diversifying their energy consumption, and reducing their dependence on oil use. Some experts, however, believe that critical national security concerns restrict broadly available information about geopolitical conditions and oil market risks. If restricted information causes oil consumers to underestimate the risks, they are likely to underinvest in oil security protection.

Even if oil consumers have accurate information about oil market risks, government intervention may be justified for a second, more fundamental reason. Oil consumers will internalize any costs of oil use that they expect to bear, but they will typically ignore any external costs that their decisions impose on other consumers. The decision to purchase an additional barrel of oil has the potential to reduce economic security, not only for the purchaser, but for all other consumers in the oil market and the economy.

Previous research has raised a number of possible oil security externalities, including the failure of buyers to consider how oil purchases affect the prices paid by others, an increase in the expected transfers paid to foreign oil producers during disruptions, an increase in the GDP losses arising from oil supply disruptions, increases in defense and other government expenditures to reduce the effects of oil supply shocks, limits that oil imports place on U.S. foreign policy, and the uses to which some oil-exporting countries put their revenue. The list is long, but not all are externalities. Externalities arise only when a market transaction imposes costs or risks on an individual who is not party to the transaction. We find that the principal security externalities associated with oil consumption are the expected GDP losses and some of the transfers that result from oil supply disruptions.

3.1 Some Welfare Analytics of U.S. Oil Consumption

When developing oil policy, policymakers are likely to be concerned with a wide range of issues, such as the aggregate economic activity supported by oil consumption, the terms of trade for imported oil, the welfare losses resulting from the pollution associated with oil use, and the vulnerability of U.S. economic activity to world oil supply disruptions. Treating vulnerability as expected losses in U.S. economic activity and increased transfers to foreign oil producers that are associated with oil supply disruptions, the expected total welfare associated with U.S. oil consumption can be represented as

$$W = Y(Q_C) - TC_D - P \cdot Q_M - X_O + E(\Delta Y) - E(\Delta P) \cdot Q_M \qquad (1)$$

where W is domestic welfare; Y is domestic GDP, which is a function of oil consumption and close substitutes (Q_C); TC_D is the total cost of domestic oil production; P is the international price of oil; Q_M is oil imports; X_O is the value of any environmental externalities associated with oil use; $E(\Delta Y)$ is the expected GDP loss associated with the price gains resulting from expected oil supply disruptions; and $E(\Delta P)\cdot Q_M$ is the expected increase in oil import costs associated with the expected oil supply disruptions.[1]

To assess how increased oil consumption affects wellbeing, we take a derivative of Equation 1 with respect to oil consumption (from both domestic and imported sources) and set the result equal to zero. Assuming that domestically produced oil is priced competitively, domestic marginal cost equals the world oil price, which allows to us write the resulting optimality condition as:

$$\frac{\partial Y}{\partial Q_C} = P\frac{\partial Q_D}{\partial Q_C} + P\frac{\partial Q_M}{\partial Q_C} + \frac{\partial P}{\partial Q_M}\frac{\partial Q_M}{\partial Q_C}Q_M + \frac{\partial X_O}{\partial Q_C} - \frac{\partial E(\Delta Y)}{\partial Q_D}\frac{\partial Q_D}{\partial Q_C} - \frac{\partial E(\Delta Y)}{\partial Q_M}\frac{\partial Q_M}{\partial Q_C}$$
$$+ \frac{\partial E(\Delta P)}{\partial Q_D}\frac{\partial Q_D}{\partial Q_C}Q_M + \frac{\partial E(\Delta P)}{\partial Q_M}\frac{\partial Q_M}{\partial Q_C}Q_M + E(\Delta P)\frac{\partial Q_M}{\partial Q_C} \quad (2)$$

where Q_D is quantity of domestic oil production. If marginal oil consumption draws from both domestic and imported sources, Equation 2 describes the optimality condition for U.S. oil consumption. Recognizing that any changes in U.S. oil consumption must come from domestic or imported sources ($\partial Q_D/\partial Q_C + \partial Q_M/\partial Q_C = 1$), the economic effects of increased U.S. oil consumption are a weighted average of the effects of increased domestic production and imports.

Rather than evaluate Equation 2, we first distinguish between domestic and imported oil. We do so by considering two extreme cases. In one case, the change in U.S. oil consumption comes only from domestic production ($\partial Q_D/\partial Q_C=1$; $\partial Q_M/\partial Q_C=0$). In the other case, the change in U.S. oil consumption comes only from imports ($\partial Q_M/\partial Q_C=1$; $\partial Q_D/\partial Q_C=0$).

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[1] We focus here on the issues that create the demand for policy. In doing so, we abstract from any effects that the increased use of unstable oil supplies may have in increasing policy costs. See section 3.2.5 below.

For domestically produced oil, the optimality condition reduces to

$$\frac{\partial Y}{\partial Q_D} = P + \frac{\partial X_O}{\partial Q_D} - \frac{\partial E(\Delta Y)}{\partial Q_D} + \frac{\partial E(\Delta P)}{\partial Q_D} Q_M \tag{3}$$

The optimal use of domestic oil occurs when the change in output resulting from its increased consumption equals its price plus the additional environmental externalities associated with its consumption, the changes in the expected GDP losses during an oil supply disruption that result from increased domestic oil production, and the changes in expected import costs during an oil supply disruption that result from increased domestic oil production.

For imported oil, the optimality condition reduces to

$$\frac{\partial Y}{\partial Q_M} = P + \frac{\partial P}{\partial Q_M} Q_M + \frac{\partial X_O}{\partial Q_M} - \frac{\partial E(\Delta Y)}{\partial Q_M} + \frac{\partial E(\Delta P)}{\partial Q_M} Q_M + E(\Delta P) \tag{4}$$

The optimal use of imported oil occurs when the change in output resulting from its increased consumption equals its price plus changes in the terms of trade for imported oil, the additional environmental externalities associated with its consumption, the changes in the expected GDP losses during an oil supply disruption that result from increased oil imports, and the changes in expected import costs during an oil supply disruption that result from increased oil imports.

3.2 The Externalities Associated with Oil Consumption

In a well-functioning market, deviations from optimal consumption of domestically produced or imported oil occur only to the extent that the elements in Equations 3 and 4 are considered externalities. For domestically produced oil, the total externalities associated with increased consumption are

$$X_D = \frac{\partial X_O}{\partial Q_D} - X_Y \frac{\partial E(\Delta Y)}{\partial Q_D} + X_{MP} \frac{\partial E(\Delta P)}{\partial Q_D} Q_M \tag{5}$$

where X_D represents the total externalities associated with increased consumption of domestically produced oil, X_Y takes a value from zero to one to represent the portion of the expected GDP loss resulting from world oil supply disruptions that is an externality, and X_{MP} takes a value from zero to one to represent the externality portion of the expected change in the terms of trade on imported oil that is attributable to the price response to an oil supply disruption.

Similarly, for imported oil, the total externalities associated with increased consumption are

$$X_M = \frac{\partial P}{\partial Q_M} Q_M + \frac{\partial X_O}{\partial Q_M} - X_Y \frac{\partial E(\Delta Y)}{\partial Q_M} + X_{MP} \frac{\partial E(\Delta P)}{\partial Q_M} Q_M + X_{MM} E(\Delta P) \tag{6}$$

where X_M represents the total externalities associated with increased consumption of imported oil, X_Y and X_{MP} take the same value as in Equation 5, and X_{MM} takes a value from zero to one to represent the externality portion of the expected change in the terms of trade during a world oil supply disruption that is attributable to the change in imports.

In assessing an oil security premium, our focus is on those externality components that may be regarded as security issues. Some of the externalities may not be security issues and not all of the terms in Equations 5 and 6 may be externalities.

3.2.1 Environmental Externalities

The consumption of both domestic and imported oil is likely to result in environmental externalities. As explained in an extensive literature, such externalities add costs to oil consumption that are unrecognized in an unregulated market.[2] These externalities are outside the present inquiry because they are not a security issue.

3.2.2 Changes in the Terms of Trade for Imported Oil

Although they do not represent a security issue, changes in the terms of trade during stable market conditions are often included in analyses of the external costs of U.S. oil imports. An increase in U.S. oil imports increases the price paid for all imported oil, and that means increased costs for those purchasing imported oil. Acting as individual price takers, U.S. consumers neither differentiate between domestic and imported oil nor consider how their individual purchases affect the global price of oil, which makes the price increase faced by other purchasers a pecuniary externality.

[2] Hall (2004) provides estimates of such externalities.

Although pecuniary externalities do not distort market outcomes, because the United States imports large quantities of oil, a U.S. policy of restricting oil imports can improve its terms of trade for imported oil. We exclude this terms-of-trade effect (also known as the *monopsony premium*) from our measure of security externalities because it is not a security concern and because pursuing these gains would distort global resource use rather than offset an externality.

3.2.3 Increased Transfers during Supply Disruptions

An increase in U.S. oil imports increases the expected transfers to foreign oil producers during a supply shock. This increase happens in two ways. Oil production in the countries identified as unstable by Beccue and Huntington (2005) expands with oil production outside the United States, which translates into bigger price shocks and larger transfers on all U.S. oil imports. In addition, an increase in imported oil increases the amount of oil subject to a foreign transfer during a disruption.

Not all of these expected transfers are externalities. When buying oil products (or oil-using goods), individuals should recognize that possible oil supply shocks and higher prices could harm them personally. So the expected transfer on the marginal purchase is not an externality, and X_{MM} ought to be fairly close to zero.[3]

On the other hand, individuals are unlikely to take into account how their purchases may affect others by increasing the size of the price shock that occurs when there is a supply disruption. So the latter portion is an externality and X_{MP} ought to be fairly close to one. When summed across the 300+ million people in the United States, this small external effect is significant in the aggregate.

In contrast with imported oil, increasing domestic oil production increases the secure elements of world oil supply, which weakens the price shocks from any given supply disruption and yields smaller transfers on all U.S. oil imports. Consequently, the third term on the right-hand side of Equation 5 has a negative value, whereas the corresponding term of Equation 6 has a positive value.

[3] In practice, consumers may not understand the likelihood of future oil supply disruptions and the consequent price effects.

3.2.4 GDP Losses

Historical experience shows that the GDP losses associated with oil supply shocks can be considerable. In fact, Finn (2000) documents that the economic losses associated with an oil price shock are greater than can be explained by simple neoclassical analysis. Economic researchers have offered a variety of explanations for the outsized effects that could yield such macroeconomic externalities. John (1995) points to market power and search costs. Rotemberg and Woodford (1996) similarly blame imperfect competition. Bohi (1989, 1991), Bernanke et al. (1997), and Barsky and Kilian (2002, 2004) attribute these effects to possible monetary policy failures. Mork (1989) and Davis and Haltiwanger (2001) point to the reallocation of resources necessitated by an oil price shock. Hamilton (1996, 2003), Ferderer (1996), and Balke et al. (2002) blame the uncertain environment created for investment, and Huntington (2003) points to coordination failures.

Whatever generates the strong impact of oil supply shocks on U.S. economic activity, the economic losses from such shocks are well beyond the possible increase in costs that any individual might expect to bear as part of an oil purchase. Consequently, those purchasing oil are unlikely to understand or consider how their own oil consumption increases the economy-wide effects of oil supply shocks. Because the exposure of the economy to the GDP losses associated with supply disruptions increases with oil consumption, individual decisions to increase oil consumption generate externalities. Therefore, the portion of the expected loss in real GDP that is an externality, X_Y, is likely fairly close to one.

Recent research, such as that by Kilian (2009) and Balke et al. (2008), shows that it is important to differentiate among the various causes of oil price shocks when analyzing or estimating the effects on GDP. Oil supply disruptions result in higher oil prices and reduced economic activity. Oil demand shocks originating from domestic productivity gains result in higher oil prices and increased economic activity. Other oil market shocks—such as foreign productivity gains—can boost oil prices and have neutral effects on U.S. output. In such cases, oil price increases do not yield economic losses.

These findings are not a reason to reject the GDP losses resulting from oil supply disruptions as externalities. Neither are they a reason to think it impossible to quantify the GDP effects of oil supply disruptions. One simply needs to be careful that any analysis of GDP losses depends on probable oil supply disruptions—not just oil price shocks—and that any parameters used in estimation are capable of distinguishing between oil supply disruptions and other factors that might serve to boost oil prices.

Although the increased consumption of either domestically produced or imported oil increases the economy's exposure to the effects of oil supply shocks, policymakers have a reason to differentiate between these two sources of oil when it comes to GDP losses. As described above, increasing imports boosts the insecure elements of world oil supply, which strengthens the oil price shocks resulting from any given oil supply disruption and exacerbates the GDP loss. In contrast, increasing domestic oil production boosts the secure elements of world oil supply, which weakens the price shocks from any given oil supply disruption and dampens the GDP loss. Consequently, the expected GDP loss is smaller for an increase in oil consumption from domestic production than imports: $-\partial E(\Delta Y)/\partial Q_D < -\partial E(\Delta Y)/\partial Q_M$.

3.2.5 Increased Government Expenditures

Government actions—such as military spending in vulnerable supply areas and expansion of the strategic petroleum reserve—are possible responses to the economic vulnerability arising from potential oil supply disruptions. Some past analyses have attributed the cost of policy actions, such as military intervention in the Middle East, to U.S. dependence on unstable oil supplies imported from the region (e.g., Hall 2004). Governments *should* balance these expenditures against the benefits of reducing the externalities associated with increased oil use, but Bohi and Toman (1996) explain that such expenditures are not another externality.

Moreover, Bohi and Toman explain that the additional policy costs of responding to increased oil imports are close to zero. U.S. foreign policy is conducted with a broad range of objectives, of which securing foreign oil supplies is only a part. In addition, the costs of policy measures, such as diplomacy or military intervention, are not likely to increase by very much with additional oil consumption or imports.

3.2.6 Limits on U.S. Foreign Policy

An overall dependence on imported oil may reduce U.S. foreign policy prerogatives. These limitations can arise because U.S. policymakers fear that the course of foreign policy that they wish to pursue would increase the probability of world oil supply disruptions or because the foreign dependence on imported oil may limit cooperation with U.S. objectives. Both explanations suggest that foreign policy is limited by the fear of economic losses associated with world oil supply disruptions. Our calculations incorporate the economic security losses, but they do not attribute any additional political insecurity costs to additional oil consumption.

4. Calculating Oil Security Premiums

To calculate the domestic and imported oil security premium, we focus on the externality components of the expected GDP losses and wealth transfers associated with world oil supply disruptions. The traditional oil import premium that assesses the cost of using imported oil over domestically produced oil is the difference between the imported and domestic oil security premiums.[4]

Our approach for calculating oil security premiums requires an assessment of the probabilities of oil supply disruptions of various sizes, estimated short-run supply and demand elasticities to compute the resulting price shocks, an estimated elasticity of U.S. GDP to oil price increases that result from supply disruptions, and a projection of world oil market conditions. These parameters and data can be used to calculate how a marginal increase in oil consumption from domestic or imported sources affects the expected U.S. GDP losses and transfers that result from each possible oil supply disruption. The probabilities are then used to combine the separate estimates.

The disruption probabilities and sizes are adapted from a recent EMF study documented by Beccue and Huntington (2005). The short-run demand and supply elasticities are adapted from the economics literature, as are the elasticities of U.S. GDP to oil price shocks. The *2009 Annual Energy Outlook* (revised) produced by the Energy Information Administration (EIA) is used to project world oil market conditions.

4.1 The Analytics

The domestic oil security premium represents the increased externality costs of the expected GDP losses and income transfers to foreign oil producers that result from changes in the consumption of domestically produced oil. Assuming that the probability and size of disruptions are separable, the security premium for consumption of domestic oil shown in Equation 5 can be rewritten as a product of individual probabilities and disruptions as follows

$$S_D = -\sum_{i=1}^{n} \varphi_i \frac{\partial Y(P(\Delta Q_i))}{\partial Q_D} + \sum_{i=1}^{n} \varphi_i \frac{\partial P(\Delta Q_i)}{\partial Q_D} Q_M \qquad (7)$$

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4 Previous oil import premium estimates also include changes in the terms of trade. We do not include this component because it is neither an externality nor a security issue, as explained above.

where S_D is the oil security premium for the consumption of domestically produced oil, φ_i and ΔQ_i are the respective probability and size of each oil supply disruption i, Y is U.S. GDP, P is the price of oil, Q_D is U.S. oil production, and Q_M is U.S. oil imports.[5]

As Equation 7 shows, two factors shape the security premium when increased consumption is met only with domestically produced oil. As shown by the terms under the first summation, exposure of the economy to the oil price gains resulting from an oil supply shock increases with oil consumption. At the same time, a marginal increase in secure domestic oil production reduces the relative importance of insecure supplies in the global oil market, which reduces the expected price shocks and dampens the expected GDP losses. For the terms under the second summation, the increase in secure production reduces the price increase resulting from any external oil supply shock, which reduces the transfers to foreign oil producers when such a shock occurs.

In a similar manner, the security premium for imported oil represents the increased externality costs of the expected GDP losses and income transfers to foreign oil producers that result from changes in the consumption of imported oil. Again, assuming that the probability and size of disruptions are separable, the security premium for the consumption of imported oil shown in Equation 6 can be rewritten as a product of individual probabilities and disruptions as follows

$$S_I = -\sum_{i=1}^{n} \varphi_i \frac{\partial Y(P(\Delta Q_i))}{\partial Q_M} + \sum_{i=1}^{n} \varphi_i \frac{\partial P(\Delta Q_i)}{\partial Q_M} Q_M \tag{8}$$

where S_I is the security premium for the consumption of imported oil.

As Equation 8 shows, two factors also affect the oil security premium when an increase in consumption is met with imported oil. As shown by the terms under the first summation, exposure of the economy to the oil price gains resulting from an oil supply shock increases with oil consumption. At the same time, a marginal increase in U.S. oil imports increases the output of insecure oil supplies, which increases expected oil price shocks and exacerbates the expected GDP losses. For the terms under the second summation, the increase in insecure production

[5] Note that $\sum \varphi_i = 1$ when one state represents a zero disruption.

boosts the price increase resulting from any external oil supply shock, which increases the transfers to foreign oil producers when such a shock occurs.

In taking this approach, we treat expected world oil supply disruptions as discrete probabilistic episodes that are exogenous. In contrast, the size of each disruption is a function of world oil market conditions and responds to changes in U.S. oil imports.

4.2 Probability of Supply Disruptions

As reported in Beccue and Huntington (2005), the EMF developed a risk assessment framework and evaluated the likelihood of foreign oil supply disruptions over a decade-long period. Although domestic problems and severe weather could result in significant disruptions, the study focused on geopolitical, military, and terrorist causes of disruptions abroad.[6] Conducted as a structured survey of experts, the final results provide a subjective assessment of the size, likelihood, and duration of disruptions over the 10-year period from 2005 to 2014. Disruptions are expressed as net outcomes, after all surplus capacity from market participants and foreign governments has been used.

We convert the EMF's decadal estimates to the annual values shown in Table 1. Each decadal estimate (denoted as φ_d) is the probability of at least one or more disruptions over the decade. If stability over the decade $(1-\varphi_d)$ has an equal chance of happening each year, the annual disruption is computed as $\varphi_a = 1-(1-\varphi_d)^{1/10}$. As shown in the table, the EMF analysis yields a relatively small probability of a disruption in any year. To extend the EMF analysis to additional years, we follow the approach described in Section 4.1 above and assume that the size of the disruptions changes with market conditions but the probabilities do not.

The world oil market conditions represented in the Beccue and Huntington (2005) analysis of supply disruptions are about the same as those projected for 2015–2016 in EIA's *2009 Annual Energy Outlook*. Our examination of historical data and projections in EIA's *2009 International Energy Outlook* shows that production from insecure sources generally rises in proportion to non-U.S. production. Using 80 million barrels per day of non-U.S. oil production as the baseline conditions under which the Beccue and Huntington estimated disruptions apply,

[6] In using the Beccue–Huntington estimates, we abstract from natural supply disruptions, such as those arising from hurricanes or other severe weather.

we scale disruption sizes up or down in proportion to non-U.S. production, while the probability of any given disruption remains unchanged.[7]

4.3 The Price Response to Supply Disruptions

We use a simple world oil market framework to estimate the price response to the gap in world oil production that results from a given oil supply disruption. The estimated price response incorporates the prevailing market conditions, the disruption size, short-run price elasticities of oil demand and supply, the income elasticity of oil demand, and the elasticity of GDP with respect to the oil price.

A survey by Atkins and Jazayeri (2004) finds that the estimated short-run elasticity of U.S. oil demand ranges from –0.00 to –0.11. Cooper (2003) and Smith (2009) find similar values for the member countries of the Organisation for Economic Co-operation and Development and the world, respectively. We use a midpoint value of –0.055 in an analysis range of –0.02 to –0.09 (Table 2). Following Huntington (2005) and Smith (2009), we assume that the short-run elasticity of oil supply has a midpoint value of 0.05 in a range of 0.025 to 0.075.

The reduction in GDP resulting from an oil price shock reduces oil demand and, in doing so, contributes to forces helping to close the gap between production and consumption that is created by a supply disruption. Assuming that the income elasticity of oil demand has a midpoint value of 0.7 in a range 0.55 to 0.85—as is consistent with Gately and Huntington (2002), Huntington (2005), Dargay et al. (2007), and Smith (2009)—the elasticity of GDP with respect to the oil price can be combined with the elasticities of demand and supply to approximate the price response. As shown in Table 3, the economics literature suggests a wider range of estimates, but we use a midpoint value of –0.044 in a range of –0.012 to –0.078 for the elasticity of U.S. GDP with respect to the world oil price.

The combination of elasticities yields a midpoint elasticity of –0.136 that we use to find the overall price response needed to close the gap between production and consumption that is created by a production disruption.[8] Although a wider range of price responses would result from combining the most extreme elasticities, a wider range of security premium estimates is found by

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[7] Owing to fungibility, we use the term *oil* to include crude oil, refined products, and all liquid fuels that are close substitutes for refined products.

[8] This parameter value roughly means that oil prices will rise by 7.35 (=1/0.136) percent for every 1 percent reduction in oil supplies that is due to a disruption.

combining the high elasticity of GDP with respect to oil price with the low values of the other elasticities, and the low elasticity of GDP with respect to oil with the high values of the other elasticities. These combinations result in an initial range of elasticities used to find the overall price response needed to close the gap between production and consumption that is –0.088 to –0.175.

The range is further widened by allowing the elasticity of non-U.S. GDP to be as much as 20 percent higher or lower than the U.S. values at either extreme. Consequently, the resulting range of elasticities used to find the price response needed to close the gap between production and consumption that results from a supply disruption is approximately –0.081 to –0.177.

4.4 The Quantitative Effects of an Oil Price Shock on U.S. GDP

The estimated effects of an oil price shock on U.S. GDP are integral to calculating oil security premiums. These effects are used to estimate the price response to a given oil supply disruption and to calculate the GDP response to the ensuing price shock. As discussed above, we use a midpoint of –0.044 in a range of –0.012 to –0.078 as the elasticity of GDP with respect to the price of oil. We consider this a good approximation of the range found in the economics literature.

In their survey of the quantitative estimates of the effects of oil price shocks on economic activity, Jones et al. (2004) find that the elasticity of U.S. GDP with respect to oil price shocks ranges widely from –0.012 to –0.12, as is shown in Table 3.[9] In a survey of models used in an EMF study, Hickman et al. (1987) find a range from –0.02 to –0.075. Leiby (2007) uses a range from –0.01 to –0.08 in his estimates of the oil import premium.

Some of the newer empirical research, such as Blanchard and Gali (2007) and Balke et al. (2008) find smaller effects than the earlier literature—with Balke et al. estimating a midpoint of –0.018 in a range of –0.012 to –0.029. Both studies control for other types of shocks to economic activity—such as productivity shocks—and argue that the confluence of oil supply shocks with other shocks may have meant that previous research exaggerated the economic losses associated with the oil price shocks arising from past oil supply disruptions. In contrast, Hamilton (2009) expresses skepticism about relying exclusively on new estimates at the lower end of the range.

[9] Brown and Yücel (2002) and Kilian (2008) survey the literature in a less quantitatively oriented manner.

We follow Hamilton's advice by using a relatively wide range of estimates for the elasticity of U.S. GDP with respect to oil price.

4.5 The Oil Security Premiums

We estimate the oil security premiums in two separate ways. We show the effects of using a range of different parameter assumptions for a reference market case that approximates projected oil market conditions for 2015–2016. We also compute security premiums from 2008 through 2030 based on recent EIA projections.

As shown in Table 4, the use of a range of assumptions about the various elasticities yields a range of estimated domestic and imported oil security premiums for 2015–2016. These calculations are based on a single set of world oil market and U.S. GDP conditions derived from EIA's *2009 Annual Energy Outlook* (revised). According to EIA's outlook, world oil consumption is 90 million barrels per day, U.S. consumption of oil and other liquid fuels is 20 million barrels per day, and U.S. production of oil and other liquid fuels is 10 million barrels per day. The United States imports 10 million barrels of oil and other liquids per day, and non-U.S. production of oil and other liquids is 80 million barrels per day. In 2007 dollars, the projected world oil price and U.S. GDP are $100 per barrel and $16.315 trillion, respectively.

Consistent with the analysis above, Table 4 shows that the expected GDP loss associated with a marginal increase in the consumption of imported oil is greater than for a marginal increase in the consumption of domestic oil. Increasing imports increases the size of potential disruptions in unstable regions because they provide more oil. In contrast, increasing domestic production weakens the price response to a given foreign oil supply disruption. The table also shows that an increase in the consumption of domestic oil reduces expected transfers and an increase in the consumption of imported oil increases expected transfers.

The net effect for domestic oil is $2.81 per barrel in a range of $0.19 to $8.70 per barrel. For imported oil the total effect is $4.98 in a range of $1.10 to $14.35 per barrel.[10] The difference between the two, which represents the external security costs of displacing a barrel of domestic

[10] Use of the –0.018 midpoint elasticity of GDP with respect to oil prices from the newer literature on the economic effects of oil price shocks generates midpoint estimates of $0.65 per barrel for the security premium on the consumption of domestically produced oil and $2.45 per barrel for the security premium on the consumption of imported oil. This lower estimate implies that a less elastic GDP response to oil prices reduces the security premium.

oil production with imported oil while keeping U.S. oil consumption unchanged, is $2.17 per barrel in a range of $0.91 to $5.65 per barrel.[11]

We also use EIA's *2009 Annual Energy Outlook* as the basis for calculating oil security premiums from 2008 to 2030. Over this time horizon, world oil consumption is projected to grow from 86 to 104.7 million barrels per day, and non-U.S. oil production is projected to grow from 77.4 to 92.2 million barrels per day. U.S. oil consumption is projected to grow from 19.4 to 20.9 million barrels per day, and U.S. oil production is projected to grow from 8.7 to 12.5 million barrels per day. Over the same time horizon, EIA projects that the price will fall from $99.08 per barrel in 2008 to $40.52 in 2009 before rising to $130.92 in 2030 (with all prices in 2007 dollars). For 2008, U.S. GDP is estimated at $13.982 trillion (2007 dollars). A slightly lower figure of $13.577 trillion (2007 dollars) is projected for 2009. After that, U.S. GDP is projected to rise to $23.810 trillion (in 2007 dollars) in 2030.

As shown in Figure 3, changing oil market conditions and U.S. economic activity yield rising estimates of the oil security premiums over the period from 2008 to 2030. For the marginal consumption of domestically produced oil, the midpoint estimate of the oil security premium rises from $2.28 per barrel in 2008 to $4.45 in 2030. For the marginal consumption of imported oil, the midpoint estimate of the oil security premium rises from $4.45 per barrel in 2008 to $6.82 in 2030. The midpoint estimate of the oil security premium for displacing domestic oil production with imports while holding U.S. oil consumption constant is the difference between the previous two estimates, and it rises only slightly, from $2.17 per barrel in 2008 to $2.37 per barrel in 2030.

Over the 22-year time horizon used for this analysis, rising U.S. GDP and U.S. oil prices are the principal factors driving the gains in the oil security premiums. Insecure oil production increases with non-U.S. production, but at a slower rate than overall world consumption, so its effect is lessened. In addition, EIA projects the United States will become less dependent on imported oil, so the quantity of imports on which transfers would be paid in the event of an oil supply disruption is reduced. The transfer components in the security premiums are enhanced, however, because oil prices are projected to rise.

[11] These estimates are lower than those reported by Leiby (2007). Leiby's estimated disruption premium for displacing domestic oil with imports includes the expected transfer on increased imports that occurs during a disruption, which is excluded from our estimates. When we include this effect, our estimates are comparable to Leiby's disruption premium.

As shown in Figure 3, there is a considerable range about the midpoint estimates of the security premiums. For the oil security premium on the consumption of domestically produced oil, plausible elasticities generate low estimates that rise from $0.02 per barrel in 2008 to $0.58 in 2030 and high estimates that rise from $7.20 per barrel in 2008 to $13.53 in 2030. For the oil security premium on the consumption of imported oil, plausible elasticities generate low estimates that rise from $0.99 per barrel in 2008 to $1.49 in 2030 and high estimates that rise from $12.85 per barrel in 2008 to $19.75 in 2030.

As above, the differences between the domestic and imported oil security premiums can be used to calculate an oil security premium for displacing domestic oil production with imports while holding U.S. oil consumption constant. For this oil security premium, plausible elasticities generate low estimates that fall from $0.97 per barrel in 2008 to $0.91 per barrel in 2030 and high estimates that rise from $5.65 per barrel in 2008 to $6.22 per barrel in 2030.

5. Conclusions and Policy Implications

Oil supply disruptions have economy-wide effects. Moreover, one person's increased oil consumption can increase the size of an oil supply disruption or its economic consequences, which means that increase in oil consumption creates a security externality. Oil security premiums are a way to measure these externalities. Estimated in dollars per barrel of oil, these security premiums reflect the externality components of expected changes in aggregate output and transfers that result from the increased consumption of domestic or imported oil.

Estimates developed with the framework described above show that the consumption of either domestically produced or imported oil yields security externalities. Because there is an integrated world oil market in which all oil prices are determined, the economy's exposure to the price effects of oil supply disruptions increases with all U.S. oil consumption. Nonetheless, the security premium on the consumption of imported oil is greater than that on the consumption of domestically produced oil. Increased domestic oil production boosts the share of stable supplies in the world oil market, and increased oil imports boost the share of unstable supplies.

The midpoint estimates of the oil security premium on the consumption of domestically produced oil rise from $2.28 per barrel in 2008 to $4.45 in 2030 (in 2007 dollars). In contrast, the midpoint estimates of the oil security premium on the consumption of imported oil rise from $4.45 per barrel in 2008 to $6.82 in 2030 (in 2007 dollars). As described above, a plausible range of elasticity assumptions generates a considerable range about these midpoint values. Both estimates are useful for evaluating the expected reduction in security costs associated with a reduction in U.S. oil consumption, such as one arising from improved energy efficiency. In practice, the expected change in security costs will be a weighted average of the two estimates.

The difference between the premiums for increased consumption of domestic and imported oil means that there is a security premium for displacing domestic oil production with imported oil without any change in U.S. consumption. The midpoint estimate rises from $2.17 per barrel in 2008 to $2.37 per barrel in 2030 (in 2007 dollars), with a considerable range about these midpoint values. Such a premium is useful for evaluating policies that would displace imports with domestic production or for policies to change the size of the strategic petroleum reserve.

The premiums also can be implemented as direct policies in the form of taxes and/or subsidies.[12] For instance, the premium for domestic oil could be implemented as a tax on U.S. consumption of refined products with an additional import tariff that represents the difference between the premiums for imported and domestic oil. Alternatively, the premium on imported oil could be implemented as a tax on U.S. consumption of refined products with the addition of a subsidy for the production of domestic oil and other liquids that are close substitutes for refined products. The premiums also can be used in the cost–benefit analysis of specific policies that alter U.S. oil consumption, imports, or domestic production.

In any case, our estimates suggest that energy security is more greatly enhanced by policies to reduce overall oil consumption than by those that substitute domestic production for imports. In addition, only moderate policy is necessary to respond to the security issues associated with U.S. oil consumption. The projections used in our analysis show oil prices rising from about $40 per barrel in 2009 to more than $130 per barrel in 2030 (in 2007 dollars). In comparison to these oil price projections, the estimated oil security premiums are relatively modest.

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[12] Because the estimated premiums change with market conditions, they may need to be reestimated to account for the changes in market conditions that result from changes in policy.

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Figures and Tables

Figure 1
Real Oil Prices and U.S. Recessions

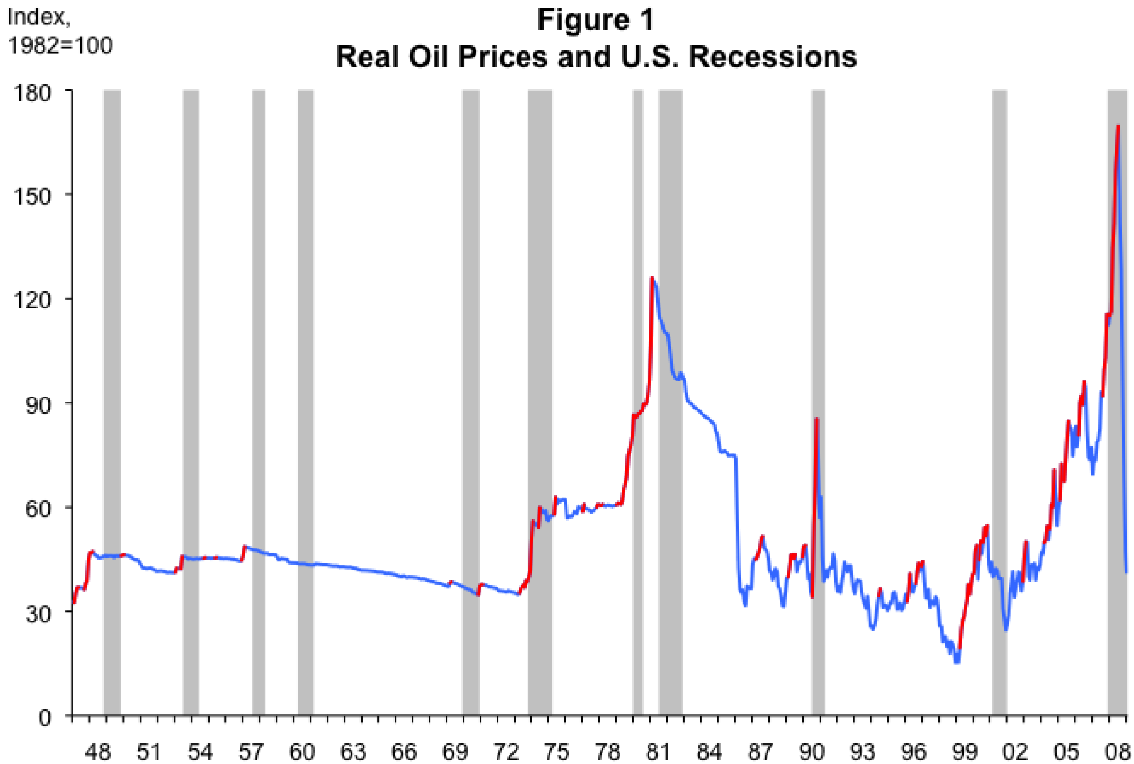

Figure 2
Worldwide Light Crude Oil Prices

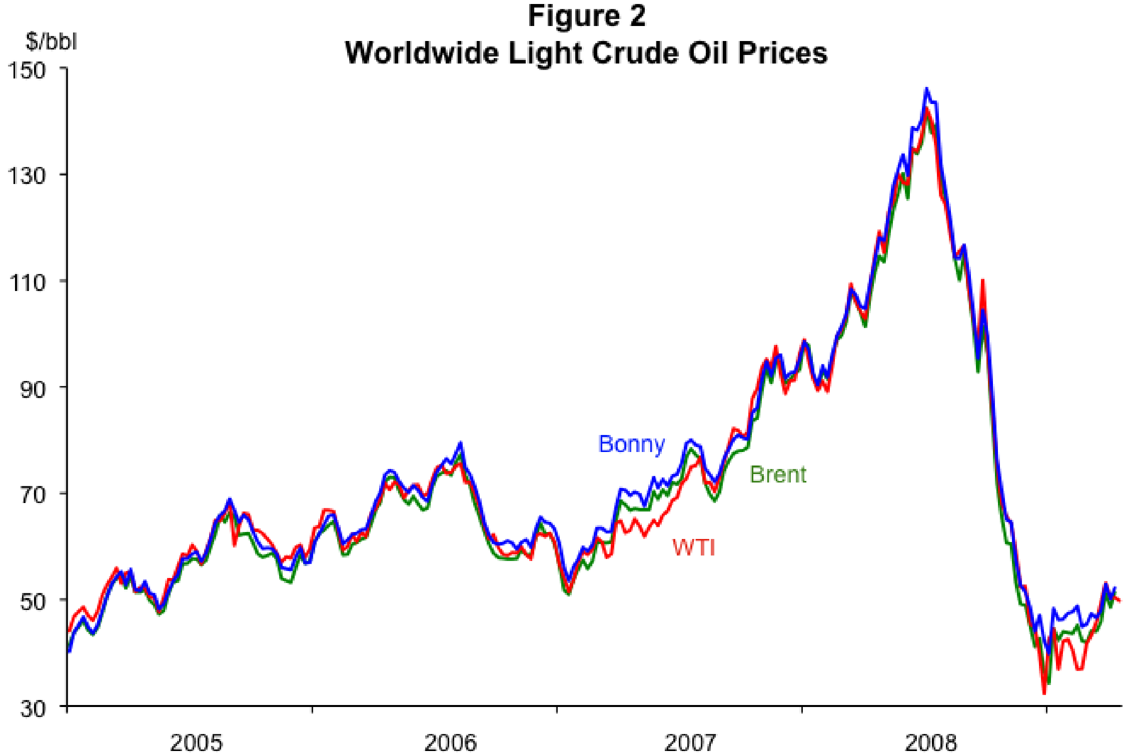

Figure 3

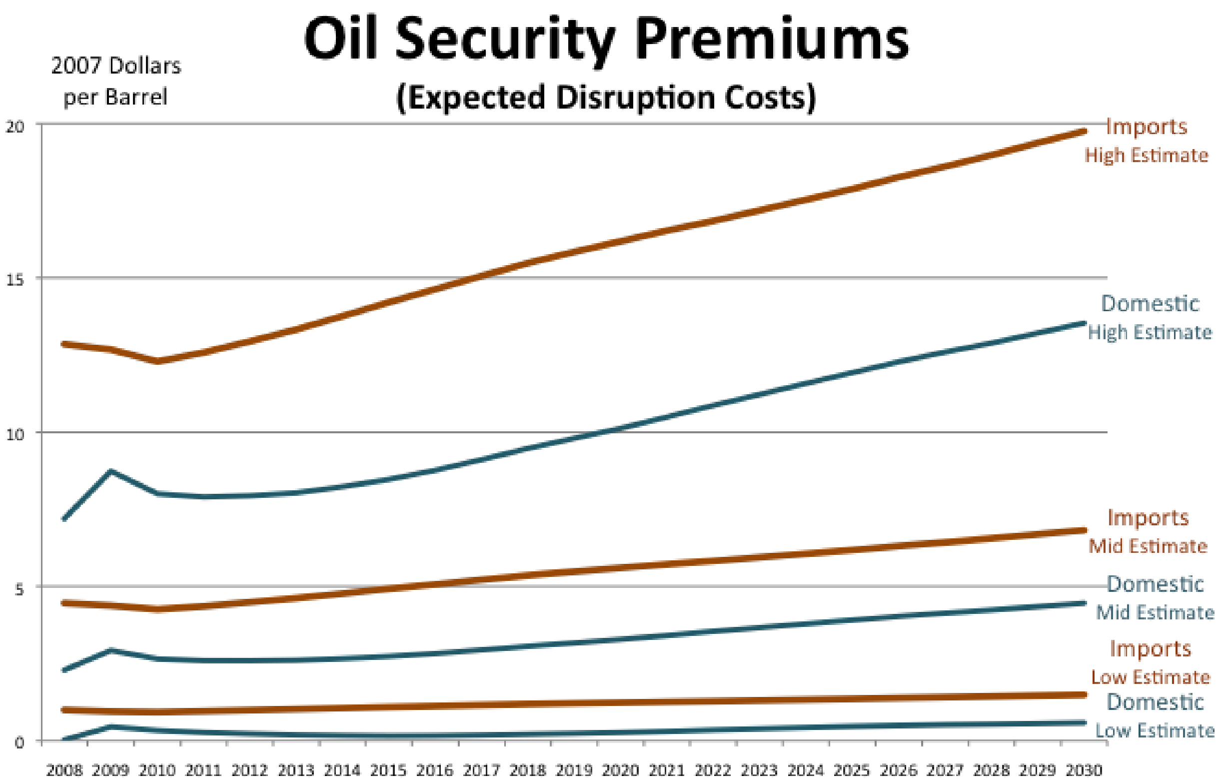
Oil Security Premiums
(Expected Disruption Costs)
2007 Dollars per Barrel
0
5
10
15
20
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Imports High Estimate
Domestic High Estimate
Imports Mid Estimate
Domestic Mid Estimate
Imports Low Estimate
Domestic Low Estimate

Table 1. Sizes and Annual Probabilities of Disruptions

Disruption size (million barrels/day)	Annual probability
0	0.843908554
1	0.030919163
2	0.032529155
3	0.045339487
4	0.002158576
5	0.007761138
6	0.010281493
7	0.010911735
8	0.007640165
9	0.001080596
10	0.001564854
11	0.001180577
12	0.001732513
13	0.000830936
14	0.000511190
15	0.000986074
16	0.000119553
17	0.000132331

Source: Adapted from Beccue and Huntington (2005).

Table 2. Income and Short-Run Price Elasticities

Elasticity type	Value
Price elasticity of supply	0.05 0.025 to 0.075
Price elasticity of demand	−0.055 −0.02 to −0.09
Income elasticity of demand	0.70 0.55 to 0.85

Table 3. Estimated Response of U.S. GDP to Oil Price Shocks Arising from Oil Supply Shocks

Reference	Elasticity
Econometric studies	−0.012 to −0.12
Leiby (2007)	−0.01 to −0.08
Energy Modeling Forum (1987)	−0.02 to −0.075
U.S. Department of Energy	−0.025 to −0.055
Newer estimates	−0.018 −0.012 to −0.029
Analysis range	−0.044 −0.012 to −0.078

Table 4. Estimated Oil Security Premiums for 2015–2016 (2007 dollars per barrel of oil)

	Domestic	Imports	Imports vs. domestic
GDP loss	3.65 0.77 to 10.67	4.87 1.03 to 14.10	1.22 0.26 to 3.43
Transfers	−0.84 0.58 to 1.97	0.11 0.07 to 0.25	0.95 0.65 to 2.22
Total externality	2.81 0.19 to 8.70	4.98 1.10 to 14.35	2.17 0.91 to 5.65

Note: Projected world oil price and U.S. GDP (in 2007 dollars): $100 per barrel and $16.315 trillion, respectively.