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Abstract

On September 7th, 2006, the U.S. Environmental Protection Agency (EPA) proposed a national renewable fuels program (more commonly known as the Renewable Fuel Standard, or RFS program). The proposed program is designed to encourage the blending of renewable fuels into the U.S. motor vehicle fuels. Wider use of renewable fuels will result in less oil U.S. consumption and less U.S. oil imports.

This study investigates the energy security benefits of reduced U.S. oil consumption and imports. A range of approaches have been developed at Oak Ridge National Laboratory (ORNL) for evaluating the social costs and energy security implications of oil use, and for evaluating policy measures that alter the U.S consumption and imports of oil. To help estimate the energy security benefits of the RFS, we updated and applied the method used in the 1997 report *Oil Imports: An Assessment of Benefits and Costs*, by Leiby, Jones, Curlee and Lee.[1] This approach estimates the marginal benefits to society, in dollars per barrel, of reducing oil U.S imports.[2] The "oil premium" approach emphasizes identifying those energy-security related costs which are not reflected in the market price of oil, and which are expected to change in response to an incremental change in the level of oil imports.

Since the 1997 publication of this report changes in oil market conditions, both current and projected, suggest that the magnitude of the oil premium may have changed. Significant driving factors that were revised or reconsidered include: oil prices, current and anticipated levels of Organization of Petroleum Exporting Countries (OPEC) production, U.S. import levels, potential OPEC behavior and responses, Strategic Petroleum Reserve levels, and disruption likelihoods. We apply the most recently available careful quantitative assessment of disruption likelihoods, from the Stanford Energy Modeling Forum's 2005 workshop series,[3] as well as other assessments. We also revisit the issue of the macroeconomic consequences of oil market disruptions and sustained higher oil prices. Using the oil premium calculation methodology which combines short-run and long-run costs and benefits, and accounting for uncertainty in the

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[1]Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997.

[2]This paper was cited and its results utilized in previous DOT/NHTSA rulemakings, including the 2006 Final Regulatory Impact Analysis of CAFE Reform for Light Trucks: US DOT, NHTSA 2006. "Final Regulatory Impact Analysis: Corporate Average Fuel Economy and CAFE Reform for MY 2008-2011 Light Trucks," Office of Regulatory Analysis and Evaluation, National Center for Statistics and Analysis, March.

[3]Energy Modeling Forum, Phillip C. Beccue and Hillard G. Huntington, 2005. "An Assessment of Oil Market Disruption Risks," FINAL REPORT, EMF SR 8, October 3.

key driving factors, we provide an updated range of estimates of the marginal energy security benefits of reducing U.S. oil imports.

The oil import premium is an informative measure of long-standing interest, but is not intended to provide complete guidance on oil security policy. The oil premium is not a measure of the full social costs of oil imports or use, or the full magnitude of the oil dependence and security problem. Rather, it is a measure of the quantifiable per-barrel economic costs which the U.S. could avoid by a small-to-moderate reduction in oil imports. The premium does not estimate the value of introducing a radical new technology, which may entail a major shift in supply or demand curves, or a substantial change in the long-run or short-run flexibility of supply or demand. As estimated, it is most consistent with the benefits of contracting domestic demand or expanding domestic supply along the existing demand and supply curves through conventional market incentives.

Finally, an estimated oil import premium of $5, $10, or $20 per barrel does not mean that a tax or tariff of that magnitude is recommended as the best policy, nor that the imposition of such a tax alone would completely solve the energy security problem and eliminate the need for any other policy. The multifaceted nature of the costs measured by the import premium suggests pursuing a combination of policies targeting key aspects of the problem. Helpful policies would promote more competitive oil supply in the long-run and short-run by diminishing the profitability and power of cartelized oil supply. They would also reduce the economy's vulnerability to oil shocks by increasing short-run supply/demand flexibility, promoting supply-region stability, developing buffer stocks and diminishing the economy's reliance on fuels with unstable supply.

I. Introduction: Purpose and Approach

This update and reassessment of the oil import premium was partly motivated by new policies to promote the reduction of gasoline use and the partial displacement of gasoline by renewable transport fuels. On September 7th, 2006, the U.S. EPA proposed a national renewable fuel program (more commonly known as the Renewable Fuel Standard program or RFS program). The proposed program will be applicable for 2007 and later and is designed to encourage the blending of renewable fuels into U.S. gasoline motor fuel. Specifically, the rule proposed the renewable fuel standards, responsibilities for refiners and other fuel producers, a credit and trading system, compliance mechanisms, and record keeping and reporting requirements.

A renewable fuel is defined in the Energy Policy Act of 2005 as a motor vehicle fuel that is produced from plant or animal products or wastes, as opposed to fossil fuel sources. Renewable fuels would include ethanol, biodiesel and other motor vehicle fuels made from renewable sources. Under the proposal, both renewable fuels blended into conventional gasoline or diesel and those used in their neat (unblended) form as a motor vehicle fuel would qualify.

The proposed rule contained preliminary analysis of the economic and environmental consequences of the expanded use of renewable fuels from the RFS program. To supplement this information, the U.S. EPA provide funding to the Oak Ridge National Laboratory to examine the energy security implications for the U.S. of the wider use of renewable fuels.

This update and reassessment of the oil import premium was partly motivated by new policies to promote the reduction of gasoline use and the partial displacement of gasoline by renewable transport fuels. Increased use of renewable fuel diversifies the energy sources used in making transportation fuel and reduces total consumption and imports of oil. To the extent that diverse sources of fuel energy reduce the dependence on any one source, the risks, both financial as well as strategic, of potential disruption in supply or spike in cost of a particular energy source is reduced. This reduction in risks is a measure of improved energy security. Reduced oil use also provides sustained benefits over the long run even in undisrupted markets, by reducing global demand pressure during what is expected to be an extended period of strong global demand, substantial OPEC market power and higher world oil prices.

I.1 Concerns About Oil Security

Concerns about oil security stem from three related problems: concentrated supply in a historically unstable region; the exercise of market power by key oil exporters; and the continued (although perhaps diminished) vulnerability of the economy to oil supply shocks and price spikes. Global oil reserves are concentrated in a volatile region of the world, with 60% of reserves in the Persian Gulf region. Partly as a consequence of this concentration of low cost reserves, OPEC producers are able to exercise market power, functioning as an imperfect ("clumsy") cartel and at times maintaining oil price well above estimated competitive levels. The strength and influence of this cartel grows and declines, largely in relation to cycles of growth in global import demand and OPEC market share. Nonetheless, OPEC's production or pricing decisions can impose sustained economic costs over many years and can exacerbate, or ameliorate, short-run supply shocks. In the face of short-run supply volatility most oil consuming nations have limited scope for flexibly adjusting their oil supply or demand, particularly as oil demand becomes increasingly concentrated in the transportation sector. Uncertainty, rigidities, and adjustment costs lead to economic dislocation, particularly during sudden and disturbing oil supply disruptions.

While evolving market institutions, strategic oil stockpiling, and declines in the energy intensity of the U.S. economy are expected to have mitigated the costs of oil disruptions to the U.S. economy compared to the 1970s and early 1980s, the problem of energy security has not been eliminated. Furthermore, recent trends have been less favorable. As noted by many experts (e.g. Hamilton 2005), including recently the National Academy of Sciences (2002:86), according to simple economic production theory the economic consequences of disruptions are *expected* to be related to the U.S. expenditure on oil relative to the gross domestic product (GDP), and to decline as that oil factor-share declines. However, Hamilton observes that the historical experience does not conform to the simple factor-share argument. The drop in GDP following the five most notable oil supply disruptions since 1950 far-exceeded the loss predicted by the oil factor share. This and other empirical test lead Hamilton (1985:10) and Huntington (2005) and Brown et al (2005) to conclude that the relationship between oil price shocks and output is more subtle and complex than originally thought, with shocks working their way through the economy in many sectors by indirect channels than can be surprisingly powerful. For these reasons we cannot be certain that the disruption component of the oil premium declines in direct proportion to oil share. Regardless of this issue, the decline in oil value share has halted and reversed. The rising expenditure share for oil in U.S. GDP over the last few years alone calls into question the assertion that the impact of disruptions on the U.S. economy is uniformly declining. Furthermore, much higher oil prices and growing oil imports also suggest that the incremental effect of U.S. oil use on world oil price and U.S. import costs could be higher than in recent years.

I.2 Summary of Method

In order to estimate the energy security benefits of reduced U.S. oil use, Oak Ridge National Laboratory has developed an approach for evaluating the social costs and energy security implications of oil imports. This approach can be used for evaluating policy measures that alter U.S. imports of oil. For estimating these energy security benefits, we updated and applied the same oil-import security premium methodology used in the 1997 report *Oil Imports: An Assessment of Benefits and Costs*, by Leiby, Jones, Curlee and Lee.[4] This paper was cited and its results utilized in previous DOT/NHTSA rulemakings, including the 2006 Final Regulatory Impact Analysis of CAFE Reform for Light Trucks.[5] It was also cited in the NAS 2002 discussion of CAFE.[6] The principal updates to the methodology applied for this analysis reflect the substantial changes in oil market conditions since 1996, as projected by the U.S. EIA for the period 2006-2015. These changes and their individual implications will be further described below. Foremost among them are substantially higher oil prices and higher U.S. oil consumption and imports. The net result is that the estimated oil import premium is greater than in the 1996-based study (see Table 1 below).

[4] Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997.

[5] US DOT, NHTSA 2006. "Final Regulatory Impact Analysis: Corporate Average Fuel Economy and CAFE Reform for MY 2008-2011 Light Trucks," Office of Regulatory Analysis and Evaluation, National Center for Statistics and Analysis, March.

[6] National Academy of Sciences 2002. *Effectiveness and lmpact of Corporate Average Fuel Economy (CAFE) Standards*, Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, National Research Council (Washington, D.C.: National Academy Press).

Table 1: Summary Results		
Effect / Study	ORNL 1997 Report (2004$/BBL)	ORNL 2006 Updated (2004$/BBL)
Monopsony Component	**$2.57** $1.54 - $3.59	**$8.90** ($2.91 - $18.40)
Macroeconomic Disruption/ Adjustment Costs	**$1.03** $1.03 - $2.05	**$4.68** ($2.18 - $7.81)
Total Mid-point	**$3.59** ($2.57-$5.64)	**$13.58** ($6.71 - $23.25)
Results in 2004$. Columns report mean estimate and ranges that include 90% of results.		

The approach estimates the incremental benefits to society, in dollars per barrel, of reducing U.S. imports.[7] This "oil premium" approach identifies those energy-security related costs which are not reflected in the market price of oil, and which are expected to change in response to an incremental change in the level of oil use. Omitted from this premium calculation are environmental costs and possible non-economic or unquantifiable effects, such as effects on foreign policy flexibility or military policy. Also omitted are any spillover-benefits that may accrue to U.S. allies and trading partners who are similarly reliant on oil, and who would benefit from a reduction in the level or volatility of world oil price.

I.3 Changes Since the 1990s Analysis of Oil Import Premium

Since the 1997 publication of the Leiby et al. ORNL report, changes in oil market conditions, both current and projected, suggest that the magnitude of the oil premium may have increased. Significant driving factors that have been considered in this new analysis are: oil prices, current and anticipated levels of OPEC production, U.S. import levels, the estimated responsiveness of regional oil demands and supplies, and disruption likelihoods. In updating their analysis, we applied projections of market conditions from the Energy Information Administration's 2006 Annual Energy Outlook and the most recently available careful quantitative assessment of disruption likelihoods from the Stanford Energy Modeling Forum's 2005 workshop series, as well as other assessments.[8] The changes in key market parameters are summarized in the Table 2 below.

[7]Technically, the oil premium is based on a "marginal" economic analysis, i.e. a differential analysis of the rate of change of costs per barrel change in imports. At times we use the term "incremental" in place of "marginal" here to avoid confusion with marginal in the more common sense of "fringe" or "close to the limit of acceptability."

[8]Stanford Energy Modeling Forum, Phillip C. Beccue and Hillard G. Huntington, 2005. "An Assessment of Oil Market Disruption Risks," FINAL REPORT, EMF SR 8, October

Table 2: Market and Parameter Changes Influencing Premium Estimate	
Condition (+ or – Indicates Directional Impact on Premium)	Percent Change Since 1996 Analysis*
U.S. Economy Larger (+)	+84%
Share of Oil in GDP (no net impact inferred)	Physical intensity -40%; Value share +84%
U.S. Oil Imports Higher (+)	+49%
World Oil Price Higher (+)	+125%
Estimated Ave. Likelihood of Oil Supply Disruption (+)	~+30%
U.S. Strategic Petroleum Reserve (SPR) Size Larger (-)	+15%
Estimated Short-run Responsiveness of U.S. Import Demand Greater (-)	+25%

*Percent changes compare the levels used in the 1996 study with the projected average level for the next 10 years, 2006-2015.

One indication that the current oil market situation for the U.S. is different from that of the mid-1990s is provided by the level of U.S. expenditure on oil imports. Real U.S. expenditures on crude oil are approaching historical highs, as shown in the following Figure.

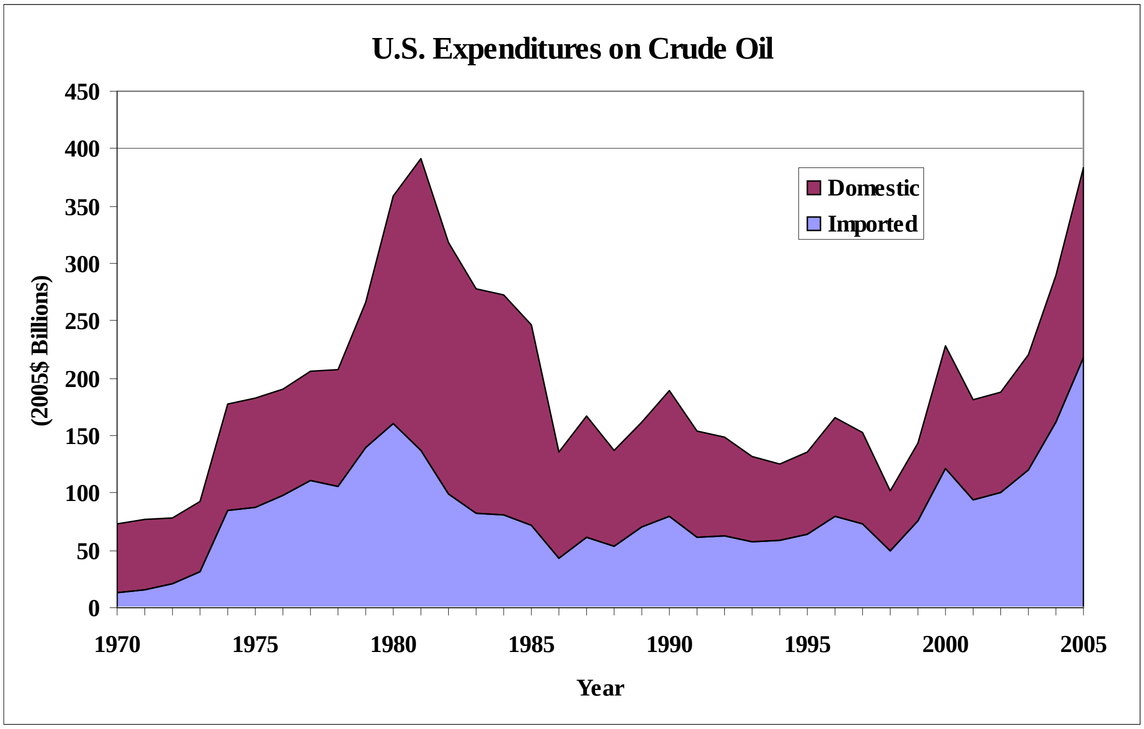

Figure 1 U.S. Expenditures on Crude Oil (Source: Annual Energy Review 2006 and International Energy Review 2004. Year 2005 values preliminary.)

The average expenditure on oil projected over 2006-2015, the period of this study, is $392 billion per year (2005$), based on AEO2006.[9]

We also revisited the issue of the macroeconomic consequences of oil market disruptions and sustained higher oil prices. There is substantial variation in the estimates of the GDP loss from an oil price shock.[10] Given the competing influences of a declining physical intensity of oil use in the economy (barrels per $ GDP) and a rising value-intensity of oil use in the economy ($ expended for oil per $ GDP), it is unclear how to modify the oil-macro calculation, if at all. The net effect of there counter influences on the oil price-elasticity of the GDP may or may not be zero. However, it is reasonable to assume that the resulting elasticity level would remain within the relatively wide (-0.08 to -0.01) range currently used in the sensitivity analysis. Accordingly, the disruption costs were estimated in the same way as the previous 1996 study. That is, the key parameter "GDP elasticity" which relates percentage GDP loss to percentage price change during a shock, was varied parametrically in a sensitivity analysis over the same range of values (-0.01 to -0.08), which encompasses the estimates of most oil-macroeconomic studies over the last decade.

[9]AEO2007 projections are slightly higher, averaging $413 billion per year.

[10]The higher estimates emerge from recent time-series analysis of the historical data, focusing on those oil price events that are sudden and outside the range of price experience in the prior 4 to 12 quarters. The lower estimates are generally produced by simulations with large-scale structural econometric models, whose results are governed by whichever mechanisms for oil prices to affect the economy are embodied in the model structure.

Using the established oil premium calculation methodology which combines short-run and long-run costs and benefits, and accounting for uncertainty in the key driving factors, we developed the updated range of estimates of the incremental energy security benefits of reducing oil imports shown previously in Table 1.

II. The Oil Premium as a Measure of Energy Security Costs of Imports

II.1 The Issue of a Reference Point: Costs Relative to What?

When assessing the costs of oil, we must choose an appropriate reference point, that is, answer the question "costs relative to what?" Three possible reference points for comparison with the current levels of oil imports and consumption are: hypothetical perfectly competitive market conditions; optimal levels of imports given market imperfections; and a marginal (small incremental) change in imports from the current level. At one extreme, the costs of oil imports can be measured relative to the competitive ideal [e.g. Greene and Leiby 1993, Greene and Tishchishyna 2000]. Such an ideal world would have competitive supply and demand, no unanticipated price shocks, and no unpriced environmental damages or other social costs. In other words, the per-barrel costs of oil could be compared to the costs that would exist in the absence of any market failures. Using the competitive ideal as a reference point would provide a general view of the magnitude of costs which we might wish to recover. This may be a useful guide for research and motivate the search for cost-effective solutions. It alone would offer only partial insight, however, on how much government can or should do about oil use or imports to avoid these costs. It would be a mistake to treat all costs beyond those of the competitive ideal as avoidable, since that would implicitly assume the existence of costless government actions which totally eliminate the market failures.

Secondly, the potential costs of oil may be defined in terms of the difference between the optimal (efficient) level and the current level of costs, recognizing that some government programs are already in place to respond to potential market failures. Since government action is not costless, the pragmatic issue is one of balancing the costs imposed by government intervention against the expected value of that intervention. For example, costs may be estimated relative to optimal U.S. policy regarding import levels [e.g., Broadman and Hogan (1986), (1988), Huntington (1993)]. The goal is to approach an efficient level of oil import costs, not to reduce those costs to zero. This optimal level is dependent on a host of conditions about the structure of the domestic and world oil markets, the vulnerability of the domestic and world oil markets to price shocks, and the relationship between oil markets and the macroeconomy. The efficient or optimal level of costs and imports may not be attainable with policies which are cost effective and pragmatically acceptable, but the concept has the merit of being a desirable reference point.

A third alternative reference point is the cost that would be caused by a marginal (small incremental) change in oil imports from the current, or alternatively, from the optimal, level. A small incremental reduction in imports may not be an efficient goal, but it has the virtue of being an achievable reference point. The marginal reduction in social costs of a change in import levels also reveals the amount we should be willing to pay (per barrel) to achieve that modest change. Hence, marginal cost is a comparatively simple but useful guide for incremental policy, and is the measure analyzed in this paper.

II.2. Interpretation of the Marginal Premium Approach

The oil import premium estimates the marginal economic benefit to the U.S. of decreasing oil imports, beyond the market price of oil. However, it does not imply that the imposition of a comparable tariff or tax would be either the most efficient or a fully adequate policy to deal with the full problem of oil dependence and security. Echoing the NAS discussion of the energy security benefits of vehicle fuel economy (NAS 2002:86), it also should be emphasized that:

> "[the oil premium] includes neither the entire benefit to the United States of 'solving' the problem of noncompetitive pricing by the OPEC nations nor the entire benefit of increasing international stability in world oil markets (or, equivalently, the cost of not solving these problems). These problems cannot be solved completely by changing the amount of oil consumed in the United States."

The full economic cost of importing petroleum into the U.S. is often defined to include three components in addition to the purchase price of petroleum itself. These are: (1) higher costs for oil imports resulting from the effect of U.S. import demand on the world oil price and OPEC market power; (2) the risk of reductions in U.S. economic output and disruption of the domestic economy caused by sudden disruptions in the supply of imported oil to the U.S.; and (3) costs of existing policies meant to enhance oil security. Possible examples of the third component are maintaining a U.S. military presence to secure imported oil supplies from unstable regions, and maintaining the Strategic Petroleum Reserve (SPR) to cushion against resulting price increases. An important point is that the policy-relevance of any of these, or any, cost categories stems from the degree to which they are generally not accounted-for in the market decisions of oil consumers or producers, and whether they can be changed by a particular policy measure under consideration. For this reason the oil security premium analysis considers only incremental changes in such unaccounted costs with changing oil consumption and imports.

The following discussion reviews the nature of each of these costs, assesses the degree to which they are likely to vary in response to changes in the level of oil imports, and provides empirical estimates of each component drawn from ORNL and recent research.

II.3 Demand Costs, or the Longer-Run Monopsony Effect

The first component of the full economic costs of importing petroleum into the U.S. follows from the effect of U.S. import demand on the world oil price over the long-run. Because the U.S. is a sufficiently large purchaser of foreign oil supplies, its purchases can affect the world oil price. This demand or "monopsony" power means that increases in U.S. petroleum demand can cause the world price of crude oil to rise, and conversely that reduced U.S. petroleum demand can reduce the world price of crude oil. Thus, one consequence of decreasing U.S. oil purchases, due to implementation of this rule or other reasons, is the potential decrease in the crude oil price paid for all crude oil purchased by the U.S., including both imported and domestically-produced petroleum. Total oil purchase costs decline, but the domestic portion of reduced oil purchase cost is offset by a loss of revenue for domestic producers, so it is omitted from the assessment of net U.S. social gains.[11] A reduction of total purchase costs for the remaining oil imports, however, represents a net welfare gain for U.S. society: the remaining imports are acquired for lower claim on the output (GDP) of the U.S. economy. The "monopsony" premium accounts for the incremental change in the total cost of petroleum imports, for a given change in the level of imports.

This demand or monopsony effect can be readily illustrated with an example. If the U.S. imports 10 million barrels per day at a world oil price of $50 per barrel, its total daily bill for oil imports is $500 million. If a decrease in U.S. imports to 9 million barrels per day causes the world oil price to drop to $49 per barrel, the daily U.S. oil import bill drops to $441 million (9 million barrels times $49 per barrel). While the world oil price only declines $1, the resulting decrease in oil purchase payments of $59 million per day ($500 million minus $441 million) is equivalent to an incremental benefit of $59 per barrel of oil imports reduced, or $10 more than the newly-decreased world price of $49 per barrel. This additional $10 per barrel "import cost premium" represents the incremental external benefits to U.S. society as a whole for avoided import costs beyond the price paid oil purchases. This additional benefit arises only to the extent that reduction in U.S. oil imports affects the world oil price.[12]

The extent of U.S. monopsony power is determined by a complex set of factors including the relative importance of U.S. imports in the world oil market, and the sensitivity of petroleum supply and demand to its world price among other participants in the international oil market. The degree of current OPEC monopoly power has been subject to considerable debate, but appears to have increased somewhat since the mid-1990s as global oil demand has grown. The consensus appears to be that OPEC remains able to exercise some degree of control over the response of world oil supplies to variation in world oil prices, so that the world oil market does not behave competitively. The substantial price increases seen over the last few years with expanding global demand could also suggest a comparable decline in prices could be achieved, should demand growth slow or demand decline. Most evidence appears to suggest that variation in U.S. demand for imported petroleum continues to exert some influence on world oil prices.

The key determinants of the magnitude of the monopsony effect are the magnitude of U.S. imports (which are subject to the prospective price change) and strength of influence of U.S. import demand levels on world oil price. The change in world oil price depends on the response of OPEC, and the collective response of competitive oil producers and consumers in the rest of the world. The response of OPEC countries to the exercise of countervailing market power by a major consumer such as the U.S. is a problem of bilateral monopoly, and essentially indeterminate.

[11] Since there are no oil import limits or tariffs in place, and the domestic oil industry is generally competitive, at the margin payments for domestic oil are equal to the real domestic resource cost of producing that oil.

[12] Note that if reduced U.S. oil import demand lowers the long-run sustained price of oil by the U.S. exercise of monopsony power, not only will U.S. import costs decline, implying a diminished foreign claim on U.S. GDP, but long run aggregate economic output will also increase. This (perhaps small) gain in long-run natural economic output (potential GDP) represents a benefit to import reduction. However, absent other market imperfections or policy interventions, the *marginal* change in potential GDP will be equivalent to the marginal benefit of oil demand, and equal to the domestic price of oil. Thus it is captured in the marginal premium calculation.

The practical responses to a U.S. import reduction could range from OPEC's complete defense of market share (complete inflexibility, maintaining output unchanged and letting price slide until all other regions accommodate the market change) to complete defense of price (complete flexibility, with OPEC contracting output to fully offset U.S. import reduction).[13] These polar alternatives correspond to an OPEC supply "elasticity" (the percentage change in supply for a percentage change in price) of zero and infinity respectively. In keeping with the 1996 study we bound the range of outcomes by OPEC supply response elasticities in a somewhat narrower range from -0.25 to –5.0, and the implied monopsony premium for that range of values is calculated. The net price-responsiveness of the producing and consuming regions other than the U.S. and OPEC is taken to be the same level used in the 1996 ORNL study (a net import demand elasticity of -0.86). The total change in world oil price is then determined based on combined response of OPEC and the net demand for imports by rest of the world outside of the U.S.

II.4 Disruption and Adjustment Costs

The second component of the external economic costs resulting from U.S. oil consumption and imports arises from the effect of oil use on the expected cost of disruptions. A sudden increase in oil prices triggered by a disruption in world oil supplies has two main effects: it reduces the level of output that the U.S. economy can produce using its available resources; and it causes temporary dislocation and underutilization of available resources, such as labor unemployment and idle plant capacity. The first effect, a reduction in "potential" economic output, is an aggregate output effect that will last so long as the price is elevated. It depends on the extent and duration of any disruption in the world supply of oil to the U.S., since these factors determine the magnitude of the resulting increase in prices for petroleum products, as well as whether and how rapidly these prices return to their pre-disruption levels.

Because supply disruptions and resulting price increases occur suddenly rather than gradually and often involve disturbing news of war or strife, empirical evidence shows they also impose additional costs on businesses and households for adjusting their use of petroleum products and other productive factors more rapidly than if the same price increase had occurred gradually over time (e.g. Hamilton 2005, Davis and Haltiwanger 1999).[14] Dislocational effects include the unemployment of workers and other resources during a period of their intersectoral or interregional reallocation, and pauses in capital investment due to uncertainty. These adjustments temporarily reduce the level of economic output that can be achieved even below the "potential" output level that would ultimately be reached once the economy's adaptation to higher petroleum prices was complete. The additional costs imposed on businesses and households for making these adjustments reflect their inability to adjust prices, output levels, and their use of energy and other resources quickly and smoothly in response to rapid changes in prices for petroleum

[13]Conceivably, there is a more extreme OPEC response, which is to punitively reduce supply by more than the amount of demand reduction to drive prices even higher. Such a strategy is unlikely to be successfully maintained in the long run given competitive oil supply regions, and is particularly unlikely in the projected situation for the next 10 years where prices are high and OPEC is anticipated to already be exercising substantial production restraint.

[14]Davis, Stephen and John Haltiwanger 1999. "Sectoral Job Creation and Destruction in Response to Oil Price Changes," National Bureau of Economic Research Working Paper W7095. Hamilton, James D. 2005. "Oil and the Macroeconomy," Palgrave Dictionary of Economics.

products. While it is widely expected that the macroeconomic costs of oil shocks will decline with declining share of energy in the economy, so far efforts to demonstrate this from the statistical record have yielded inconclusive results (e.g. Huntington 2004, Brown, Fu and Yücel 2005). Furthermore, as mentioned above, while the physical intensity of oil use in the economy has declined by 40% since 1996, the *value* share of oil in the economy has increased by 67%. For these reasons the range of parameters used to estimate the macroeconomic impacts of price shocks in this study is unchanged from that used in the 1996 analysis.

Since future disruptions in foreign oil supplies are an uncertain prospect, each of these two components of the disruption cost must be weighted or adjusted for the probability that the supply of petroleum to the U.S. will actually be disrupted. Thus, the "expected value" of these costs – the product of the probability that a supply disruption will occur and the sum of costs from reduced economic output and the economy's abrupt adjustment to sharply higher petroleum prices -- is the relevant measure of their magnitude. Further, when assessing the energy security value of a policy such as the implementation of the Renewable Fuels Standard, it is only the *change* in the expected costs of disruption that results from the policy that is relevant. The expected costs of disruption may change from lowering the normal (pre-disruption) level of domestic petroleum use and imports, or from altering the short-run flexibility (elasticity) of petroleum use.

While the total vulnerability of the U.S. economy to oil price shocks depends on both petroleum consumption and the level of U.S. oil imports, variation in imports alone may have some effect on the magnitude of the price increase resulting from any disruption of import supply. In addition, changing the quantity of petroleum imported into the U.S. may also affect the probability or size of such a disruption. If either the size of the supply loss, the size of the resulting price increase, or the probability that oil import supply will be disrupted is affected by the pre-disruption level of oil imports, then the expected value of the costs stemming from supply disruptions will also vary in response to the level of oil imports.

II.5 Role of Market Mechanisms

When estimating an oil security premium we need to recognize the availability of market mechanisms that allow the U.S. economy to adjust to oil supply disruptions. A variety of market mechanisms – including oil futures markets, energy conservation measures, and some technologies that permit rapid fuel switching – are now available within the U.S. economy for businesses and households to anticipate and "insure" themselves, to some extent, against the effects of petroleum price increases. In principle, by employing these mechanisms – for example, by investing in energy conservation measures or installing technologies that can operate using multiple fuel sources – businesses and households can reduce their costs of adjusting to sudden increases in oil prices.

The availability of these mechanisms has undoubtedly reduced the potential costs to the U.S. economy that could be imposed by disruptions in the world supply of oil. While the degree to which markets anticipate and account for the long-run risk of price increases from strategic oil shocks is not known with certainty, the estimates reported here seek to explicitly account for futures markets and other anticipatory mechanisms. Private firms and individuals are described as anticipating a large fraction of disruption price increases, and the direct costs to them of those expected price increases are excluded from the premium.

However, the existence of private mechanisms like the futures market and energy conservation opportunities does not assure that the socially optimal level of protection of disruption risk is attained. The most important reason is that private markets do not automatically take into account the external and non-market consequences of producer and consumer choices. Even given the availability of measures to self-insure against disruptions, consumers and firms can only be expected to take protective actions against the economic risks that they expect to bear directly (i.e., their own individual, private costs).

Furthermore, the scope for private anticipatory protection is limited. The futures market extends only a limited time into the future,[15] the private cost of long-term petroleum stockpiling by individual consumers or firms against strategic oil disruptions is prohibitive, and dual fuel technology is only available and cost-effective in limited applications.[16] Recognizing that private agents use futures to hedge only private risk, not the social effects (risk) of their oil market actions, and that only a subset of economic actors participate directly in the futures market, this study seeks to implicitly accounts for futures and other possible precautionary behavior by assuming that private actors internalize some fraction of their private risk. That is, 0, 25% or 100% of the expected oil price increase due to shocks is assumed to be accounted for in private behavior, and excluded from the social premium calculation.

Consumers of petroleum products are unlikely to take into account the potential costs that a disruption in oil supplies imposes on other sectors of the U.S. economy, or the indirect effect of their investment, consumption, or import decisions on those wider disruption costs. Thus, changes in petroleum imports continue to affect the expected cost to the U.S. economy from potential oil supply disruptions, although the current value of this component of oil-related societal cost is likely to be significantly smaller than those estimated by some studies conducted in the wake of the oil supply disruptions that occurred during the 1970s.

While their availability has undoubtedly reduced the potential costs that could be imposed by disruptions in the world supply of oil, a substantial portion of these costs is probably not reflected in the market price of petroleum or in the response of economic agents. There are two reasons. Second, and more importantly, even if measures are available to self-insure against disruptions, consumers and firms can only be expected to take protective actions against the economic risks that they expect to bear directly. Consumers of petroleum products are unlikely to take account of the potential costs that a disruption in oil supplies imposes on other sectors of the U.S. economy. Thus, changes in petroleum consumption continue to affect the expected cost to

[15]The limited scope of the futures markets is highlighted by the observation that virtually all trading is short term in nature, with contract terms of under 18 months. Over the years 2001 to 2006, on average 43% of the volume of trading for NYMEX light sweet crude futures fell within the first month (spot) delivery, and 91% fell within 4 months delivery term. The futures markets for products (heating oil and unleaded gasoline) are even more heavily loaded toward the first three to four months than is the case for crude. Futures trading seems more attentive to short-run volatility, not strategic shock risk.

[16]For example, dual and flex-fuel vehicles (notably alcohol FFVs) are beginning to enter the fleet, but up to this point the fuel infrastructure is not widely available and many FFV owners are even unaware that their vehicles have the capability.

the U.S. economy from potential oil supply disruptions, although the current value of this component of oil-related societal cost is likely to be significantly smaller than those estimated by some studies conducted in the wake of the oil supply disruptions that occurred during the 1970s.

We estimate that under reasonable assumptions about the probability that world supplies will be disrupted to varying degrees in the future, the disruption component of the social cost of U.S. oil imports ranges from less than $2.18 to over $7.81 per additional barrel of oil consumed by the U.S., with adjustment costs accounting for the largest share of this total. An average estimate is $4.68.

II.6 Military Security and Strategic Petroleum Reserve Costs

The third and last commonly-identified component of possible external economic costs of oil imports is the cost to the U.S. taxpayers for existing energy security policies. Chief among these are maintaining a military presence to enhance the security of oil supply from potentially unstable regions of the world and to keep trade routes open, and maintaining the Strategic Petroleum Reserve (SPR) to provide buffer supplies during a supply disruption. This assessment excludes both of these costs from the reported estimates for the following reasons.

Military costs are excluded because of the problems of attribution and "incrementality." It is very difficult to attribute military costs, and specific activities and forces, to oil consumption or imports *per se*. Military activities, even in world regions that represent vital sources of oil imports, undoubtedly serve a broader range of security and foreign policy objectives than simply protecting oil supplies. Furthermore, these costs may not vary in any measurable way with incremental variations in oil use. The scope and duration of any specific U.S. military activities that were undertaken for the purpose of protecting imported oil supplies seem unlikely to be tailored to the actual volume of petroleum imports from the regions where they take place. As a consequence, annual expenses to support U.S. military activities do not seem likely to vary closely in response to changes in the level of oil imports prompted by conservation efforts or other policies. More specifically, reductions in gasoline use resulting from this final rule seem unlikely to result in identifiable savings in the military budget that could be included as additional benefits. This does *not* mean that there is no relation between military costs and oil security concerns, but that estimating the magnitude of incremental effects from changing oil use is problematic.

While the optimal size of the SPR, from the standpoint of its potential influence on U.S. costs during a supply disruption, may be related to the level of U.S. oil consumption and imports, its actual size has not appeared to vary in response to recent changes in the volume of oil imports. There are two consistent approaches for accounting for SPR policy during the calculation of the incremental benefits of reduced oil use. Given lower oil imports and potentially reduced disruption costs, the analysis could consider the incremental savings from reducing the size of the SPR while maintaining the same level of expected protection. Alternatively, the analysis could include the value of the greater level of overall protection achieved with the current SPR. Since the past size or budgetary cost of the SPR have not varied directly with oil imports or consumption, the former approach posits an unlikely policy as well as being more cumbersome. Therefore, we adopt the latter approach and assume no change in the SPR from its current size.[17] However, the role of the SPR in addressing shock effects and reducing disruption costs is explicitly accounted in the estimates.

SPR use during a disruption requires a Presidential determination of need based on a range of foreign policy and national security considerations. Since past use during some disruptions has been cautionary, future use in all possible disruptions is neither assured nor official policy. The current analysis considers two SPR management strategies: idealized SPR use, with a prompt and full offset of all major supply shocks, to the extent of SPR capabilities; and a more cautionary SPR strategy in which the SPR is applied to shocks in half of the events. When calculating the premium, a range of shocks is probabilistically simulated and, depending on the size and duration of the supply loss and the SPR utilization strategy, some or all of shock price increase may be eliminated.

[17]This analysis does reflect the impact of a larger current SPR (688 million barrels) than was available at the time of the 1996 study (600 million barrels).

III.1 Marginal Welfare Changes and the Mathematical Definition of the Marginal Premium

The principal method used in this report is the marginal analysis of U.S. welfare, employing the standard concepts of the *economic* welfare function and the oil import premium. The marginal costs of imported oil (in dollars per barrel) are the incremental costs associated with a unit change in oil imports.[18] Their estimation does not require that we know total costs, but only how total costs change with the level of oil imports.

The usual analytical approach is to begin with a functional description of how U.S. economic net benefits depend on the level of oil imports.[19] We begin with a representation of U.S. economic net benefit (relative to an arbitrary reference point), $N(q_{iu})$, which depends on the quantity of U.S. imports (q_{iu}).[20] Given the focus on imports, it is convenient to combine the domestic oil demand and oil supply curves into a net import demand curve. This corresponds to combining the private benefits of consumption and the private costs of domestic production into an import private benefits function $B_i(q_{iu})$. The net economic welfare function includes import benefits $B_i(q_{iu})$, less the direct costs of imports ($P_w q_{iu}$), and less all other costs associated with externalities, shocks, and market failures ($C_f(q_{iu})$), which individual producers and consumers do not ordinarily consider in their market transactions.

$$N(q_{iu}) = B_i(q_{iu}) - P_w q_{iu} - C_f(q_{iu}) \tag{1}$$

The marginal welfare from a change in imports is then the marginal private benefit of imports less the marginal direct cost of imports less all the other marginal non-private costs identified:

$$\begin{aligned} N'_{social} \equiv \frac{\partial N(q_{iu})}{\partial q_{iu}} &= B'_i - \frac{\partial (P_w q_{iu})}{\partial q_{iu}} - \frac{\partial C_f(q_{iu})}{\partial q_{iu}} \\ &= B'_i - \left(P_w + q_{iu} P'_w\right) - \frac{\partial C_f(q_{iu})}{\partial q_{iu}} \end{aligned} \tag{2}$$

Here the prime symbol (′) denotes the derivative with respect to import levels. The *oil import premium* is defined as the difference between the marginal private net benefits of oil and the marginal social net benefits. Since it is generally believed that the social benefits of imports equal the private benefits, the import premium is the difference between marginal social costs and

[18]Technically, marginal cost is the derivative of total cost, and is based on an infinitesimal change in oil use.

[19] The term "net benefits" means the difference between benefits and costs. Similarly, regional "net import demand" refers to the difference between a region's oil demand and its supply.

[20] Naturally, net benefit also depends on levels of oil production and consumption, but at first we abstract from these issues.

marginal private costs.[21] In this case, the marginal social benefit is accurately measured by the price U.S. consumers would be willing to pay for oil, given the import quantity q_{iu}. This price, $P_{iu}(q_{iu})$, corresponds to the point on the import demand curve above quantity q_{iu}.

$$N'_{social} \equiv (P_{iu} - P_w) - \left(q_{iu} P'_w + \frac{\partial C_f(q_{iu})}{\partial q_{iu}} \right) \tag{3}$$

The marginal private cost of oil is the prevailing world oil price, P_w. So the marginal private net benefit of imports is $P_{iu}(q_{iu}) - P_w$. At any level of U.S. imports q_{iu} the oil import premium, π, being the difference between marginal private and marginal social net value, is:

$$\begin{aligned} \pi(q_{iu}) &\equiv N'_{private} - N'_{social} \\ &= (P_{iu} - P_w) - N'_{social} \\ &= \left(q_{iu} P'_w + \frac{\partial C_f(q_{iu})}{\partial q_{iu}} \right) \end{aligned} \tag{4}$$

As will be discussed below, the first term of the premium corresponds to the monopsony or consumer buying power premium. Strictly speaking the second term includes all other marginal social losses associated with imports, but in this study we limit our attention to identifying and estimating the expected economic losses from disruptions. So we will refer to the two components as the monopsony premium and the disruption premium:

$$\begin{aligned} \pi(q_{iu}) &\equiv \pi_{monops}(q_{iu}) + \pi_{disr}(q_{iu}) \\ &= q_{iu} P'_w + \frac{\partial E\left[C_{disr}(q_{iu})\right]}{\partial q_{iu}} \end{aligned} \tag{5}$$

The two components are essentially long-run and short-run in nature respectively, since the first accounts for the effect of a sustained import reduction on the long-run undisrupted oil price, while the second principally includes the change in expected short-run losses during transitory disruptions. A key challenge of this analysis is to identify those costs stemming from market imperfections which are not accounted for in private behavior, and which vary at the margin with oil imports (or oil consumption).

[21] Note that so long as private oil purchasers gain all the benefits of oil consumption (so that marginal private benefit equals marginal social benefit) and there exists no import tax or constraints (so that the marginal private cost of oil equals the world oil price) then the import premium can be defined as the marginal social costs of imports minus the price of imported oil.

$$\begin{aligned} \pi &\equiv N'_{private} - N'_{social} = (B'_{private} - C'_{private}) - (B'_{social} - C'_{social}) \\ &= C'_{social} - C'_{private} = C'_{social} - P_w \end{aligned}$$

III.2 The Base Import Premium and the Optimal Import Premium

The premium can be measured under base conditions (of essentially free-market policy) or under conditions where policy has reduced import demand. The former estimates the social gains from an incremental imports reduction from the current base level, while the latter estimates the social gains after imports have been reduced by a non-trivial quantity. Once the socially efficient level of imports is identified (that which maximizes social net benefit), the "optimal" import premium which applies at that level can be estimated. As imports decline, the premium declines. Note that neither the premium nor imports is necessarily reduced to zero at the optimal level. Many studies of oil import costs seek to estimate the optimal premium, since it serves as a guide for longer-run policy after a transition to lower level imports has been made. On the other hand, the base or "free market" premium provides an estimate of the potential social gain from reducing imports by a small amount from their current level, and suggests a level of societal effort or incentive that may be appropriate for some time until progress in reducing oil use is achieved.

A graphical representation may clarify the concepts of the base and optimal premia. Under free-market policy, import demand will adjust until the marginal private benefit equals world price, and the marginal private net benefit is zero. This is shown by the intersection of the import supply and demand curves in Figure 2, at imports level M_o. The base premium, $\pi(M_o)$, is shown as the difference between the private marginal cost (import supply) curve P_w and the social marginal cost curve C'_{social} above imports level M_o. As shown, the premium is greater for higher levels of oil use if the social costs rise faster with use than privately accounted costs (i.e., than the world oil price.

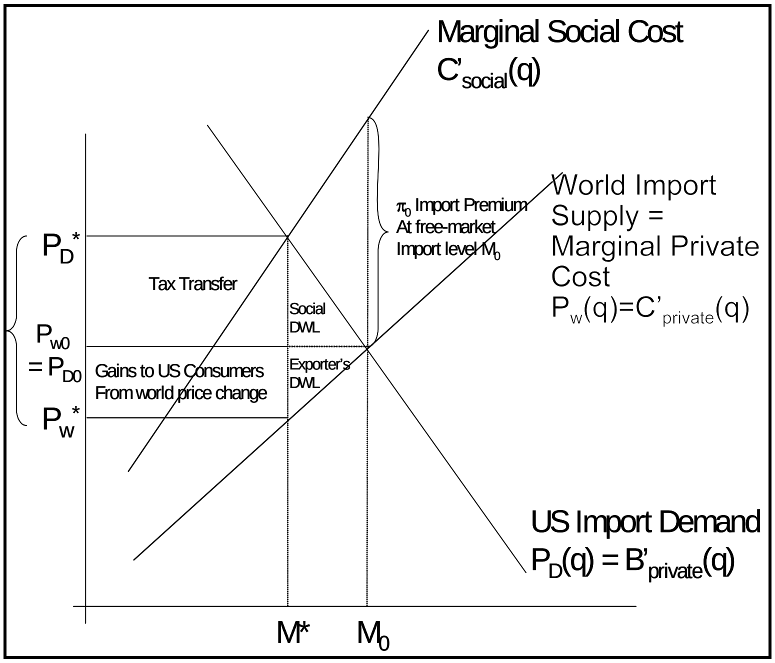

Figure 2: Deviation Between Marginal Social Cost and Marginal Private Cost of Imports Implies a Premium.

If a policy is introduced to reduce imports below the free market level, M_o, to any other level, say *M*, then the marginal private benefits diverge from private costs. When imports are reduced to the level M^*, the optimal imports level, the social marginal cost curve intersects the private demand curve (Figure 2). Social marginal costs equal social and private marginal benefits and no further reduction is beneficial:

$$\begin{aligned} C'_{social}(M^*) &= P_d(M^*) = B'_{social}(M^*) \\ P_d(M^*) - P_w(M^*) &\equiv \tau(M^*) = \pi(M^*) \end{aligned} \tag{6}$$

The oil import premium is a useful concept for summarizing non-market costs, but should not be directly interpreted as an instrument of policy (e.g. N.E.S. Draft 1990:9). For example, Plummer et al. (1982) and Bohi and Montgomery (1982) make the clear point that the two basic components of the import premium associated with non-competitive market costs and disruption costs each may motivate a different policy. The import premium indicates the marginal social value of a sustained reduction in imports, but does not indicate the most efficient policy for achieving that reduction. Similarly, the disruption component of the import premium should not be interpreted as the marginal value of stockpiling against a disruption, in order to offset imports during a disruption. This value could be estimated separately, as in the Plummer et al. (1982) "stockpiling premium," or numerous other stockpiling studies [e.g., Teisberg (1981), Hogan (1982), Leiby and Lee (1988), DOE/Interagency Study (1990), Leiby and Bowman 1998, 2005].

III.3 Monopsony Power and the Monopsony Premium

This section reviews the basis of possible U.S. monopsony power, and discusses some of the issues involved in the estimation of the monopsony premium. These issues concern how to represent the response behavior of other agents in the world oil market, particularly non-U.S. importers and OPEC.

III.3.1 Monopsony Power

Most analysts agree that the U.S. has at least limited monopsony power. However, they disagree about whether that power can and should be exercised. Some argue that the monopsony power of the United States is, in fact, very small. Others have argued that the explicit exercise of monopsony power, especially the adoption of an import tariff or quota, would call for retaliation on the part of oil exporters. Clearly some policies to exercise monopsony power are more visible and provocative than others. The prospect for retaliation may be related to the manner in which monopsony power is used. The argument that OPEC would fully offset or even retaliate in response to a U.S. import reduction becomes less compelling at times when OPEC is already exercising substantial supply restraint and maintaining prices at a comparatively high levels. On the other hand, when OPEC is poorly coordinating its monopoly power and is at best acting as a "clumsy cartel," the blatant assertion of monopsony power could lead to greater solidification of the oil cartel and result in world oil price increases.

To the extent that the U.S. has monopsony power and faces market power in oil supply, the failure to exercise monopsony power can be viewed as an opportunity cost. The impacts of an import reduction depend on the elasticity of net import supply, which is the subject of much debate. The greater the U.S. share of the world oil market, the greater the potential of the United States to exercise monopsony power. A relevant question in assessing these potential benefits is the response of other importing countries. Will they act collectively with the U.S. to reduce consumption, will they not react, or will they take actions to actually increase their import levels? One's specific modeling approach and thus the estimated benefits of monopsony actions are very much dependent on the assumed reactions of oil producers and other importing countries.

III.3.2 Issues in Estimating the Monopsony Premium

Since the U.S. is a large consuming nation, in theory it could influence world oil prices by altering its level of imports. The monopsony premium is the marginal reduction in excess wealth transfer resulting from imports reduction. The "monopsony cost" of imported oil is the failure of oil consumers to coordinate and use their market power to recapture monopoly rents transferred to oil exporters (Murphy, Toman, and Weiss 1986:68). Broadman (1986:243) has described the monopsony cost effect as follows.

> "If an increase in the demand for imports leads to a rise in the world price of oil, the increase in price affects all imports .... In this case, the demand increase by the

> marginal importer produces an external cost by raising total payments abroad for oil imports by more than the price [it pays]."

In the exposition above on the import premium, the first term in the premium of Equation (4) corresponds to the monopsony premium. The monopsony premium is just the incremental change in world oil price induced by the import reduction times the level of imports:

$$\pi_{monops}(q_{iu}) = P_w^{/} q_{iu} \tag{7}$$

If η_{is} is the supply elasticity for oil imports, then the imported oil monopsony premium is also expressible as:

$$\pi_{monops}(q_{iu}) = \frac{P_w(q_{iu})}{\eta_{is}} \tag{8}$$

The social cost exceeds the private cost by P/η_{is}. This formula shows explicitly that the monopsony premium will vary with world oil price, import levels, and the price elasticity of net supply of imports to the United States. If the supply of imports is very elastic, the monopsony premium will be very small, and very large if supply is inelastic. This is illustrated by the following graph. For any given slope of world oil price with respect to U.S. imports the monopsony premium is greater for higher U.S. imports. For any given net elasticity of import supply to the U.S. the monopsony premium is greater for higher world oil price. Thus by either of these measures we would expect the monopsony premium to be larger over the next decade than in the past decade.

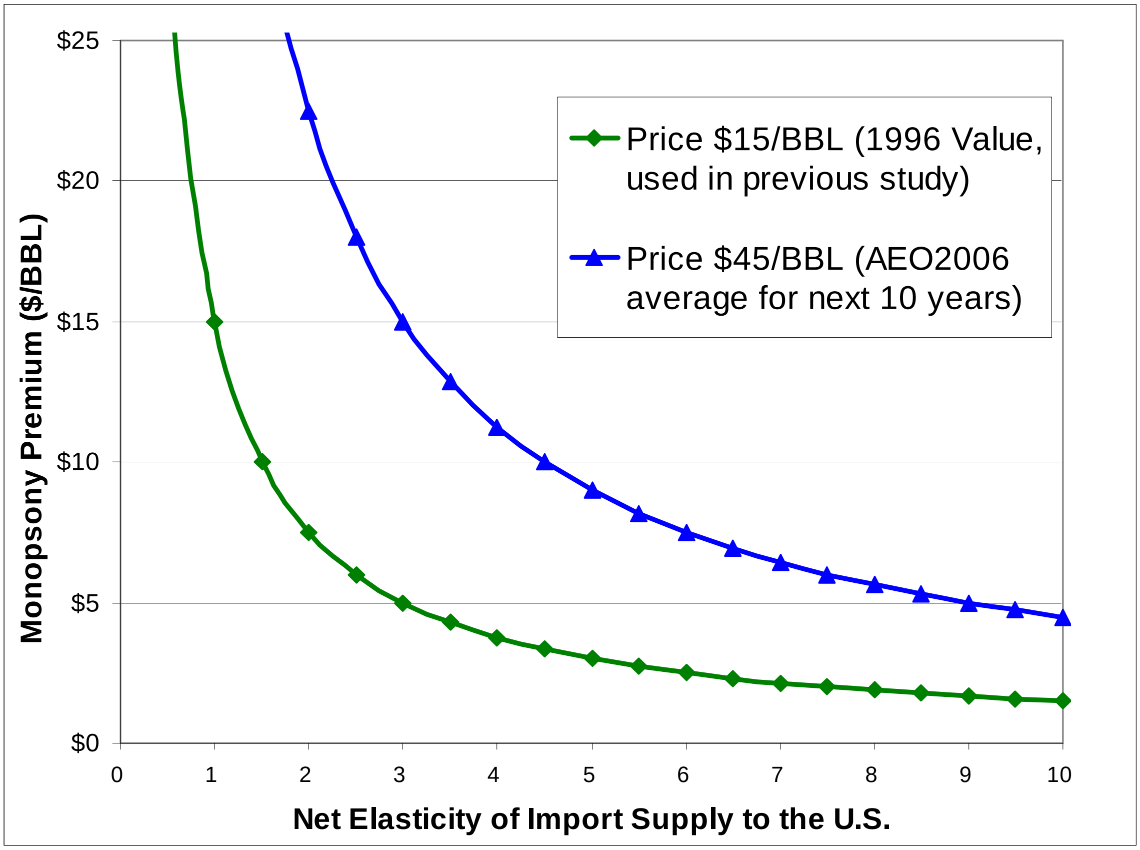

Figure 3 Relationship of oil monopsony premium to the elasticity of net import supply to the U.S., and the world price of oil.

Estimating the monopsony premium has always been recognized as difficult because it requires the specification of non-U.S. response, and particularly OPEC response, behavior (Plummer 1981:6). Should the United States reduce imports through some policy measures, the following categories of response are possible:

- Non-U.S. Importer Responses
  - Market-based (some limited increase in demand as price drops, no policy change)
  - Joint/Coordinated policy effort with United States (amplifying the U.S. effect)
  - Contradictory/Compensating policy (offsetting the U.S. effect)

- OPEC Supply Responses
  - Maintain production at cartel-agreed levels
  - Partial (elastic, unitary elastic)
  - Cartelized - Full Offset (perfectly elastic)
  - Cartelized - Retaliatory (no supply curve)

Non-U.S. Importer Response Representation

The premium estimates here include a market-based response by other importers and non-OPEC producers as prices fall, partially offsetting the monopsony power of the United States. The U.S. is a net importer of oil, as is the group of all other nations outside of OPEC, collectively. The monopsony power of the United States and the size of the monopsony premium increases with the share of world oil trade comprised by U.S. imports.[22] For 2006 to 2015, the projected average level of U.S. imports as a share of OPEC net exports (total non-OPEC net imports) is around 36 percent. (In the mid 1990s the current and projected U.S. share was near 30 percent.)

The marginal benefits to the United States of a coordinated policy with other oil consuming nations would be greater than those of a unilateral action, because of the global nature of the monopsony gains. The estimated import or consumption premium would be correspondingly higher, when the free market outcome is compared to a coordinated policy. Under coordinated policy action, non-U.S. importers are typically assumed to reduce their consumption in the same proportion as the United States [e.g., Stobaugh (1979)]. The early Energy Modeling Study [EMF-6 (1982)] considered the base monopsony premium or "buying power wedge" for both unilateral and joint OECD action. Tests with nine oil models all indicated that the base monopsony premium was 3 to 3.5 times larger given coordinated OECD action (Gately 1982:46). Joint action by the United States and other importers effectively increases the share of world oil trade under monopsony control, and increases the monopsony premium faster than linearly with the share of imports monopsonized (see previous footnote).[23]

OPEC Supply Response Representation

Most estimates of the monopsony premium component assume some positive relation between price and OPEC supply, or include OPEC supply in a world import supply curve [e.g., EMF-6, Gately (1982), Broadman and Hogan (1986), Walls (1990), Huntington (1993)]. If OPEC is a true monopolistic supplier, then there is no well-defined conventional upward-sloping supply

[22] The elasticity of net import supply (η_i) can be decomposed into the elasticity of OPEC supply (η_{sO}) and the elasticity of net import demand from non-U.S., non-OPEC regions (η_{iN}):

$$\pi_{monops} = \frac{P_w}{\eta_i}$$

$$\eta_i = \frac{\eta_{sO} q_{sO} - \eta_{iN} q_{iN}}{q_{iU}}$$

$$\Rightarrow \pi_{monops} = \frac{P_w s_U}{\eta_{sO} - \eta_{iN}(1 - \sigma_U)}$$

where σ_U is the share of non-OPEC net imports imported by the U.S., that is $\sigma_U \equiv q_{iu}/(q_{iu} + q_{iN})$.

[23] An extreme alternative to joint action by importers is the possibility of contradictory/compensating measures in other importing countries. Brown and Huntington (1994) note that Hoel's (1991) work on unilateral environmental actions also applies to unilateral oil conservation efforts: unilateral action by the United States could weaken its bargaining position with other importers who are considering comparable policy. In this case other countries could relax their efforts and, in theory, world oil imports could increase.

curve. A monopolist sets a price in inverse proportion to the elasticity of demand for its product, so in this case it may be more important for an import demand policy to increase demand elasticity than reduce the quantity demanded.

Nesbitt and Choi (1988) offer one polar alternative representation of OPEC supply. They apply a depletable-resource cartel model of OPEC behavior to estimate the effects of an import tariff and conclude "the degree of monopsony power that can be exerted by the United States is small, indeed almost minuscule" (Nesbitt and Choi 1988:46). They estimate that a $10.50 tariff such as that proposed by Broadman and Hogan would sharply reduce U.S. imports (by 30 percent in the first year) but would only reduce world oil price by $1.30/BBL. The insensitivity of world price to demand results from their assumption of a highly elastic world supply, and the treatment of oil supply according to dynamic depletable resource theory, in which price paths are strongly driven by the estimated resource base size and backstop price. Alternatively, viewing OPEC as a von Stackelberg monopolist suggests that while the elasticity of import supply may be ill-defined, the price charged will depend on U.S. consumption via the effect of U.S. consumption on OPEC's market share [Greene (1991), Greene and Leiby (1993)]. If the world could somehow reduce OPEC's market share enough, there would be pressure for prices to return toward competitive market levels.

Some critics of the monopsony premium approach question whether the exercise of monopsony power would be a justifiable interference in oil markets. If monopsony power can lower monopoly prices, why not use it to lower competitive market prices as well? Why not use it in all phases of international trade? According to standard theory, there are two good reasons:
1) competitive market prices produce an economically efficient allocation of resources; and 2) the indiscriminate exercise of monopsony power would likely shatter painstakingly negotiated free trade agreements. In short, there is too much to lose. But if free trade in competitive world markets is the goal, then judicious use of monopsony power against monopoly pricing may be a step in the right direction, while indiscriminate use of monopsony power against competitive producers is counterproductive.

III.4 Methodology for Calculating the Disruption Component of the Oil Import Premium

We defined the disruption component of the import premium as the marginal change in expected disruption losses:

$$\pi_{disr}(q_{iu}) \equiv \frac{\partial E\left[C_{disr}(q_{iu})\right]}{\partial q_{iu}} \qquad (9)$$

Consider representing the uncertain future oil market by a set of possible discrete market states (disruptions sizes and lengths) indexed by j. Thus the expected disruption cost over the next decade is taken over a set of possible supply losses ΔQ_j each with annual probability φ_j. For each possible disruption ΔQ_j with an associated increase in imported oil price of ΔP_i (ΔQ_j), the disruption costs are composed of the incremental imports costs (foreign payments) plus the dislocational GNP losses due to the disruption price. The expected total disruption costs are the probability-weighted sum:

$$E_{\{\Delta Q\}}[C_{disr}] = \sum_j \varphi_j\left[C_{Idisr}(\Delta P(\Delta Q_j)) + C_{GNPdisr}(\Delta P(\Delta Q_j))\right] \qquad (10)$$

The disruption premium is the marginal change of this expected cost expression with respect to the long-run level of U.S. import, q_{iu}.

III.4.1 Disruption Premium - Import Cost Component

Consider the marginal change in the first term, disruption import cost, recognizing that added import costs during a disruption are given by the change in price times the level of imports:

$$C_{Idisr}(\Delta P(\Delta(Q_j)) = q_{iu}\cdot\Delta P(\Delta(Q_j)) \qquad (11)$$

Taking the derivative:

$$\pi_{Idisr}(q_{iu}) \equiv \frac{\partial E_{\{\Delta Q\}}[C_{Idisr}]}{\partial q_{iu}} = \frac{\partial}{\partial q_{iu}}\sum_j \varphi_j\left[q_{iu}\cdot\Delta P(\Delta(Q_j))\right] \qquad (12)$$

There are many channels by which changing import levels during normal (undisrupted) periods could influence the import costs during a disruption. These channels are highlighted by the each of the three terms in the derivative of the product of φ_j, q_{iu}, and ΔP below:

$$\frac{\partial}{\partial q_{iu}} \sum_j \varphi_j \left[q_{iu} \cdot \Delta P(\Delta Q_j) \right]$$

$$= \sum_j \left(\frac{\partial \varphi_j}{\partial q_{iu}} \right) \left[q_{iu} \Delta P(\Delta Q_j) \right] + \sum_j \varphi_j \left[\Delta P(\Delta Q_j) \right] + q_{iu} \sum_j \varphi_j \frac{\partial}{\partial q_{iu}} \left[\Delta P(\Delta Q_j) \right] \tag{13}$$

The first term on the right-hand side is the effect of pre-disruption import levels on the *probability* of disruption. This is sometimes called the deterrence effect if reducing import levels is thought to reduce the likelihood of intentional shocks. While models of this type of effect could be offered, in which the likelihood of some categories of disruption (e.g. embargoes) might diminish with U.S. import levels, in this analysis we do not include any effect of import levels on disruption probability ($\partial \varphi / \partial q_{iu} = 0$). An alternative, non-zero assumption about the marginal effect of pre-disruption imports on disruption likelihood, even if very small, would have a pronounced effect on the premium estimate.

The second term is the direct effect of reducing pre-disruption import levels on the number of import barrels which are subject to the price increase ΔP during disruptions. We assume that the import levels during the start of a disruption event are the same as the long-run pre-disruption import levels. That is, the reduction of normal-period oil imports by one barrel would also (on average) reduce the level of oil imports during random disruptions by one barrel. The cost reduction per barrel of import reduction is just the expected price increase due to shocks ($E_{\{\Delta Q\}}[\Delta P(\Delta Q)]$). We track this cost component but recognize that it is not necessarily external to the decision calculus of economic actors who consume or import oil. This direct price increase that must be paid by those using another barrel of oil at the time of a (random and presumably unexpected) shock may be partially or fully accounted-for by foresighted agents when they make oil purchases during the undisrupted periods. Given our decadal planning period, the key here is the degree to which prospective geo-political oil disruptions over the next decade are both anticipated and accommodated through preparatory behavior when oil purchases are made at any time in the decade. We assume that ordinarily some-to-all of the shock price increase is internalized. This component of the disruption premium is reduced by the fraction posited to be internalized, based on a parameter which takes values of 0%, 25%, and 100% internalization.

The third term in the import-cost component of the disruption premium is the expected change in import costs due to the impact of pre-disruption import levels q_{iu} on the magnitude of the price increase during each possible disruption.

$$q_{iu} \sum_j \varphi_j \frac{\partial}{\partial q_{iu}} \left[\Delta P(\Delta Q_j, q_{iu}) \right] = q_{iu} \sum_j \varphi_j \left[\frac{\partial \Delta P(\Delta Q_j, q_{iu})}{\partial \Delta Q_j} \frac{\partial \Delta Q_j}{\partial q_{iu}} + \frac{\partial \Delta P(\Delta Q_j, q_{iu})}{\partial q_{iu}} \right] \tag{14}$$

Note that this term is an exact analog to the monopsony premium, where in this case we are accounting for the impact of U.S. import levels on the expected disruption price *increase* rather than the pre-disruption price *level*. Again, the monopsony effect is not likely to be considered by individual economic agents, and again it is powerful by being multiplied by the entire level of imports.

The expected price increase from shock is governed by the bracketed terms, which are the indirect effect of pre-disruption import levels on the expected size of the supply loss, and the effect of pre-disruption import levels on the sensitivity of shock price change ΔP to the quantity of supply loss ΔQ_j (that is, the effect of import levels on the short run elasticity of global net import demand).

III.4.2 Disruption Premium - GDP Dislocation Cost Component

Analogously to the premium associated with import costs during disruptions, the GDP dislocation premium component is the marginal change in expected GDP losses during disruptions. For a discrete distribution of disruptions sizes ΔQ_j each with annual probability φ_j

$$\pi_{GDPdisr}(q_{iu}) \equiv \frac{\partial E_{\{\Delta Q\}}[C_{GDPdisr}]}{\partial q_{iu}} = \frac{\partial}{\partial q_{iu}} \sum_j \varphi_j \cdot \Delta GDP(\Delta P_j, q_{du}(q_{iu})) \tag{15}$$

for

$$\Delta P_j = \Delta P(\Delta Q_j, q_{iu})$$

This formulation highlights the relationship between GDP losses and the disruption induced price change ΔP_j, as well as the possibility that the magnitude of GDP loss for any given price change could also depend directly on the level of U.S. oil demand q_{du}. In this formal analysis we are examining the marginal effect of an import reduction on societal costs, *without* positing a particular change in domestic supply or demand to generate the imports change. Thus, for this partial equilibrium analysis, we hold domestic demand levels fixed and drop q_{du} from the equations. More generally, if we know that the policy which causes the imports reduction is an oil demand reduction, then there would be an additional disruption premium component associated with the change in GDP sensitivity to oil price changes.

$$\pi_{GDPdisr}(q_{iu}) \equiv \sum_j \frac{\partial \varphi_j}{\partial q_{iu}} \cdot \Delta GDP(\Delta P(\Delta Q_j, q_{iu})) + \sum_j \varphi_j \cdot \frac{\partial}{\partial q_{iu}} \Delta GDP(\Delta P(\Delta Q_j, q_{iu})) \tag{16}$$

Again, we omit the possible effect of import levels on disruption probability, and expand the second term:

$$\begin{aligned} \pi_{GDPdisr}(q_{iu}) &\equiv \sum_j \varphi_j \cdot \frac{\partial \Delta GDP}{\partial \Delta P} \frac{\partial}{\partial q_{iu}} (\Delta P(\Delta Q_j, q_{iu})) \\ &= \frac{\partial \Delta GDP}{\partial \Delta P} \sum_j \varphi_j \cdot \left[\frac{\partial \Delta P}{\partial \Delta Q} \frac{\partial \Delta Q}{\partial q_{iu}} + \frac{\partial \Delta P(\Delta Q_j, q_{iu})}{\partial q_{iu}} \right] \end{aligned} \tag{17}$$

These are the terms that must be evaluated to determine the GDP-Dislocation component of the Disruption import premium. The bracketed terms are the same two components that were identified for the Disruption Premium Import Cost component, which determine the marginal effect of pre-disruption import levels on the expected disruption price change.

III.5 Calculating the Optimal Premium

The total premium at any level of imports q_{iu} is given by the sum of the monopsony and disruption components:

$$\pi_{tot}(q_{iu}) \equiv \pi_{monops}(q_{iu}) + \pi_{Idisr}(q_{iu}) + \pi_{GDPdisr}(q_{iu}) \qquad (18)$$

Once the total premium $\pi_{tot}(q_{iu})$ can be calculated for any level of imports q_{iu}, by calculating each of its components, the optimal premium can be numerically determined by iteratively searching for the level of imports that equalizes marginal social costs and marginal private consumption benefits (see Figure 2 and the discussion). The net import supply to the U.S. is composed of the posited OPEC supply behavior minus the non-US net import demand curve. The resulting function for net import supply can be inverted to yield the world price of oil as a function of U.S. import demand, $P_w(q_{iu})$. Similarly, long-run U.S. domestic supply curves and demand curves combine to yield the U.S. net import demand curve, which can be inverted to yield the marginal benefits of U.S. oil imports, $B_{priv}'(q) = P_D(q_{iu})$. By definition, the marginal social cost of oil imports is the sum of the world price of oil plus the marginal oil import premium:

$$C'_{social}(q_{iu}) \equiv P_w(q_{iu}) + \pi_{tot}(q_{iu}) \qquad (19)$$

The optimal import premium π^* is the premium at the imports level q_{iu}^* that equalizes marginal social costs and marginal private consumption benefits:

$$\begin{aligned} P_w(q^*_{iu}) + \pi_{tot}(q^*_{iu}) &= B'_{private}(q^*_{iu}) \equiv P_D(q^*_{iu}) \\ \pi^* &\equiv \pi_{tot}(q^*_{iu}) \end{aligned} \qquad (20)$$

Conclusions

On September 7th, 2006, the U.S. EPA proposed a national renewable fuel program (more commonly known as the Renewable Fuel Standard program or RFS program). The proposed program will be applicable for 2007 and later and is designed to encourage the blending of renewable fuels into U.S. gasoline motor fuel. As part of the rule making, the U.S. EPA asked the Oak Ridge National Laboratory to assess the energy security benefits of increasing the use of renewable fuels.

Increased use of renewable fuel diversifies the energy sources used in making transportation fuel and reduces total U.S. consumption and U.S. imports of oil. To the extent that diverse sources of fuel energy reduce the dependence on any one source, the risks, both financial as well as strategic, of potential disruption in supply or spike in cost of a particular energy source is reduced. This reduction in risks is a measure of improved energy security. Reduced U.S. oil use also provides sustained benefits over the long run even in undisrupted markets, by reducing global demand pressure during what is expected to be an extended period of strong global demand, substantial OPEC market power and higher world oil prices.

In the face of projected higher oil prices, growing U.S oil imports, a large and slowly growing role of U.S. imports in world oil trade, a growing economy and the general expectation that the oil market may be somewhat more risky over the next decade, our estimate of the oil import premium is notably larger than estimated in 1997. Like the prior estimates, this study excludes possible effects of imports on U.S. costs whose relation to import levels is difficult to ascertain or measure, such as military expenditures and foreign policy effects.

This marginal "premium" approach estimates the effect on U.S. society-wide economic costs of an incremental reduction in imports. It does not directly apply to the effects of a broader policy change which not only alters the quantity of oil imports, but may also shift other features of the oil market in important ways. Possible changes in market relationships that are not modeled but could strongly influence oil security costs include:

- increased (or decreased) flexibility of demand and supply, in short-run or long-run
- decreased cartel power or discipline
- coordinated (amplifying or offsetting) policies by other oil importing countries.

While the study estimates the marginal societal economic benefit of a reduction in imports, it does not argue that an oil tax or import-tariff equal in magnitude to that marginal societal premium is an efficient policy for addressing oil security. This is because the root market failures at work are non-competitive global oil supply and the failure of long-term private oil market transactions to foresee and account for the economy-wide macroeconomic dislocations that are borne during disruptions as a consequence of the chosen pre-disruption levels of oil use. An externality-type (Pigouvian) tax on undisrupted-market oil imports does not directly or efficiently address either of these imperfections. While the oil import premium does estimate how reducing oil imports could diminish the costs of non-competitive supply and reduce macroeconomic losses during disruptions, it does not address the value to society of reducing these costs through other measures.

Parameters for the Updated (2006) Oil Import Premium Analysis

Demand Elasticities

Author	Short-Run	Long-Run	Adjustment Rate	Region
Kalymon (1975)	--	-0.5	--	various
Brown and Philips (1980)	-0.08	--	--	
Dahl (1993)	-0.05 to -0.09	-0.16 to -0.23	0.6 to 0.7	various
Peseran, et al. (1998)	-0.03	-0.48	0.9	
Gately & Huntington (2002)	-0.05	-0.59 to -0.64	0.9	OECD
Gately & Huntington (2002)	-0.03	-0.16 to -0.27	0.8 to 0.9	non-OECD
Cooper (2003)	0.0 to -0.11	0.0 to -0.53	0.8	23 countries
Cooper (2003)	-0.024 to -0.069	-0.18 to -0.45	0.8 to 0.9	G-7
Hunt & Ninomiya (2003)	--	-0.08 to -0.12	--	Japan, UK

Figure 4 Summary of representative estimates of short-run price elasticity of demand and adjustment rates. (Source: Atkins, Frank J. and S. M. Tayyebi Jazayeri 2004.)

Disruption Probabilities

Decadal Probabilities of 1 or More Disruptions of a Given Size			
Case	1 Million Barrels/Day	3 Million Barrels/Day	6 Million Barrels/Day
1996 Study Low	50%	10%	5%
1996 Study Mid	70%	30%	15%
EMF-2005	25%	36%	13%

Figure 5: Table of Disruption Probabilities

Historical Disruptions

Historical Disruptions in the World Supply of Oil			
Type	**Number**	**Duration (months)**	**Size (% of world Supply**
Accidents	5	5.2	1.1%
Internal Political Struggles	9	6.5	2.3%
International Embargos/ Economic Disputes	4-6**	11.0 (6.1*)	6.2%
Wars in Middle East	4-7**		
Total/Average	24	8.1 (6.0*)	3.7%
Notes: *Excluding 44 month Iranian Oilfield Nationalization. **Some events difficult to classify. Sources: Event listing from U.S. EIA. Categorization by Paul Leiby, ORNL.			
Figure 6: Summary of historical oil disruptions, 1950-2003			

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