ORNL/TM-2007/028

Estimating the Energy Security Benefits of Reduced U.S. Oil Imports

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Revised July 23, 2007

Prepared by
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Managed by
UT-BATTELLE
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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Abstract

This update and reassessment of the oil import premium was motivated by renewed concern about energy security, and interest in policies to promote the reduction of gasoline use in the United States. To the extent that conservation or fuel-diversification reduces dependence on any one source, the financial and strategic risk of potential disruption in supply or spike in cost of that source is reduced. This reduction in risks is a measure of improved energy security. Reduced oil imports also provides sustained benefits over the long run even in undisrupted markets, by reducing global demand pressure and oil prices during what is expected to be an extended period of strong global demand growth, substantial OPEC market power and higher world oil prices. We consider projected oil market conditions over the next ten years, relying on official U.S. EIA projections. A current estimate of the oil import premium is $13.60 per barrel (in 2004 dollars), with a wide 90% confidence interval ($6.70 - $23.25) to reflect many of the unresolved uncertainties. While this central value is above some estimates from the mid-1990s and early 2000's, it is well within the range of prior estimates up to 1993, many of which were made at times when oil market conditions were more similar to what is now anticipated. The essential message is that we may have passed through a brief period of comparatively greater energy security and lower dependence costs, but strong market and geopolitical forces have returned the societal costs of oil imports to greater prominence. An important note is that this premium estimate omits any costs for military programs, and the difficult-to-quantify foreign policy impact of oil import reliance.

Background and Purpose

There is considerable interest in the highest U.S. policy circles with taking action to improve energy security.[1] There are active proposals to reduce oil consumption and displace oil with alternative and renewable fuels.[2] This study investigates the energy security benefits of

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[1]For example: “Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world.” (President G.W. Bush, State of the Union, Jan 2006). “Our dependence on oil creates a threat to America's national security, because it leaves us more vulnerable to hostile regimes, and to terrorists who could attack oil infrastructure,” (President George W. Bush, statement on CAFE and alternate fuel standards Monday, May 14, 2007, in the Rose Garden). The President’s “Twenty in Ten” proposal (GW Bush, 2007 State of the Union Address) has the goal of “strengthening energy security and addressing climate change by reducing gasoline use by 20% in ten years” (http://www.whitehouse.gov/stateoftheunion/2007/initiatives/energy.html).

[2] The U.S. has had sustained interest in alternative motor fuels, as codified in the Energy Policy Acts of 1992 and 2005, and AMFA, the Alternative Motor Fuel Act of 1988. In 2007, the U.S. Environmental Protection Agency (EPA) finalized a national renewable fuels program (more commonly known as the Renewable Fuel Standard, or RFS program).

reduced U.S. oil 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 reducing oil imports, 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.[3] This approach estimates the marginal benefits to society, in dollars per barrel, of reducing oil U.S. imports.[4] 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.

We acknowledge, as did others before, that oil security and dependence costs are not strictly a function of imports alone. Other attributes, such as the level of oil consumption, the oil intensity of the economy, and the structure and flexibility of oil supply and use are also important determinants of the societal economic costs of oil use. These points are well made by Toman in his comprehensive survey pieces on energy security (1993, 2002). To the extent that a reduction in oil imports is accompanied by a reduction (increase) in oil consumption, or by the introduction of technologies or fuel sources that increase (decrease) the short-run or long-run price-responsiveness of energy supply and demand, the incremental benefits to society would be greater (less) than estimated here.

I. Introduction and Approach

This update and reassessment of the oil import premium is meant to help measure the energy security implications of new policies to promote the reduction of petroleum use in the United States. 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 the full magnitude of the oil dependence and security problem. Rather, it is a measure of the quantifiable per-barrel economic costs that 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.

It is important to note that 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 does it mean that the imposition of such a tax alone would completely solve the energy security

[3] 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.

[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: US DOT, NHTSA, "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 2006.

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. Bohi and Montgomery (1981) compellingly made this point. 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.

Since publication of Leiby *et al*. 1997, 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,[5] 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 key driving factors, we provide an updated range of estimates of the marginal energy security benefits of reducing U.S. oil imports.

I.1 Concerns About Oil Security

Concerns about oil security stem from three related problems: concentrated supply in a historically unstable region; the sustained exercise of market power by key oil exporters; and the continued (although perhaps diminished) vulnerability of the economy to episodic 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 prices 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 [e.g. Gately 2001, 2004, Greene, Jones and Leiby 1998]. 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 (IEA 2005) and given early evidence that the demand for oil in the light duty vehicle sector is becoming increasingly inelastic (Hughes, Knittel and Sperling 2008). Uncertainty, rigidities, and adjustment costs lead to economic dislocation,

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

particularly during sudden and disturbing oil supply disruptions (Hamilton 2005, Davis and Haltiwanger 1999, 1999a).

While evolving market institutions, declines in the energy intensity of the U.S. economy, and strategic oil stockpiling 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. Our approach accounts for the benefits of Strategic Petroleum Reserves (SPR). The power of the other two proposed mitigating factors is less well established. As noted by many experts (e.g. Hamilton 2005, 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 tests lead Hamilton (1985:10), 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 that 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, recent trends have been less favorable. The decline in oil value share has halted and reversed. The rising expenditure share for oil in U.S. GDP over the past 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 prior years.

I.2 Summary of Method

In order to estimate the energy security benefits of reduced U.S. oil use, we 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.[6] 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.[7] It was also cited in the NAS 2002 discussion of CAFE.[8] The

[6] 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.

[7] 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.

[8] 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).

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).

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. In the case of the 1997, the ranges reflect the subjectively defined "narrowed range." In the case of the new study, the ranges include 90% of results from the risk-analysis simulation.

The approach estimates the incremental benefits to society, in dollars per barrel, of reducing U.S. imports.[9] This "oil premium" approach identifies those energy-security related costs that are not reflected in the market price of oil, and that 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.[10]

[9] 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."

[10] Estimates of the oil import premium when counting marginal benefits for all OECD are typically about 3 times as large as the premium estimated from the perspective of U.S. benefits alone (e.g., Kline 1981).

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 the 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. The changes in key market parameters are summarized in the Tables 2 and 3 below.

Table 2: Evolving Oil Market Conditions and U.S. Oil Use

	1996 Study Conditions	2006 Conditions	AEO2006 Base, for 2006-2015
Oil Price ($2004)	$20.33	~$55	$45.00
US Oil Imports	8.82	~12.3	12.83
US Oil Demand	18.22	~21.0	22.65
OPEC Supply	28.4	33.9	35.08
US GDP	$8538	~$11800	$14085
Oil Share of GDP	1.76%	3.74%	2.64%

Evolving historical and projected oil market conditions influence the premium estimate. Note that all these parameters are positively related to the size of the import premium, to varying degrees.

Table 3: 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 +67%
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.

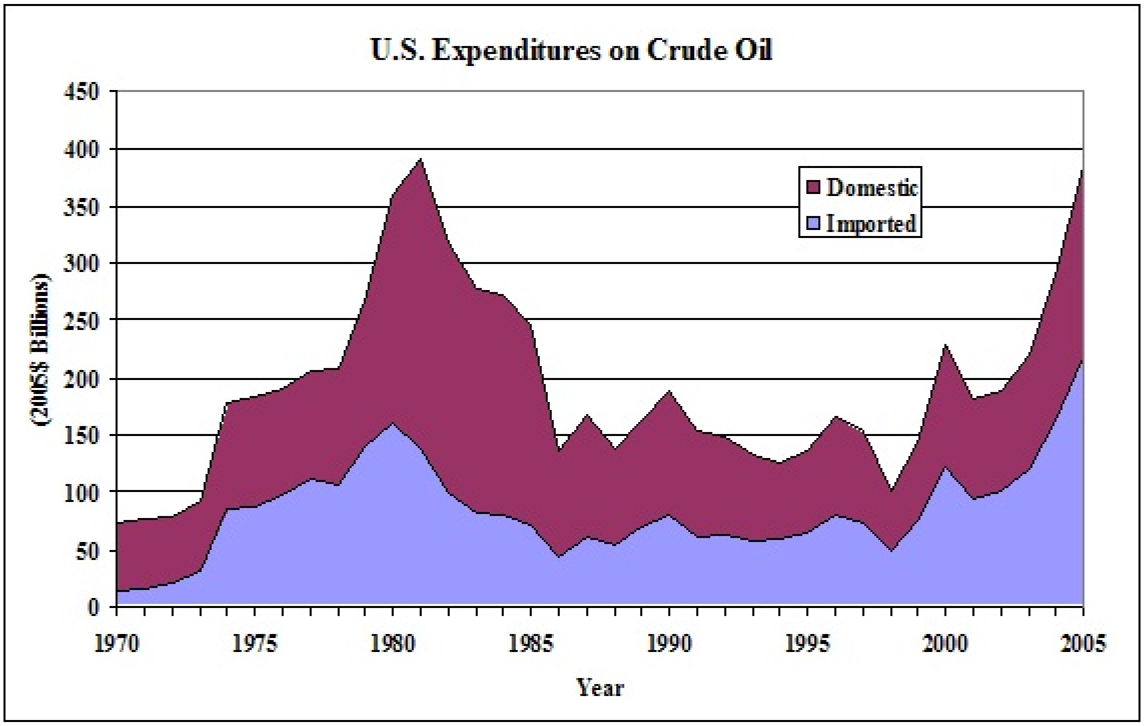

Figure 1 U.S. Expenditures on Crude Oil (Source: Annual Energy Review 2006 and International Energy Review 2004. Year 2005 values preliminary.)

The average annual expenditure on oil projected over 2006-2015, the period of this study, is $392 billion per year (2005$), based on AEO2006.[11]

We also revisited the issue of the macroeconomic consequences of oil market disruptions and sustained higher oil prices. There is substantial variation among the estimates of the GDP loss from an oil price shock.[12] 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 these 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 remains within the relatively wide (-0.08 to -0.01) range currently used in the sensitivity analysis.[13] Accordingly, the disruption costs were estimated in the same way as the previous 1996 study. That is, the key parameter "GDP elasticity" that 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), encompassing the estimates of most oil-macroeconomic studies over the last decade.

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

[12] 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.

[13] This GDP elasticity summarizes the cumulative loss of GDP expected over 2 years as a fraction of one year's GDP for a sudden, unanticipated doubling of world oil prices.

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 an updated range of estimates of the incremental energy security benefits of reducing oil imports shown 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 oil market conditions; optimal levels of imports given market imperfections; and marginal (small incremental) changes 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.[14] Using the competitive ideal as a reference point would provide a general view of the magnitude of costs that 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 that totally eliminate the market failures.

Secondly, the potential costs of oil imports may be defined in terms of the difference between the costs at the optimal (efficient) level and the current level of imports, recognizing that complete elimination of social costs is not cost effective, and that some government programs are already in place to respond to potential market failures. Since corrective 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 import costs may not be attainable with policies that are cost effective and pragmatically acceptable, but the concept has the merit of being a desirable reference point.

A third comparison 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 optimal or adequate 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

[14] Note that non-competitive oil supply in the face of unpriced environmental externalities would lead to offsetting effects (see, e.g. Huntington and Brown 2004.

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 United States 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."

II.3. Prior Estimates of the Oil Import Premium

The oil import premium gained attention as a guiding concept for energy policy beginning in the late 1970s, around the time of the second and third major post-war oil shocks (Plummer 1981, Bohi and Montgomery 1981, EMF 1982). Stobough and Yergin (1979) focuses interest on the demand or monopsony premium with their widely read estimates of the "buying power wedge," which they placed at a minimum value of $25/bbl to as much as three times that level.

The works in Plummer (1981, 1981a) provided valuable discussion of many of the key issues related to the oil import premium as well as the analogous oil stockpiling premium. They also provide a range of premium estimates.

In a book-length treatise, Bohi and Montgomery (B&M, 1981) carefully detailed the theoretical foundations of the oil import premium and exposed, through their thoughtful analysis, many of the critical analytic relationships. Because of its early position in the literature, and its comprehensiveness, it is informative to consider their work in more detail. They argued for attention to rigorous efficiency (cost and benefit) considerations and for evaluating what policies might be appropriate in that context rather than paying undue attention to the level of oil imports *per se.* They clearly defined the components of the oil premium as the "demand" or monopsony-related component and the "security" or disruption-related component (B&M 1981:5), with the premium measuring how those two cost components vary at the margin with the level of imports. In keeping with much of the early work that discussed the optimal oil import tariff as a measure of the oil import premium, B&M 1981 highlighted the manner in which the incidence and optimal size of an import tariff depend on the elasticity of U.S. import demand, the elasticity of net supply of imports to the U.S. and the level of U.S. imports.[15] These same fundamental relationships drive our estimates of the monopsony premium component, since they determine the degree to which an import reduction would drive down world oil prices or be offset by supply and demand responses globally with little price change.

Relying on theoretical arguments, Bohi and Montgomery carefully pointed out the ways in which market behavior and interactions (involving oil exporters, consumers and firms) could reduce the social costs of imports below the level commonly estimated by "conventional" frameworks. While they noted possibly indirect (secondary) repercussions and costs of the import-demand induced oil price increases beyond the direct "wealth transfers abroad" (examples offered relate to exchange rates, capital formation, income distribution, and productivity), B&M 1982 ruled these out as too speculative, and with possible offsetting considerations. Similarly, they argued on theoretical grounds that private agents can be expected to respond efficiently to the risks of oil market disruptions by balancing the marginal costs of protective action with their discounted expected cost of oil price increases. Example protective actions cited include reduced oil use, investment in flexible capital or substitute fuel capability, and stockpiling oil or substitutes. While they noted it is sometimes argued that private agents have less complete or accurate information about disruptions than the government, and that there may be deficiencies in private precautionary planning, they reject these arguments in the absence of convincing empirical evidence. We note, however, that this standard is not applied with uniformity to all their theoretical arguments.

Overall, Bohi and Montgomery rigorously scrutinized each argument for a cost that possibly provides a rationale for government intervention. In many cases, they conclude the argument melts away under the presumption of efficient market behavior, leaving only the most essential rationales remaining as sources of the oil import premium: the wealth transfer due to demand power in normal markets, the additional expected wealth transfer or demand component during disruptions stemming from higher imports, and any marginal effect of imports on "indirect macroeconomic costs" due to economy-wide dislocations and adjustments during oil shocks. Our study here generally comes to essentially the same conclusions, and relies on largely the same key components. Like Bohi and Montgomery, we recognize that economy-wide dislocations during shocks are more properly a function of oil consumption than imports. We also exclude most marginal disruption costs that are directly born by private oil-consumers and producers, and which may be anticipated and addressed by private precautionary behavior. However, we agree with Parry and Darmstadter's (2004) assessment that "Most analysts believe that the full extent of market upheaval is *not* fully captured in firm behavior" (p.14, emphasis added), so we consider the possibility that some fraction of expected price shock increases is not internalized.

[15] B&M1982 and others note that the oil import premium is not synonymous with "optimal tariff," and does not necessarily call for a tariff of like magnitude, given the complexities of trade policy. Rather it is an estimate of the net benefits of reducing imports, guiding the amount that we might be willing to spend per barrel to do so. The premium arises from diverse phenomena, hence "no single instrument" should be expected to adequately address the separate reasons a premium exists. Multiple instruments may achieve the most efficient/least cost intervention.

Despite their rigorous standards for inclusion in the premium and generally optimistic assumptions regarding market efficiency in the face of higher oil prices and disruptions, Bohi and Montgomery still offered what might now be viewed as moderately large estimates of some components of the oil import premium. They did not provide estimates of the disruption portion of the import premium. While they noted that "uncertainties... preclude an unambiguous conclusion about the magnitude of the premium," they concluded (in 1981) that the long-run monopsony premium probably lies below $10/bbl (1980$), or $20.19/bbl in 2004$. In their Appendix they provide a range of estimates of the optimal import tariff usually around $8.08/bbl (1980$), or $16.32 in 2004$.

Kline (1981) and the Energy Modeling Forum (1982) reported on oil import premia calculated from a set of controlled experiments with nine different models of the world oil market. Unlike many analytic approaches that are essentially static estimates of the long-run oil premium, these multi-period models of interacting regional oil supplies and demands allowed the observation of a dynamic response to changing import levels or tariffs. The premium for each model was then calculated as the net present value of incremental benefit minus costs divided by the cumulative reduction in imports over the forecast horizon. One feature of this analysis is that the early years reflect a short-run premium and the later years trend toward the long-run premium. The 1981 EMF-6 model comparison yielded oil import premia in the range of $10.30 to $34.32/bbl (2004$). The mean and median premium values for the nine models were $22.52 and $18.17/bbl respectively (2004$). Two other insights revealed by this analysis were that the disruption premia were typically about 1/3 the size of the monopsony premia, and premia counting spillover net benefits for all of OECD were about 3 times the size of the U.S. premia (partly by construction).

Hogan (1982), and Broadman and Hogan (1986,1988) revised and extended the established analytical framework to calculate base and optimal oil import premia with a more detailed accounting of macroeconomic effects (building on the macroeconomic framework of Nordhaus 1980). The method explicitly includes indirect costs from balance of payments adjustments and inflationary effects (for a summary, see Leiby *et al*. 1997:22-24). Extending Hogan (1981), they determined the exchange rate variation necessary to restore the trade balance after an incremental increase in imports occurs and an assumed fraction of the increase in oil import payments is recycled. They also accounted for the impact of Strategic Petroleum Reserve policy on the security component of the premium. Based on probabilistic simulations, Hogan and Broadman (1988:11 Table 2) reported two ranges of oil import premium, for two possible future reference price paths. The median of the two ranges are $14.02 and $16.92/bbl (2004$). The 50% confidence intervals they provide for a range (25^{th} percentile and 75th percentile) are roughly +/- $3/bbl.

The Broadman and Hogan results are unusual in their more equal contributions of the monopsony and security components than prior studies. Their results also highlight the offsetting interactions between the oil demand component and the security component of the *optimal* premium. The optimal premia indicate the societally-efficient level of marginal cost to reduce imports. It is generally the case that including policy actions (particularly taxes or tariffs) that respond to a larger value of one component would reduce the optimal level of marginal expenditure to address the other component. (Bohi and Montgomery 1981 also note that conditions and assumptions implying a larger security premium can imply some degree of reduction of the optimal monopsony premium.)

Broadman (1986) revisited the analytics of the oil import premium, offering a typology that subdivides the monopsony and security components into direct and indirect parts. He also summarizes a range of oil import premium estimates available prior to 1986 (Table 1, p. 247). Including the high and low estimates for multiple studies from 1979 to 1982, the range is quite large ($2/bbl to over $150/bbl in 2004$, mean $38, median ~$18). About half of Broadman's observations were from the EMF 1982 study.

A decade after the Energy Modeling Forum's 1981-2 study of world oil models (EMF-6), in 1991 it examined another, mostly different, set of models focusing on oil demand and the prospects for oil demand reduction (EMF 1992, the EMF-11 study). While this study did not explicitly conduct experiments to elicit the import premium, Huntington (1993) established a method to roughly infer their values from controlled oil price-path cases. Again, the premia were estimated from a per-barrel average of the discounted multi-year dynamic responses. Huntington imputes values for the oil import premium with a range of $11.39 to $20.58/bbl (2004$), excluding an outlier value of $53.24. The mean and median premium values for the six EMF-11 models were $15.82 and $15.65/bbl respectively (2004$).

Leiby, Jones, Curlee and Lee 1997 provided an extended review of the literature and issues regarding the estimation of the premium to date. They also estimated a widely inclusive range of oil import premium values, showing the variation of each component with key driving factors such as OPEC behavior, the likelihood of disruptions, and the extent to which those disruptions induce external shock effects. The analytical framework used is derived from Broadman and Hogan 1988, but Leiby *et al.* omitted the explicit indirect costs for balance of payments and inflationary effects as less-well established empirically or theoretically than other costs. They used a single measure of macroeconomic dislocation costs during disruptions parameterized by empirical studies. The Leiby *et al.* estimates were based on 1994 oil market conditions, a period of markedly lower prices, comparative stability, and excess supply capacity. Under these conditions, a widely inclusive range of premia extended from $0 to $12.23 (2004$). Excluding the case of no OPEC market power and essentially no costly disruptions, but assuming fairly responsive OPEC supply, a narrowed range of roughly $2.60 to $5.60 was also constructed.

Parry and Darmstadter (2004) recently provided an overview of work on the oil import premium. Based on a review of prior estimates, they offered their summary judgement: "...we put our best assessment of the quantifiable component of the oil premium at $5/bbl, with a wide range of $0 to $14 to account for the diversity of opinion among analysts." (P&D2004:14). Note, however, that while this summary assessment was published in 2004, it makes reference to data only through 2001, observing "since the mid-1980s prices have fluctuated between $12 and $25 per barrel." [p.3].

As mentioned, this paper essentially updates the oil premium estimates of Leiby *et al.* 1997 with revised EIA projections of oil market conditions and some revision of oil market parameters (elasticities) to reflect further research. We also perform a probabilistic risk analysis (following Broadman and Hogan 1986, 1988, and the recommendations of Toman 1993:1213) to generate a range of potential premium values. The extreme (optimistic) cases of *no* exercise of cartel power and *zero* probability of future disruptions that induce external costs on society are omitted as unrealistic and unhelpful in the current oil market and policy environment.

III. Cost Components

The full economic cost of importing petroleum into the United States 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 dislocations of the domestic economy and reductions in U.S. economic output 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* cost category stems from the degree to which it is generally not accounted-for in the market decisions of oil consumers or producers, and whether it can be changed by a particular policy measure under consideration. For this reason the oil security import premium analysis considers only the incremental changes in such unaccounted costs as the level of imports changes. To summarize, the premium components include non-internalized, marginal costs.

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 our studies and other recent research.

III.1 Demand Costs, or the Longer-Run Monopsony Effect

The first component of the full economic costs of importing petroleum follows from the effect of U.S. import demand on the long-run world oil. Because the United States 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 imports is the potential decrease in the price paid for all barrels of crude oil purchased by the United States Purchase costs for both imported and domestically-produced petroleum decline, but the gain from lower domestic oil cost is offset by a loss of revenue for domestic producers, so it is omitted from the assessment of net U.S. social gains.[16] A reduction of total purchase costs for the remaining oil imports, however, represents a net welfare gain for U.S. society: the 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, per barrel change in the level of imports.[17]

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 by other participants in the international oil market to world oil price. 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 past few years with expanding global demand 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 demand or monopsony effect can be readily illustrated with an example. If the United States 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 for oil purchases. This additional benefit arises only to the extent that reduction in U.S. oil imports affects the world oil price.

The key determinants of the magnitude of the monopsony premium 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

[16] 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.

[17] 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.

United States is a problem of bilateral monopoly, and essentially indeterminate. However, the problem can be bounded.

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).[18] 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 United States 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 United States

III.2 Disruption Costs

The second component of the oil import premium, the "disruption premium," arises from the effect of oil imports 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 increases the costs of imports in the short run, further expanding the transfer of U.S. wealth to foreign producers; and it can lead to macroeconomic contraction, dislocation, and GDP losses.

III.2.1 Disruption: Higher Costs of Oil Imports and Wealth Transfer During Shocks

During oil price shocks, the higher price of imported oil causes increased payments for imports and an acceleration of the transfer of wealth from U.S. society to oil exporters. This increased claim on U.S. economic output is a welfare loss to the United States that is separate from and additional to any reduction in economic output due to the shock. For some disruptions (wars or revolutions) a portion of this increased import cost may also reflect the opportunistic extension, or simply maintenance, of cartel supplier power in the face of reduced supply. In the case of other disruptions, such as supply embargoes, strikes, and economic disputes, the bulk of price increase may be attributable to market power. Regardless of cause, we count the increased wealth transfer during shocks as a welfare loss to the degree that the expected price increase is not anticipated and internalized by oil consumers.

[18] 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. Note that if OPEC defends market share to some degree and lets price fall, the framework used here captures benefits to the United States in the monopsony premium. However, if OPEC instead defends price and sacrifices market share, the method here does not yet include the likely benefits from the diminishment of OPEC power that comes with declining share, or any benefits from increased slack oil production capacity in OPEC countries.

III.2.2 Disruption Macroeconomic Costs: Potential Output Loss and Dislocation/Adjustment Costs

Macroeconomic losses during price shocks reflect aggregate output losses and allocative losses.[19] The former are a reduction in the level of output that the U.S. economy can produce fully using its available resources; and the latter stem from temporary dislocation and underutilization of available resources due to the shock, such as labor unemployment and idle plant capacity. The aggregate output effect, a reduction in "potential" economic output, 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, 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.

In addition to the aggregate contraction, there appear to be "allocative" or "adjustment" costs associated with dislocated energy markets. Because supply disruptions and resulting price increases occur suddenly and often involve disturbing news of war or strife, empirical evidence shows they also impose additional costs on businesses and households that must adjust their use of petroleum and other productive factors more rapidly than if the same price increase had occurred gradually (e.g. Hamilton 2005, Davis and Haltiwanger 1999,1999a).[20] Dislocational effects include the unemployment of workers and other resources during the time needed for 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 is complete. The additional costs imposed on businesses and households for making these adjustments reflect their limited ability to adjust prices, output levels, and their use of energy, labor, and other inputs quickly and smoothly in response to rapid changes in prices for petroleum products.

While it is widely expected that the macroeconomic costs of oil shocks will decline with declining share of oil 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 the disruption cost components must be weighted by the probability that the supply of petroleum to the United States 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

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[19] For recent surveys of the literature on oil prices and the macroeconomy, see Brown and Yücel 2002, Jones, Leiby and Paik 2004, and Hamilton 2005.

[20] 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.

relevant measure of their magnitude.[21] Further, when assessing the energy security value of a policy to reduce oil use, 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, from any induced alteration in the likelihood or size of disruption, 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 United States 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. We express this formally in Section IV.4.

In summary, the steps needed to calculate the disruption or security premium are:

- First, determine the likelihood of an oil supply disruption in the future;
- Second, assess the likely impacts of a potential oil supply disruption on world oil price;
- Third, assess the impact of the oil price shock on the U.S. economy (in terms of import costs and macroeconomic losses); and
- Fourth, determine how these costs change with imports.

The value of price spike cost avoided by reducing oil imports becomes the oil security portion of the premium.

III.2.3 Role of Market Mechanisms in Reducing Costs

When estimating the disruption component of the oil import 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 added energy conservation measures in anticipation of shocks, stockpiling oil, 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

[21] Note that the use of the expected cost measure embodies an assumption of risk neutrality with respect to disruption risk. Risk aversion would imply larger premia.

U.S. economy that could be imposed by disruptions in the world supply of oil. But the degree to which markets anticipate and account for the long-run risk of price increases from strategic oil shocks is not known with much confidence. Nonetheless, 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). The marginal private disruption risk per barrel of imports is equal to the expected oil price increase due to shocks.

Furthermore, the scope for private anticipatory protection is limited. The futures market extends only a limited time into the future,[22] 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.[23] Recognizing that private agents use futures to hedge at most only their own 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 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.

In sum, while the availability of private protective mechanisms has undoubtedly reduced the potential costs that could be imposed by disruptions in the world supply of oil, a substantial portion of these disruption costs is probably not reflected in the market price of petroleum or in

[22]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.

[23]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 response of economic agents. There are two reasons. First, the availability of cost-effective mechanisms for private agents to avoid long-term risk is limited. 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.

We estimate that under reasonable assumptions about the probability of future disruptions in world oil supplies 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 United States, with adjustment costs accounting for the largest share of this total. An average estimate is $4.68.

III.3 Policy Costs: Military Security and Strategic Petroleum Reserve Costs

The third and final commonly-identified component of possible external economic costs of oil imports is the cost U.S. taxpayers bear 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 difficult to attribute military costs, and specific activities or 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 military 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 U.S. or world 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. 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. Our contribution here is in calculating other components of the oil import premium.

While the optimal size of the SPR, from the standpoint of its potential influence on U.S. costs during a supply disruption, *may* be positively 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. It is also more cumbersome to analyze.[24] Therefore, we adopt the latter approach and assume no change in the SPR from its current size.[25] However, our estimates do explicitly account for the role of the SPR in addressing shock effects and reducing disruption costs. To the extent that the current SPR is able to more-completely buffer shocks at lower import levels, that marginal cost change is accounted.

SPR use during a disruption requires a Presidential determination of need based on a range of economic, foreign policy, and national security considerations.[26] 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.

[24] See Leiby and Bowman (2003, 1998) and U.S. DOE (1990) for comparatively recent studies. Earlier studies were by, e.g. Teisberg 1981, Hogan 1982, Murphy, Toman and Weiss 1986 and Devarajan and Weiner 1989.

[25] 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). Under the International Energy Agency (IEA) agreement, all signatories agree to hold emergency oil stocks equivalent to 90 days of oil imports, in crude or product form (See e.g. International Energy Agency 2007, *IEA Response System for Oil Supply Emergencies*.) There is some flexibility of accounting, particularly regarding how private inventories are included along with public stocks. The U.S. DOE's current assessment is that the IEA requirements are met and exceeded, since "SPR and private company import protection" is measured as approximately 118 days (U.S. DOE Fossil Energy website, http://www.fossil.energy.gov/programs/reserves/spr/spr-facts.html).

[26] Specifically, under Section 3 of the Energy Policy and Conservation Act (EPCA), the President must ordinarily make a determination of a "severe energy supply interruption". For more details, see the U.S. DOE SPR website http://www.fe.doe.gov/programs/reserves/spr/spr-epca.html.

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

The principal method used in this paper is the marginal analysis of U.S. welfare, employing the standard concepts of the *economic* welfare function and the oil import premium. The marginal cost of imported oil (in dollars per barrel) is the incremental cost associated with a unit change in oil imports.[27] Its estimation does not require that we know total costs, but only how total costs change with the level of oil imports.

We begin with a functional description of how U.S. economic net benefits $N(q_{iu})$ depend on the level of oil imports (q_{iu}).[28] [29] 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 identified marginal non-private costs:

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

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

[27] Technically, marginal cost is the derivative of total cost, and is based on an infinitesimal change in oil use. Its units are dollars per barrel.

[28] 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. Net benefits can be measured relative to an arbitrary reference point, since our interest is in marginal changes.

[29] Naturally, net benefit also depends on levels of oil production and consumption, but at first we abstract from these issues. For example, the macroeconomic dislocation losses from disruptions are expected to be more directly a function of oil or energy consumption levels or intensities than import levels. However, even if the contemplated policies directly target consumption, because of the identity linking supply, demand and imports a separate examination of the import premium alone is informative. Certain costs, notably the sustained costs of non-competitive oil supply and the higher import costs borne during disruptions, are directly functions of imports. Others, such as macroeconomic disruption costs may be indirectly functions of imports to the extent that import levels alter the expected frequency or magnitude of shocks or the severity of their impact on the oil market. It is these direct and indirect marginal effects of import levels that we focus on here, in keeping with the established literature on the import premium as an informative guideline for energy security or dependence policies.

marginal private costs.[30] 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}.

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

The marginal private cost of oil is the prevailing world oil price, P_w. So the marginal private net benefit of imports is $N'_{private} = P_{iu}(q_{iu}) - P_w$. 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:

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

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 in keeping with earlier approaches as far back as Plummer (1982) we divide the oil import premium into two components: 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

[30] 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.

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

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).

IV.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 marginal 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.

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).

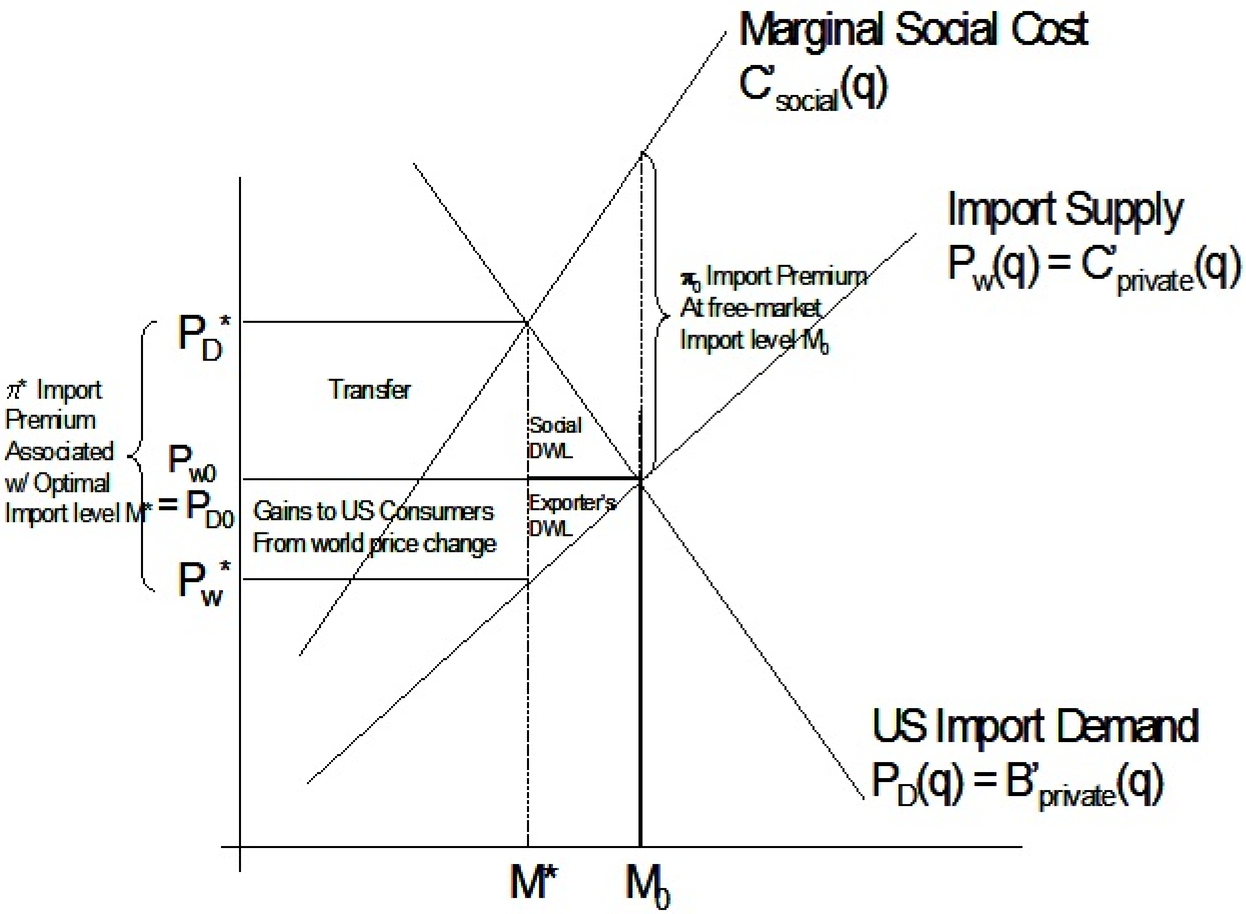

Figure 2: Deviation Between Marginal Social Cost and Marginal Private Cost of Imports Implies a Premium.

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:

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

Note that neither the premium nor the level of imports is necessarily reduced to zero at the optimal level M^*. 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. The results presented here focus on the smaller "optimal premium."

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)].

IV.3 Monopsony Power and Calculating 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.

IV.3.1 Monopsony Power

Since the United States 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]."

Most analysts agree that the United States 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. In the past, others have argued that the explicit exercise of monopsony power, especially the adoption of an import tariff or quota, could 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 might have greater plausibility when OPEC is poorly coordinating its monopoly power and is at best acting as a "clumsy cartel." In this case, the blatant and prominent assertion of monopsony power could lead to greater solidification of the oil cartel and result in world oil price increases. On the other hand, the suggestion of OPEC retaliation becomes less compelling at times (such as the current and projected market conditions) when OPEC is already exercising substantial supply restraint and maintaining prices at a comparatively high levels.

To the extent that the United States 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 some uncertainty. Arguably, 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 United States to reduce consumption, will they not react, or will they take actions to actually increase their import levels? We assume all other major oil consuming and importing regions outside of OPEC do not alter their policies, but respond competitively to any price reduction induced by U.S. policy.

IV.3.2 Issues in Estimating the Monopsony Premium

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 net 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.

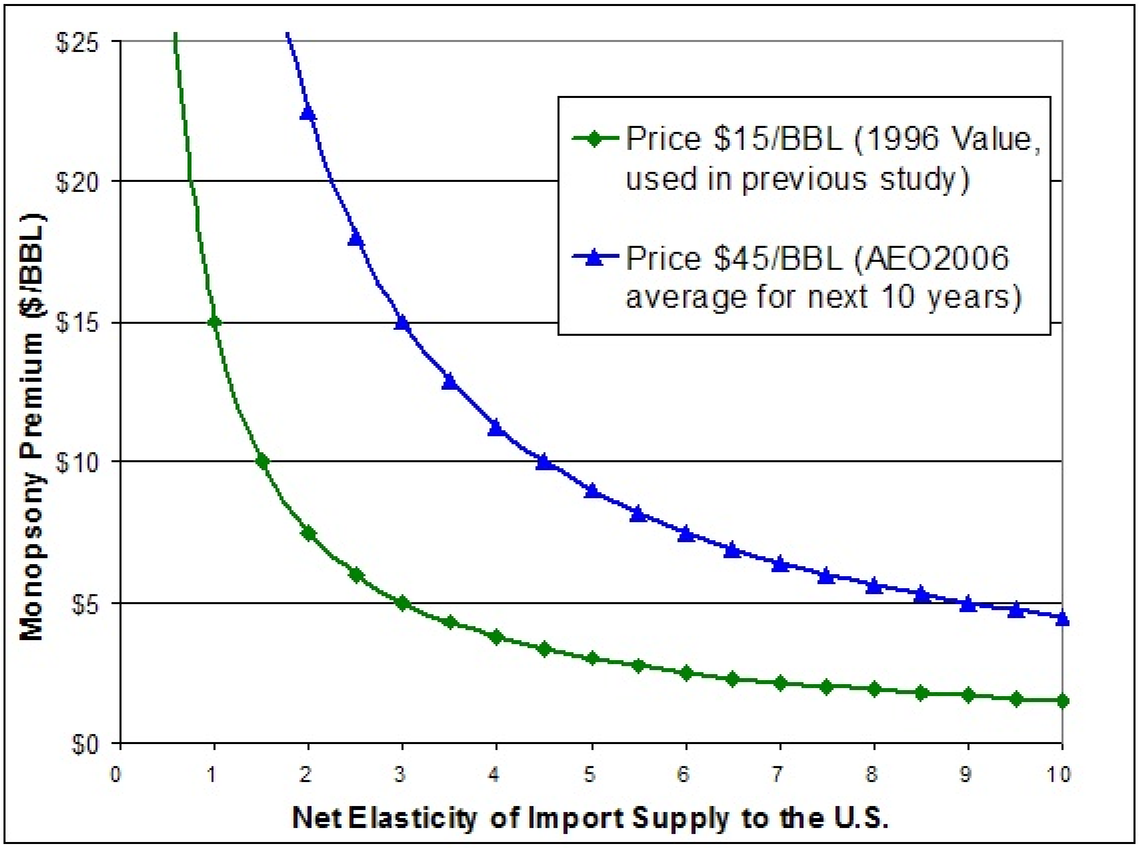

Figure 3 Relationship of oil monopsony premium to the elasticity of net import supply to the United States, and the world price of oil.

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 United States 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.[31] 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).[32]

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

[31] 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 United States, that is $\sigma_U \equiv q_{iu}/(q_{iu} + q_{iN})$.

[32] 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. It seems especially unlikely that other major oil consuming countries would take an opportunistic or even non-cooperative strategy given current widespread concern about the need for energy conservation and climate change.

is a true monopolistic supplier, then there is no well-defined conventional upward-sloping supply 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. However, the limits of depletable resource theory as a positive description of petroleum markets are well established (e.g. Watkins 1992, 2005). 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 undermine 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.

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

We defined (Eq. 5) the disruption component of the import premium as the marginal change in expected disruption losses:

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

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 $\Delta P_i\ (\Delta Q_j)$, 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:

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

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}.

IV.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:

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

Taking the derivative:

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

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:

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

The first term on the right-hand side of Eq. 13 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 or terrorist attacks) 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 that 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 that 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.

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

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).

IV.4.2 Disruption Premium - GDP Dislocation Cost Component

Analogous 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

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

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 that 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. Note that we do *not* assume any change in the sensitivity of GDP to price shocks (∂ GDP/∂ P) from a change in the level of *imports*, since the GDP losses from oil shocks are thought to be more properly a function of consumption levels. If the change in imports is also accompanied by a change in consumption, then the full import/consumption premium would be larger by that term.

IV.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:

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

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 United States 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:

$$C^{/}_{social}(q_{iu}) \equiv P_w(q_{iu}) + \pi_{tot}(q_{iu}) \tag{19}$$

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

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

V. Results

A range of results was constructed by probabilistic simulation, reflecting uncertainty regarding the key factors.

- All estimates utilize the AEO-2006 Base oil market projection. (Otherwise, the range of estimates would be much wider and asymmetrically XXXhigher).
- OPEC supply response elasticity varies from 0 to 5, with mode of 1.0.
- Long-run supply and demand elasticity utilized the same 1997 study values.
- Disruption probabilities are taken from the Energy Modeling Forum 2005 survey (see EMF/Beccue and Huntington 2005), aggregated into 3 discrete disruption sizes (see Appendix).

- GDP Loss elasticity with respect to oil shock price varied from -0.01 to – 0.08. This range encompasses essentially the bulk of the recent econometric and modeling estimates for the cumulative loss of GDP for 2-3 years after a shock, expressed as a percentage of one-year's GDP.
- Short-run elasticity of U.S. import demand ranges from -0.087 to -0.163. This range is supported by the range of estimates from the literature shown in the Appendix, although a argument can be made for smaller short-run elasticities.
- Disruption size reduction with imports varies from 0% to 30%, with the upper end corresponding roughly to the share of world oil trade flows demanded by U.S. imports.

Parameter distributions are generally taken as either discrete over three low-mid-high values (with probabilities of 25%, 50% and 25% each) or a continuous triangular distribution.

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. In the case of the 1997, the ranges reflect the subjectively defined "narrowed range." In the case of the new study, the ranges include 90% of results from the risk-analysis simulation.

The estimated range and mean value for each component of the import premium is shown in Table 1, reproduced in this section for convenience. The estimated oil import premium for the United States is composed of about two-thirds monopsony premium and one-third disruption premium. Over the full range of simulations, the net elasticity of oil import supply to the United States varies from -1.3 to well over -15. One informative measure is the implied change in world oil prices from a change in U.S. imports. For the stated elasticity range, the implied oil price decrease per million-barrel-per-day reduction in U.S. imports ranges from $0.2/bbl to $3.8/bbl (the 90% confidence interval is smaller), with a value for the mean premium estimate of about $0.82/bbl/MMBD. This price-sensitivity is well within the range of other estimates.[33] The

[33] As one basis of comparison, the NRC (2002) cited other (EMF) studies in which the oil price would be decreased by between 0.8 percent and 2.9 percent per million barrel per day oil import reduction. They noted that "applying that same percentage to current [2001] prices would give a monopsony component between $2.20 and $8.20/bbl." Applying the same price sensitivity here to average EIA projected prices for the next 10 years implies price changes (slopes) of -$0.36/bbl/MMBD to -$1.31/bbl/MMBD, and monopsony premia ranging from $4.61/bbl to $16.70/bbl.

disruption premium in turn is about two-thirds macroeconomic losses from dislocation and one-third losses from increased oil import costs during shocks. That is, the mean estimate of the un-internalized portion of the expected disruption price increase is between $1 and $2/bbl.

Generally, the 2006 import premium estimates are notably higher than those we produced 1996. While higher, this result is consistent with many other estimates (e.g. Plummer 1982, Broadman and Hogan 1988, Huntington 1993), which were constructed at times when oil market conditions were more similar to those currently projected by EIA than the conditions of the mid-1990s. This is seen in Figure 4, which plots the newest estimates (enclosed in the ellipse on the right side of the graph) along with estimated ranges from 11 other studies.[34] At least two of the studies (EMF 1982 and Huntington 1983) also provided ranges derived from multiple oil market models. Results from each study are plotted according to their publication date. Each of these study ranges was based on prevailing or projected oil market conditions around the time of the study. While many oil market conditions contribute to the premium estimate, we have superimposed the contemporaneous world oil price on the plotted estimates as one important market indicator.

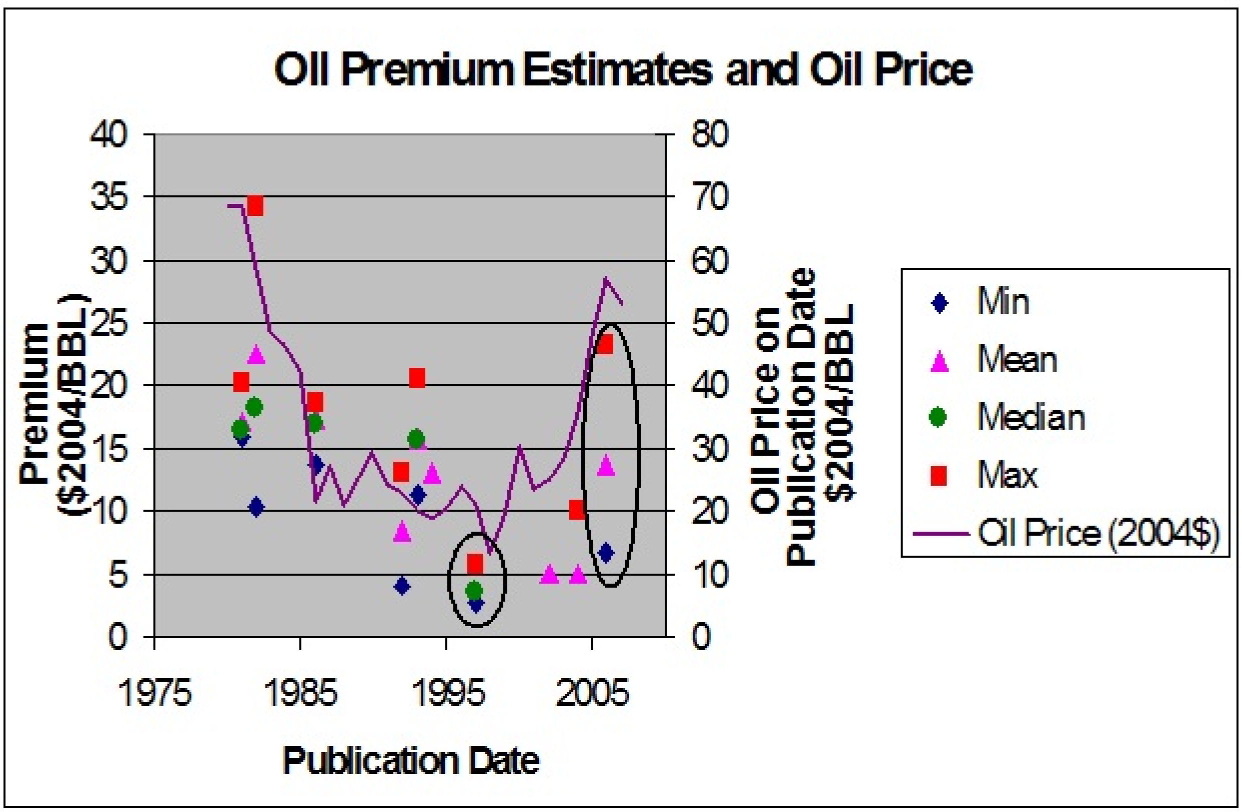

Figure 4 New estimates consistent with past estimates under similar market conditions.

[34]Source studies for this graph included: Bohi & Montgomery 1981, EMF 1982, Broadman 1986, Behrens et al. (CRS) 1992, Huntington 1993, CEC 1994, Leiby et al. ORNL 1997, Moore et al. CRS 1998, NRC 2002, Parry & Darmstadter 2004, and Leiby 2006.

Finally, we note that the possible range from our current study is wider still if one considers the simultaneous combination of all best- or worst-case assumptions. However, the likelihood of these more extreme combinations should be viewed as remote.

VI. Conclusions

This study assesses the marginal net economic benefits to the U.S. economy of reduced U.S. imports of oil. "Security" gains stem from reduced exposure to the economy-wide costs of potential disruptions in oil supply or spikes in oil cost. Reduced U.S. oil imports also provide sustained "monopsony" benefits over the long run even in undisrupted markets, by reducing global demand pressure and oil prices during what is expected to be an extended period of strong global demand, substantial OPEC market power, and higher world oil prices. The monopsony benefits during normal markets or disrupted markets reflect a recovery of U.S. wealth that would otherwise be extracted as cartel rents through the non-competitive exercise of market power by OPEC countries.

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 a 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 our 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. However, those costs remain relevant and worthy of more careful consideration.[35]

Apart from omitting foreign policy, military, and national security considerations from this economic analysis, three other factors were omitted which, if included, would possibly increase the economic estimate of the premium:

- Any further premium due to risk aversion (the disruption analysis is based on expected values);
- Possible "deterrence effects" of energy security and import reduction measures (the frequency of disruptions might be reduced if greater U.S. energy security reduces the motivation for intentional shocks (embargoes or terrorist acts)); and
- Spillover benefits to U.S. allies (some benefits of U.S. import reduction, particularly the benefit of lower import prices, would spill over to all major oil consuming nations, many of which join us in a formal International Energy Agency agreement to reduce energy use and promote joint energy security. Based on prior estimates, including the full OECD premium resulting from U.S. import reduction would result in a value approximately three time larger).

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 that 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:

[35] E.g. the Council on Foreign Relations (2006) high-level panel of energy and foreign policy experts warns that America's dependence on imported energy increases its strategic vulnerability and constrains its ability to pursue foreign policy and national security objectives. Stern (2006) makes the strong case that large cartel rents have contributed to the development of rich, radicalized, and militarily more powerful hostile states. He argues for the exercise of U.S. monopsony power not simply to recover wealth, but because OPEC market power underwrites terror and other threats to U.S. national security.

- 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 5 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

References

Atkins, Frank J. and S. M. Tayyebi Jazayeri 2004. "A Literature Review of Demand Studies in World Oil Markets," University of Calgary, Department of Economics, Discussion Paper 2004-07, April.

Behrens, C.C., J.E. Blodgett, M.R. Lee, J.L. Moore, and L. Parket 1992. External Costs of Oil Used in Transportation, 92-574 ENR. Washington DC: Congressional Research Service.

Bohi, Douglas R. And W. David Montgomery 1982. *Oil Prices, Energy Security, and Import Policy* (Washington, D.C.: Resources for the Future, Johns Hopkins University Press).

Bohi, Douglas R. 1981. Analyzing Demand Behavior: A Study of Energy Elasticities. , Resources for the Future, Washington, DC (1981).

Bohi, Douglas R. and M. Zimmerman 1984. An update on econometric studies of energy demand. *Annual Review of Energy* Vol 9 (1984), pp. 105–154.

Bohi, Douglas R. And Michael A. Toman 1996. *The Economics of Energy Security* (Norwell, MA: Kluwer Academic Publishers).

Broadman, H. G. 1986. “The Social Cost of Imported Oil,” *Energy Policy* June: 242-252 (1986).

Broadman H.G. and W.W. Hogan, 1986. “Oil Tariff Policy in an Uncertain Market.” Energy and Environmental Policy Center, Discussion paper E-86-11.

Broadman H.G. and W.W. Hogan, 1988. “Is and Oil Import Tariff Justified? An American Debate: The Numbers Say ‘Yes’.” *The Energy Journal* 9: 7-29.

Brown, Stephen, Nathan S. Balke and Mine K. Yücel 2002. “Oil Price Shocks and the U.S. Economy: Where Does the Asymmetry Originate?” *The Energy Journal* 23(3).

Brown, Stephen and Mine K. Yücel 2002. “Energy Prices and Aggregate Economic Activity: An Interpretative Survey,” *Quarterly Review of Economics and Finance*, 42(2).

Brown, Stephen P. A., Dong Fu and Mine K. Yücel 2005. “Energy Prices and Aggregate Economic Activity: A Changing Relationship?” Federal Reserve Bank of Dallas. Draft presented at Western Economics Association, 2005.

Cooper, John C.B. 2003. “Price Elasticity of Demand for Crude Oil: Estimates for 23 Countries,” *OPEC Review*, March.

Costello. Dave, U.S. EIA, 2006. "Reduced Form Energy Model Elasticities from EIA's Regional Short-Term Energy Model (RSTEM)," May 9, 2006

Council on Foreign Relations 2006. *National Security Consequences of Oil Dependency*, Independent Task Force Report No. 58, John Deutch and James R. Schlesinger, Chairs, David G. Victor, Project Director.

Dahl, Carol A. (1986). "Gasoline demand survey." *The Energy Journal* 7(1):67–82.

Dahl, Carol A. (1993) "A Survey of Oil Demand Elasticities for Developing Countries," OPEC Review, XVII (4), Winter, pp. 399-419.

Dahl, Carol A. (1994) "A Survey of Oil Product Demand Elasticities for Developing Countries," OPEC Review, XVIII(1), pp. 47-87.

Dahl, Carol A. (1994) "A Survey of Energy Demand Elasticities for the Developing World," Journal of Energy and Development, Vol 18 (I), Autumn. pp. 1-48.

Dahl, Carol A. (1995) "Demand for Transportation Fuels: A Survey of Demand Elasticities and Their Components" *Journal of Energy Literature*, 1(2), Fall.

Dahl, Carol A., and Thomas Duggan (1998). "Survey of Price Elasticities from Economic Exploration Models of US Oil and Gas Supply," *Journal of Energy Finance and Development*, 3(2):129-169.

Dahl, Carol A. and Thomas Duggan (1996). "U. S. Energy Product Supply Elasticities: A Survey and Application to the U.S. Oil Market," *Resources and Energy Economics*. 18:243-263.

Dahl, Carol A. and Sterner, Thomas (1991) "Analyzing Gasoline Demand Elasticities: A Survey," *Energy Economics*, July, Vol 13(3):203-210.

Dahl, Carol A. and Sterner, Thomas (1991) "A Survey of Econometric Gasoline Demand Elasticities," *International Journal of Energy Systems*, 11(2):53-76.

Davis, Steven J. And John Haltiwanger 1999. "On the Driving Forces behind Cyclical Movements in Employment and Job Reallocation," *The American Economic Review*, 89(5):1234- 1258.

Davis, Stephen and John Haltiwanger 1999a. "Sectoral Job Creation and Destruction in Response to Oil Price Changes," National Bureau of Economic Research Working Paper W7095.

Energy Modeling Forum 1982. *World Oil*, EMF Report 6 (Stanford University Press: Stanford CA).

Energy Modeling Forum 1991. *International Oil Supplies and Demands*, EMF Report 11

(Stanford University Press: Stanford CA).
.

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

Gately, Dermot, J.F. Kyle and D. Fischer 1977. "Strategies for OPEC's Pricing Decisions," European Economic Review, 10:209-30, December.

Gately, Dermot 1982. "Technical Detail on OPEC Modeling," Appendix A in Plummer, James (Ed.) 1982. *Energy Vulnerability*, (Ballinger: Cambridge, MA).

Gately, Dermot 1982a. "OPEC and the Buying-Power Wedge," Chapter 3 in Plummer, James (Ed.) 1982. *Energy Vulnerability*, (Ballinger: Cambridge, MA).

Gately, Dermot 2001. "How Plausible is the Consensus Projection of Oil Below $25 and Persian Gulf Oil Capacity and Output Doubling by 2020?" *The Energy Journal*, 22(4):1-27.

Gately, Dermot 2004. "OPEC's Incentives for Faster Output Growth," *The Energy Journal*, 25(2):75-96.

Gately, Dermot, and Hillard Huntington (2002). "The Asymmetric Effects of Changes in Price and Income on Energy and Oil Demand," *Energy Journal*, January 2002, 23(1): 19-55.

Greene, David L. and Paul N. Leiby, 1993. *The Social Costs to the U.S. of Monopolization of the World Oil Market, 1972-1991*, Oak Ridge National Laboratory ORNL-6744.

Greene, David L. Donald W. Jones and Paul N. Leiby 1998. "The Outlook for US oil Dependence," *Energy Policy*, Vol. 26, No. 1, pp. 55-69.

Greene, David L. and Nataliya I. Tishchishyna, 2000. *Cost of Oil Dependence: A 2000 Update*, Oak Ridge National Laboratory, ORNL/TM-2000/152, May.

Greene, David L. and Paul N. Leiby 2006. *The Oil Security Metrics Model: A Tool for Evaluating the Prospective Oil Security Benefits of DOE's Energy Efficiency and Renewable Energy R&D Programs*, Oak Ridge National Laboratory, ORNL/TM-2006/505, May.

Hamilton, James D. 2005. "Oil and the Macroeconomy," *Palgrave Dictionary of Economics*.

Hogan, William W. 1981. "Import Management and Oil Emergencies," Chapter 9 in Deese, David and Joseph Nye, eds. *Energy and Security* (Cambridge, MA: Ballinger Publishing Co.).

Huang, Bwo-Nung, M.J. Hwang, Hsiao-Ping Peng 2005. "The asymmetry of the impact of oil price shocks on economic activities: An application of the multivariate threshold model," *Energy Economics* 27(3):455– 476.

Hughes, Jonathan E., Christopher R. Knittel and Daniel Sperling 2008 (Forthcoming). "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand," *The Energy Journal*, 29(1), January 2008.

Huntington, Hillard G. 1993. "Limiting U.S. Oil Imports: Cost Estimates," *Contemporary Policy Issues*, XI:12-29, July.

Huntington, Hillard G. 2004. "Shares, gaps and the economy's response to oil disruptions," *Energy Economics*, Volume 26(3):415-424, May.

Huntington, Hillard G. 2005. "The Economic Consequences of Higher Crude Oil Prices," Final Report, EMF SR 9, Energy Modeling Forum, October 3, 2005.

Huntington, Hillard G. and Stephen P. A. Brown 2004. "Energy Security and Global Climate Change Mitigation," *Energy Policy*, 32(6):715-718, April.

Jones, Donald W., Paul N. Leiby and Inja K. Paik, 2004. "Oil Price Shocks and the Macroeconomy: What Has Been Learned Since 1996," *The Energy Journal*, 25(2)1-32.

Ketcham, B. & Komanoff, C. 1992. Win-Win Transportation: A No-Losers Approach To Financing Transport in New York City and the Region. New York: KEA (270 Lafayette #400, New York 10012.

Kline, David. 1981. "Long-Run Import Reduction and the Import Premium," in Volume 2 of *World Oil*, EMF Report 6, (Stanford University Press: Stanford CA).

Kline, David M. 1981a. "The import premium: Measuring the cost of imported oil," Stanford University; *Decision and Control including the Symposium on Adaptive Processes*, 1981 20th IEEE Conference on Dec. 1981. 20: 852-854.

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.

MacKenzie, James J., Roger C. Dower and Donald D.T. Chen 1992. *The Going Rate: What it really costs to drive*, World Resources Institute.

National Academy of Sciences 2002. *Effectiveness and Impact 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)

Nordhaus, Willam D. 1980. "The Energy Crisis and Macroeconomic Policy," *Energy Journal*, 1(1).

Parry, Ian W.H. and Joel Darmstadter 2004. "The Costs of US Oil Dependency," Resources for the Future, November 17, 2004 (also published as NCEP Technical Appendix Chapter 1: Enhancing Oil Security, the National Commission on Energy Policy 2004 *Ending the Energy Stalemate - A Bipartisan Strategy to Meet America's Energy Challenges*.)

Plummer, James L. 1981. "Methods for Measuring the Oil Import Reduction Premium and the Oil Stockpile Premium," *Energy Journal* 2(2):1-18.

Plummer, James L. (Ed.) 1982. *Energy Vulnerability*, (Cambridge MA: Ballinger Publishing Co.)

Plummer, James L., Hung-Po Chao, Dermot Gately and Richard Gilbert 1982. "Basic Concepts, Assumptions and Numerical Results," Chapter 2 in Plummer, James (Ed.) 1982. *Energy Vulnerability*, (Ballinger: Cambridge, MA).

Stern, Roger 2006. "Oil market power and United States national security," Proceedings of the National Academy of Sciences (PNAS), 103(5):1650–1655, January 31.

Stobaugh, Robert and Daniel Yergin, eds. 1979. *Energy Future* (New York: Random House Books).

Toman, Michael A. 1993. "The Economics of Energy Security: Theory, Evidence, Policy," *Handbook of Natural Resource and Energy Economics*, vol. III, edited by A.V. Kneese and J.L. Sweeney, Chapter 25. (New York: Elsevier Science Publishers B.V.).

Toman, Michael A. 2002. "International Oil Security Problems and Policies," *The Brookings Review*, 20(2):20-23, Spring.

U.S. 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.

Yücel, Mine K. 1994. "Reducing U. S. Vulnerability to Oil Supply Shocks," *Southern Economic Journal*, 61(2):302-310 (Oct., 1994).

Watkins, G.C., 1992. "The Hotelling Principle: Autobahn or Cul de Sac?" *Energy Journal* 13(1).

Watkins, G.C., 2006. "Oil scarcity: What have the past three decades revealed?" *Energy Policy* 34(5):508-514, Mar.

Wirl, Franz 1990 Do Volatile Oil Prices and Consumer Adjustment Costs Justify An Additional Petroleum Tax?," *Energy Journal*, 11(1):147-150, January.