PETROLEUM TARIFFS AS A SOURCE OF GOVERNMENT REVENUE

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EXECUTIVE SUMMARY

This report evaluates the desirability of using a tariff on crude oil and/or refined petroleum products as a source of additional government revenue. In conducting this evaluation, the costs resulting from various potential tariffs are compared to the costs that would result from sales or excise taxes on refined petroleum products that would raise the same revenue.[1] We consider tariffs of $5 per barrel on crude oil and all refined petroleum products and tariffs of $5 per barrel on crude oil and gasoline (but not on other refined products). We also consider tariffs on the same two groups of products that would yield the maximum increase in government revenue.[2]

Two measures of the costs of a tariff or a sales tax are presented in the Summary Table. First, we examine the cost to consumers per dollar increase in government revenue. The cost to consumers is the reduction in the well-being of consumers because they have to pay more for a product after

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[1] Petroleum excise taxes are considered here for comparison, not because they are expected to be superior to other tax alternatives, but rather because their costs can be estimated within the same analytical framework as that employed in estimating the costs for petroleum tariffs.

[2] Our estimate of the increase in government revenue resulting from a tariff or sales tax differs from the revenue raised by the tariff or tax because of existing taxes on gasoline. Because the tariff or tax causes a reduction in the quantity of gasoline purchased, the revenue collected from the existing taxes will decline. This partially offsets the increased revenue from the new tariff or tax.

the tariff or tax is imposed.[3] As shown in the Summary Table, the cost to consumers per dollar increase in government revenue ranges from $2.54 to $4.69 for the various tariffs we consider. With the sales tax alternatives, the consumer cost per dollar of revenue ranges from $1.05 to $1.13. Thus, the consumer cost of a tariff is as much as four times the cost of a sales tax that would raise the same amount of revenue.

The second measure of cost we consider is the net cost to society per dollar of additional government revenue raised. While the welfare of consumers decreases when a tariff or tax is imposed, other segments of society gain. For example, government revenue increases. In addition, crude oil producers and refiners may gain when a tariff is imposed. The net cost to society subtracts the gains to others from the cost to consumers to arrive at a net cost of the tariff or tax.[4] The net cost to society of a tariff would range between $0.22 and $1.05. In contrast, the net cost to society from a comparable sales tax would be between $0.05 and $0.13 per dollar of new revenue raised.[5]

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[3] In addition, there is a cost to the consumer because after the price rises, she no longer purchases as much of the product.

[4] The net cost to society may be the preferable measure to use in comparing nondistributional aspects of different proposed taxes or tariffs. Some consumers are likely to benefit from the increased government revenues either because other taxes can be reduced or because government will make additional expenditures from which they benefit. Further, at least some consumers are likely to benefit from increased oil firm profits.

[5] Since crude oil producers and refiners are unaffected by these sales taxes, the net cost to society is the amount the consumer cost exceeds the increase in government revenues. Hence, the cost imposed on consumers with a sales tax exceeds the increase in government revenue by between $0.05 and $0.13 per dollar of new revenue.

SUMMARY TABLE

Comparison of Various Petroleum Tariffs and Equivalent Sales Taxes
(Cost Per Dollar of Revenue Raised)

	Cost of a Tariff		Cost of Equivalent Sales Tax[1]	
	Cost to Consumers	Net Cost To Society	Cost to Consumers	Net Cost To Society
$5 Tariff on Crude Oil and All Refined Products	$2.54	$0.22	$1.05	$0.05
$5 Tariff on Crude Oil and Gasoline	2.95	0.51	1.12	0.12
Maximum Revenue Tariff on Crude Oil and All Refined Products	3.85	0.65	1.06	0.06
Maximum Revenue Tariff on Crude Oil and Gasoline	4.69	1.05	1.13	0.13

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[1] An equivalent sales tax is a sales tax on the refined products (but not on crude oil) listed in the left hand column, which raises the same amount of revenue as the listed tariff.

Generally, excise taxes are preferable to import tariffs because they impose less costs on both consumers and society. The consumer cost arising from a tariff or tax depends upon the degree to which product prices increase to consumers as a result of the tariff or tax. Similarly, the net cost to society depends on the distortion of prices arising from the tariff or a tax. Since the quantity of imports on which a tariff can be levied is less than the quantity of refined product on which a tax can be levied, a tariff must necessarily be of a greater magnitude than an excise tax in order to yield the same government revenue. Consequently, the consumer cost and net cost to society would be greater for a tariff than a comparable excise tax.[6]

Quite clearly, a tariff is a very inefficient way to raise government revenue.[7] In all cases--whether we are talking about a tariff on crude oil and just gasoline or a tariff on crude oil and all refined products, and whether we are talking about a tariff of $5 per barrel or that tariff which would maximize the addition to government revenue--the costs of a tariff would be several times the costs of a comparable excise tax.

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6 All estimates assume that the prices of imported crude oil and imported refined products would not change as a result of the taxes or tariffs being considered. While some change in these prices might occur, we do not believe that the likely magnitude would be great enough to significantly alter our conclusions. [See Appendix, Section VIII.]

7 To reach a broader conclusion about the desirability of a tax on refined petroleum products, it would be necessary to evaluate other ways of raising revenue. We have not done this, nor have we evaluated the desirability of increasing government revenue at all. Thus, our conclusions must be limited to a comparative statement about the relative desirability of petroleum tariffs versus sales taxes on refined products. In this report, we do not consider the desirability of tariffs or taxes as a policy instrument to achieve other conceivable policy objectives, such as reducing environmental pollution or increasing energy security.

I. Introduction

In the search for ways to reduce the federal budget deficit, the imposition of a tariff on imported petroleum is increasingly cited as a potential source of increased revenue. The *Washington Post* has observed, "As the Government's need for tax revenues grows more urgent, the idea of an oil import fee is (once again) turning up here and there."[1] Other press articles have cited petroleum tariffs as options being considered now that tax increases have been accepted by the Bush administration as necessary for federal deficit reduction.[2] At least one member of Congress has been quoted as supporting a tariff because, among other objectives, it would raise revenue to reduce the deficit.[3] A former Director of the Congressional Budget Office has

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[1] "An Oil Import Fee?" *The Washington Post*, January 3, 1989, p. A-16.

[2] "Hot Question in Washington: Have You Read Bush's Lips on Taxes LATELY?" *The Wall Street Journal*, May 9, 1990, p. 2; "Eating His Words." *Time*, July 9, 1990, p. 16.

[3] Patrick Crow, "No major gains, losses seen for oil industry with Bush as President," *Oil and Gas Journal*, December 26, 1988, p. 22. Another example of support for a tariff as a way to, among other things, raise revenue can be found in George P. Mitchell, "It's Time to Put a Tax on Imported Oil," *New York Times*, January 22, 1989, p. F2. Supporters of a tariff almost always cite other benefits of an oil tariff, such as reduced dependence on foreign oil, in addition to increased revenue, as reasons for imposing such a tariff. For a discussion of the disadvantages of a tariff in achieving energy security objectives, see Anderson and Metzger (1987).

suggested that an oil import tariff might be part of a deficit reduction plan.[4]

The purpose of the present paper is to explore the desirability of using an oil import tariff to reduce the federal deficit. If structured correctly, a tariff on petroleum imports could, as proponents note, raise some revenue to reduce the deficit. However, this does not establish that a tariff is a desirable source of revenue. Imposing tariffs will cause the prices paid by consumers of petroleum products to rise.[5] This would make consumers worse off. Further, while a tariff would result in increased government revenues and in increased profits for (at least some) producers in the oil industry, the cost to consumers will generally be greater than the benefits to others. As a result, the U.S. economy as a whole will be made worse off if a tariff is imposed.

Other methods of raising government revenue also impose costs on the economy. If a sales or excise tax were imposed on one or more products, the cost of those products would rise and make consumers of those products worse off. Further, just as with tariffs, the losses to consumers would generally be greater than the increases in government revenue. That is, an excise tax imposes costs on the economy, just as does a tariff.[6]

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[4] Rivlin (1989). However, Rivlin appears to see the tariff more as a way to overcome petroleum industry objections to a gasoline tax than as a source of revenue.

[5] Strictly speaking, a tariff levied on just crude oil imports might not cause the prices of refined petroleum products to rise if imports of refined products were not also restricted. However, as we will discuss below, a tariff on crude oil alone would, at most, raise negligible amounts of revenue.

[6] Browning and Browning (1979), pp. 288-292. Most other methods the government could use to raise additional revenue would also impose costs on the economy.

In order to determine the desirability, or lack thereof, of a particular revenue-raising technique, it is necessary to compare the costs to consumers and to the U.S. economy of that revenue source with the costs of alternatives. A revenue raising method is relatively desirable if the costs resulting from its use are small. In the current paper, we compare the costs from the imposition of petroleum tariffs with the costs from new excise taxes on refined petroleum products that would raise comparable levels of government revenue.[7] We show that the costs resulting from tariffs would be substantially greater than those from comparable sales or excise taxes. Since we do not consider other alternative revenue sources nor address the need for additional federal revenues, we cannot conclude that it is desirable to impose excise taxes on refined petroleum products.[8] However, we do demonstrate that a tariff is a

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[7] In arguing against using increased gasoline taxes as a way to reduce the federal deficit, representatives of the American Petroleum Institute have argued that net government revenues would only increase by about one-third of the revenue raised by the sales tax. [See, *e.g.*, "API plumps for government action to shore up U.S. energy posture," *Oil and Gas Journal*, November 21, 1988, pp. 16-17; and "API: U.S. economic growth threatened by gasoline tax hike," *Oil and Gas Journal*, January 2, 1989, p. 27. See also, DRI/McGraw-Hill (1989b).] The crux of their argument appears to be that the increase in the price of gasoline resulting from a tax increase would increase inflation and cause sufficient disruption in the economy that it would reduce revenue from other taxes and require increased government outlays equal to about two-thirds of the revenue raised by the tax. Without evaluating the validity of this argument, we note that, in order to raise a specific level of revenue, prices would rise more with a tariff than with a sales tax (see, *e.g.*, pp. 15-16, below) and that therefore any dislocations would be greater with a tariff than with a tax.

[8] We note that, using a somewhat different criteria of desirability, a recent analysis by DRI concluded that either expenditure cuts or a broad-based value added tax would be

relatively costly, and therefore undesirable, way to raise additional government revenue in the event it is judged desirable to raise such revenue.[9]

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preferable to a gasoline tax as a way of reducing the deficit. [DRI/McGraw-Hill (1989a).]

[9] In this report, we demonstrate only that, if one wishes to raise additional government revenues, tariffs on petroleum imports impose more costs on consumers and society than do comparable excise taxes. We do not consider the desirability of either tariffs or taxes as a policy instrument to achieve other conceivable policy objectives, such as reducing environmental pollution or increasing energy security. We note, however, that the most efficient way to reduce pollution resulting from consumption of fossil fuels is likely to be a direct tax on the emissions resulting from burning the fuels, rather than either a tariff or a tax on fuel consumption. Further, in our earlier work, we showed that adding to the strategic petroleum reserve appeared to be less costly than a tariff if one wished to increase energy security. [See Anderson and Metzger (1987).]

II. The Model and Assumptions Used in Measuring the Effects of Tariffs and Taxes

In measuring the effects of tariffs or taxes on the petroleum industry, we have used a comparative statics model of a competitive petroleum industry, which is similar to the model used in our earlier work.[10] The refining sector of the petroleum industry is modelled along with the crude production sector so that we can separately estimate the effects on these two groups of firms. In addition, the demand for refined petroleum products is divided into two groups: gasoline and all other refined products. This allows us to differentiate between the effects on consumers of gasoline and on consumers of other products. It also permits us to consider tariffs and taxes on gasoline alone as well as tariffs and taxes on all refined products.[11]

While our analysis deals with only a single price and quantity for each good, rather than a series of prices and quantities representing market conditions at different points in time, we have attempted to measure the effects of the various taxes and tariffs so as to be generally representative of the effects that would be observed in this country in the 1990's. Specifically, changes are measured from the average prices and quantities for the various products that are

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[10] Anderson and Metzger (1987).

[11] As in many studies of this type, we adopt the simplifying assumption that a change in U.S. demand for imports of crude oil or refined petroleum products would not affect the world price of those goods. As we discuss in Section D of Chapter IV and in greater detail in Section VIII of the Appendix, we do not believe that this assumption significantly affects the results we present here.

expected in the U.S. during the 1990's.[12] Furthermore, in measuring the effects of price changes, we attempt to estimate the change that would occur in the fifth year after a price increase first appeared.[13] Consequently, our results can be viewed as broadly representative of the effects that would result in the average year of the current decade if a tariff or tax were imposed in 1990.

Our analysis focuses on four different tariff scenarios and comparable sales taxes. In two of these scenarios, we assume that a tariff would be imposed on crude oil and on all refined products. In the other two, we assume a tariff on only gasoline and crude oil. The tax to which each tariff is compared is a sales tax on the refined products covered by the comparable tariff--either all refined products or gasoline alone. Within each pair of scenarios, one involves a tariff of $5 per barrel--approximately 12 cents per gallon--on imports of crude oil and the refined products subject to a tariff. In the other scenario, we focus on that tariff which would raise the most government revenue.[14]

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[12] These are simple averages of the prices and quantities projected by the U.S. Department of Energy as the most likely values for each year in the period 1990 to 1999. [U.S. Department of Energy (1989a), Appendix A.] For more detail on the values used, see Section III of the Appendix. In light of recent petroleum price increases due to escalating MidEast tensions, it is interesting to note that the conclusions of this study are generally strengthened if a baseline with higher initial prices is assumed. [See Appendix, Section VIII.]

[13] For a discussion of how these changes were estimated, see Section IV of the Appendix.

[14] In searching for the maximum revenue tariff, we restricted ourselves to tariffs of the same magnitude on crude and all included products. That is, if the tariff were $8 per barrel on crude oil, the tariff would also be $8 per barrel on gasoline and $8 per barrel on other products (if other refined products are included under the scenario in

We examine tariffs on crude oil and gasoline, in addition to tariffs on crude oil and all refined products, because it may not be feasible politically to impose tariffs or additional taxes on important nongasoline refined products. For example, historically consumers of heating oil have been successful in obtaining special relief from import restrictions and other regulations in order to limit increases in heating oil prices.[15] Similar special treatment designed to limit price increases has been granted to importers of residual fuel oil. We have no way of knowing whether any new tariff would or would not include nongasoline products.[16] Therefore, we

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question). However, as discussed below, if the U.S. becomes self-sufficient in one or more products before the price rises by the full amount of the tariff, the price increases may differ from product to product.

[15] Dam (1971), pp. 19, 38-39; and Kalt (1981), p. 17.

[16] The special treatment of heating oil and residual fuel oil may have been the result of the importance of these fuels to particular groups of consumers. While these fuels remain important to these groups, their importance may have declined somewhat in recent years. For example, historically, heating oil has been the major source of energy for home heating in the New England states. Between 1960 and 1975, distillate fuel oil (which includes diesel fuels and some oils used in electric power generation in addition to home heating oil) accounted for more than 60 percent of total BTUs of energy consumed in a group of six northeastern states--Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. However, by 1985, distillate accounted for only 45 percent of the BTUs consumed in these same states. [U.S. Department of Energy (1987b).]

Similarly, heavy oils, such as residual, have been an important source of energy for electricity generation in these states. In 1970, heavy oils constituted more than two-thirds of the BTUs used in electric generation in the same group of six states. By 1985, this proportion had fallen to one-third. [U.S. Department of Energy (1987b).]

have chosen to present results both with and without tariffs on refined products other than gasoline.

We restrict our attention to tariffs covering both crude oil and, at least some, refined products, because tariffs on only crude oil or only refined products would not raise significant amounts of revenue. For example, since even small increases in the price refiners pay for imported crude oil would make it unprofitable for domestic refiners to process imported crude oil, it would become more economical to import refined products.[17] Similarly, a small increase in the price of imported gasoline or other refined products would make it more economical to import additional crude oil and to produce all refined products in this country.[18] For example, we estimate that all imports of crude oil would be eliminated if a tariff of about $0.40 per barrel was imposed on crude oil alone. Similarly, all imports of refined products would be eliminated by any tariff on gasoline and other refined products (but not on crude oil) that exceeded $0.20 per barrel--about 0.6 cents per gallon.[19]

Several other studies have examined questions similar to those considered here.[20] However, none has modelled the

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[17] If the tariff does not cover partially refined products, such as unfinished oil or motor gasoline blending stocks, then imports of these products may soar with domestic refineries processing the intermediate products into finished product.

[18] In technical economic terms, refiners' demand for crude oil and supply of refined products are highly elastic in terms of both the price of their input (crude oil) and in terms of their outputs (refined products).

[19] See Section VII of the Appendix, for further details on these estimates.

[20] See, e.g., Boyd and Uri (1989), Congressional Budget Office (1986), Melo, Stanton and Tarr (1988), Uri and Boyd (1989), and U.S. Department of Energy (1986).

petroleum industry in as much detail as is done in this study. For example, none of the prior studies has separated refining from crude oil extraction. Failure to analyze these two industries separately can lead to misleading conclusions about the effects of tariffs on crude oil alone. In addition, at least some of the prior studies have aggregated natural gas and crude oil in their analyses, which can again lead to incorrect conclusions about the effects of tariffs and taxes. Finally, our study uses data for the 1990's, a time period that is more relevant for future policymaking than the earlier periods used in the other studies.[21]

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[21] For a more complete discussion of the earlier studies, see Section IX of the Appendix.

III. The Estimated Costs of Tariffs and Taxes: The Concepts Involved

A. Changes in the Prices of Crude Oil and Refined Products

Our estimates of the effects of the four tariffs and comparable taxes are reported in Tables 1 through 4. Much of the same data is presented graphically in Figures 1 through 4.[22] The first section of each table reports the change in the prices of crude oil and refined products that would occur if a particular tariff or tax was imposed. In most cases, the price increase will be equal to the amount of the tax or tariff imposed. For example, looking at Table 1, a tax of $1.95 per barrel on all refined products would raise the same amount of revenue as a $5 tariff on crude oil and all refined products. If such a tax were imposed, the price of all refined products would rise by $1.95 per barrel. Similarly, Table 1 shows that if a $5 per barrel tariff were imposed on crude oil and on all refined products, the prices of crude oil and refined products other than gasoline would rise by $5 per barrel. This occurs because the price of imports determines the domestic price both before and after the tariff or tax is imposed; and the price consumers must pay for imports increases by the amount of the tariff or tax.

In some cases, the price rise that results from the imposition of a tariff may result in the elimination of imports of that product. This would occur where the price rise causes a sufficient increase in domestic production of the protected product together with a sufficient decline in the quantity consumers purchase to cause domestic supply to

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[22] Additional detail on these estimates and on the model and assumptions that underlie them is found in Sections II through VIII of the Appendix. In addition, comparisons of our results with those of other researchers who have investigated similar tariffs and taxes is found in Section IX of the Appendix.

satisfy total demand. When this occurs, price would be determined by domestic demand and supply; and the price increase resulting from the tariff would be less than the amount of the tariff.[23] For example, Table 1 shows the price of gasoline rising by only $4.55 per barrel when a tariff of $5 per barrel is imposed. Once the price of gasoline rises by $4.55, domestic refiners produce enough gasoline to meet all consumer demand.[24]

B. Changes in Government Revenues

The second section of each table provides estimates of the effects on government revenues of a tariff or tax. There are two elements included in this change. First, we provide an estimate of the revenue that would be raised by the new sales tax or by the tariff. In the case of a tax, this figure is equal to the quantity of the product that would be

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[23] It is also possible that the increase in consumer price resulting from the imposition of a sales tax would cause demand to decline by enough to eliminate all imports. In such a case, which does not arise in any of the cases we consider in this paper, the price rise would be less than the amount of the tax.

[24] This is only true in conjunction with the other price changes imposed in Table 1--specifically, when the price of crude oil and of other refined products rises by $5 per barrel. If the price of crude oil did not rise, gasoline imports would, as noted before, disappear with a much lower increase in gasoline price. If the price of other refined products did not rise, the increase in the quantity of gasoline produced by domestic refiners would be smaller and it would take a greater increase in the price of gasoline before domestic supply was equated to demand. This occurs because we have assumed that the ratio of gasoline to other refined products produced by refineries is fixed. As a result, the quantity of refined product that refineries choose to produce is a function of the weighted average of the prices for which they can sell the various products they produce.

consumed after the tax was imposed multiplied by the tax rate. In the case of the tariff, it is equal to the product of the amount of the tariff and the quantity of imports after the tariff was imposed.

Secondly, government revenue from existing gasoline taxes would be reduced, partially offsetting the revenue raised by the new taxes or tariffs. Existing federal and state sales taxes on gasoline amount to an average of $10 per barrel.[25] If a new tariff or tax was imposed on gasoline, consumers would respond to the price increase by reducing the quantity of gasoline they purchase. This change in quantity multiplied by the $10 per barrel existing tax rate is the decline in revenues from existing gasoline taxes reported as the second element of the revenue figures in the tables.

C. Changes in Consumer Welfare

The next several entries on the tables report on the effect of a tariff or tax on the welfare of users and producers of petroleum products and crude oil. First, we report the effect on consumers. The cost to consumers of gasoline is reported separately from the cost to consumers of other petroleum products in the tables.[26] In the figures, only the total effect is presented. In addition, in the figures

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[25] Current tax rates on motor gasoline levied by the federal government--9.1 cents per gallon--and by the various states are reported in U.S. Department of Energy (1988c), p. 365. The average value was computed by multiplying the various state taxes by the quantities of gasoline sold in those states. Where a state tax was expressed in percentage terms, rather than in cents per gallon, we assumed the price of gasoline to be $1 per gallon.

[26] If a tariff or tax is imposed only on gasoline and not on other refined products, there is no effect on consumers of these other products in any of the cases we consider in this study. Therefore, no effect is reported in the relevant table.

we have adopted the convention of presenting costs, *e.g.*, costs to consumers, as negative values.

Consumers are made worse off anytime the price of a commodity they purchase rises. (Conversely, they are made better off when a price falls.) When a price rises, consumers have to pay more for each unit of a good that they continue to purchase; and this increased payment for, say, gasoline means that they have less income with which to purchase other goods and services. In addition, there is some quantity of gasoline that consumers found worthwhile to purchase at the old price but not at the new higher price. Therefore, consumer well-being is also reduced by the value consumers place on these units of output less the price that they had to pay for them before the tariff or tax was imposed. The sum of these two elements is reported as the cost to consumers.[27]

D. Changes in Producer Profits

The next two entries represent the gains--increase in profits--to different groups of firms involved in the production of petroleum products. The first entry is the increased profits of crude oil producers. If a tariff is imposed on imported crude oil, the price refiners must pay for imported oil would rise. The price received by domestic producers of crude oil would rise as well, since the price of domestic crude oil is constrained by the price of imports.[28] This increase in revenue, reduced by the amount of any

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[27] Additional detail on the computation of the costs or benefits to the various groups, including a graphical presentation, is found in Section VI of the Appendix.

[28] The same is true of producers of natural gas plant liquids and other petroleum products that can be used as substitutes for crude oil in the refinery process. When the price of crude oil rises, the value of these other products rises. We expect that this will lead to an increase in the prices of these products.

increase in costs because domestic producers choose to produce more crude at the new higher price, represents increased profits of the crude producers.[29]

In the same way, refiners gain if a tariff causes the price they receive for their products to rise. However, the case of refiners is more complicated since the price of the crude oil they must purchase to run their refineries may also be increased by a tariff. The net effect for a refiner is the increase in revenue from higher prices on his output minus the increased cost caused by the higher price on his crude oil input. Because of this, refiners can either gain or lose from a tariff depending on whether the increase in revenue is greater or less than the increase in cost.

When a sales tax rather than a tariff is imposed, there is no gain to either crude producers or to refiners. Sales taxes apply equally to products produced by domestic and foreign firms. While a tax does result in an increase in the price paid by consumers, all of the price increase accrues to the government with the result that the producer receives the same price as before the tax was imposed.[30]

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[29] Some percentage of this increase is likely to find its way back to the owners of the land under which the oil is located.

[30] If a sales tax affected the price refiners receive for their products, there would be reductions in their producer surplus. As noted previously, this would occur if the tax led to the elimination of all imports. However, this does not occur in the cases examined in this study. A sales tax would also affect domestic refined product prices if world prices varied with the level of U.S. demand for imports. This possibility is discussed in Section VIII of the Appendix.

E. Net Social Cost or Cost to the U.S. Economy

The net social cost, or cost to the U.S. economy, resulting from the imposition of a tariff or a tax is the amount by which the loss to those made worse off by the policy action outweighs the gains to those made better off. For example, in the context of a sales tax on gasoline, the cost to the U.S. economy would be equal to the cost borne by consumers less the increase in government revenue from the imposition of the tax. In the case of a tariff, the net social cost would be the difference between the losses to consumers and the sum of the gains to crude oil producers, refiners, and the increase in government revenue.[31,32]

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[31] Because the members of society who benefit from increased producer profits or from increased government revenue are likely to be some of the same individuals who suffer from increased product prices, the net social cost measure may provide the best measure for comparing nondistributional aspects of proposed policy actions.

[32] In addition, some analysts have considered other possible effects of a tariff or tax. For example, exchange rates may change when U.S. demand for imported crude oil and refined products change. It has also been argued that tariff and tax increases can affect the amount of work people are willing to do, because such increases reduce the real wage earned by working an additional hour. [See, e.g., Rousslang (1989).] While we do not include these measures in our analysis, we believe that consideration of them would not alter our conclusion that a tariff is a more costly source of revenue than an excise or sales tax. In the Appendix we demonstrate that exchange rate changes are not likely to reverse our conclusions. [See Section IX.] As to the distortionary effects in the labor market, we note that a tariff involves a greater distortion in the price of petroleum products than does a sales tax. As a result, the distortion in the labor market will be greater with the tariff than with the tax alternative.

IV. The Estimated Costs of Tariffs and Taxes: Specific Tariffs

In this section of the paper, we present the results of our analyses of various tariffs and of the sales taxes that would generate the same additions to government revenue. In all cases we will see that the costs of a tariff are greater than the costs of a comparable tax. This occurs because prices of refined products must rise more to achieve a particular increase in revenue when a tariff is used than when the revenue is raised with a tax.[33] Whether a tariff or a tax is used, the price rises on all purchases of the refined products covered.[34] Therefore, because the price increase is greater in the case of a tariff, the cost to consumers is greater with a tariff than under a tax. Similarly, although crude producers and perhaps refiners gain under the tariff options,

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[33] This occurs because the government collects tariffs only on imports of crude oil plus imports of the refined products covered by the tariff, while a tax is collected on all consumption of the covered refined products. In none of the cases we consider do imports of crude oil and refined products covered by the tariff, after the imposition of a tariff, constitute as much as one-quarter of total consumption of these products. As a result, even though the sales tax option covers only refined products, the base on which the tax would be levied is always more than twice as large as the base on which the comparable tariff would be levied.

[34] In the case of a tariff, the price of the domestic product rises because the domestic product performs the same function as imports. As a result, when the imposition of a tariff forces the price of imports to rise, consumers of the good will attempt to buy more of the lower-priced domestic good. This will cause the price of the domestic good to rise. The process will continue until the price of the domestic good is again equal to the price of the imported product.

the cost to society is greater with the tariff than with the tax.

A. A $5 Tariff on Crude Oil and All Refined Products

Table 1 and Figure 1 report the results of our analysis of a $5 per barrel tariff on crude oil and on all refined products. As noted previously, while the price of crude oil and of refined products other than gasoline would rise by the full amount of the tariff, the U.S. would become self sufficient in gasoline, and the price of gasoline would rise by only $4.55 per barrel.[35] Net revenue raised by these tariffs would amount to $12.0 billion per year--the tariffs would raise $13.1 billion, but this would be offset by a $1.1 billion reduction in revenues from existing gasoline taxes.[36] Consumers would be made worse off by $30.5 billion per year, with gasoline consumers suffering a loss of $11.8 billion. Thus, consumers would suffer losses of $2.54 for each dollar increase in government revenue.

Crude oil producers would benefit from the tariff. In this case their gain would come to $15.8 billion per year. Refiners would gain a little--$100 million per year. Taking the difference between the losses to consumers and the gains to other parts of the economy, we see that the net cost to society resulting from this tariff would come to $2.7 billion per year, or $0.22 per dollar of revenue raised.

If a sales tax were imposed rather than a $5 tariff on crude oil and refined products, the tax would have to be $1.95 per barrel of refined product to raise the same $12.0 billion. Because of the smaller price increase, the cost to consumers would be considerably lower, only $12.6 billion per

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[35] The values of tariffs, taxes, and price increases are reported to the nearest $0.05 per barrel throughout this report.

[36] Individual figures may not sum to reported totals due to independent rounding.

TABLE 1

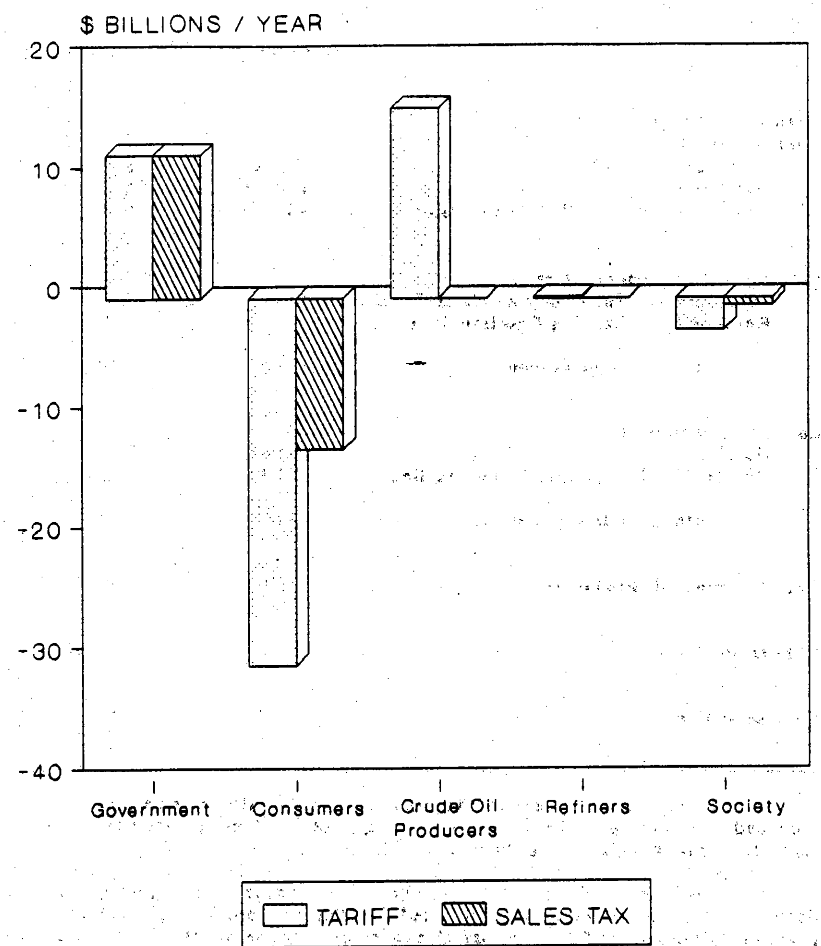
Comparison of Annual Costs and Benefits of a $5 Tariff on Crude Oil and All Refined Petroleum Products And a Sales Tax on Refined Product That Will Raise the Same Revenue
(Billions of 1986 Dollars, Unless Otherwise Noted)[1]

	$5 Tariff	Sales Tax of $1.95
Change in Price of (Dollars Per Barrel)		
Crude Oil	+$5.00	$0.00
Gasoline	+$4.55[2]	+$1.95
Refined Products, Other Than Gasoline	+$5.00	+$1.95
Changes in Government Revenue		
Revenue from Tariff or New Sales Taxes	+$13.1	+$12.5
Revenue from Existing Gasoline Taxes	-1.1	-0.5
Net Change in Revenue	**+12.0**	**+12.0**
Cost to Consumers of		
Gasoline	11.8	5.1
Refined Products, Other Than Gasoline	18.7	7.5
Total Cost to Consumers	**30.5**	**12.6**
Gain to Crude Oil Producers	**15.8**	**0.0**
Gain to Refiners	**0.1**	**0.0**
Net Social Cost	**2.7**	**0.6**

[1] Totals may not equal the sum of individual elements due to independent rounding. The values of tariffs, taxes, and price increases are reported to the nearest $.05 per barrel.

[2] While a tariff of $5.00 per barrel is imposed on gasoline, all domestic demand for gasoline is satisfied by domestic production once the price of gasoline rises $4.55 per barrel above the baseline value. Therefore, the price does not increase by more than this amount.

FIGURE I
$5 Tariff on Crude Oil and Refined Product: Comparison of Tariff and Equivalent Sales Tax



year, or about $1.05 per dollar of revenue raised. Further, the cost to society would be only about $600 million per year, or 5 cents per dollar of revenue raised. Therefore, in this case a sales tax imposes only about 40 percent of the consumer cost and only one-quarter of the cost on the economy of a tariff.

B. A $5 Tariff on Gasoline and Crude Oil

In the above analysis, we assumed that a tariff or tax was imposed on all refined petroleum products. However, as we discussed previously, imposing additional taxes on nongasoline refined products may be politically infeasible. Therefore, Table 2 and Figure 2 consider the effects of a $5 per barrel tariff on only gasoline plus crude oil and the comparable sales tax on gasoline.

If a tariff is imposed only on part of the refiner's output, it becomes unprofitable to refine as much crude oil domestically.[37] As a result, crude oil demand would fall, and imports would disappear with a price increase for crude oil of only about $2.60 per barrel, while the price of gasoline would rise the full $5.00. With a $5 tariff on crude oil and gasoline, revenues would rise by only $4.4 billion per year--$5.6 billion would be raised from the new tariff, but $1.3 billion in revenue from existing gasoline taxes would be lost as the quantity of gasoline consumed declines. The increased cost to gasoline consumers, which results from the higher price of gasoline, would come to $12.9 billion per year, or about $2.95 per dollar of revenue raised.

Since the price of crude oil would only rise by $2.60 in this scenario, the gain to producers of crude oil would be smaller--only $8.1 billion per year. Further, because not all

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[37] This is true provided the tariff on gasoline is equal to the tariff on crude. With a large enough tariff on gasoline, refiners could gain as much or more in terms of increased revenue as they lose as a result of the increased cost of crude oil.

TABLE 2

Comparison of Annual Costs and Benefits of a $5 Tariff on Crude Oil and Gasoline and a Sales Tax on Gasoline That Will Raise the Same Revenue
(Billions of 1986 Dollars, Unless Otherwise Noted)[1]

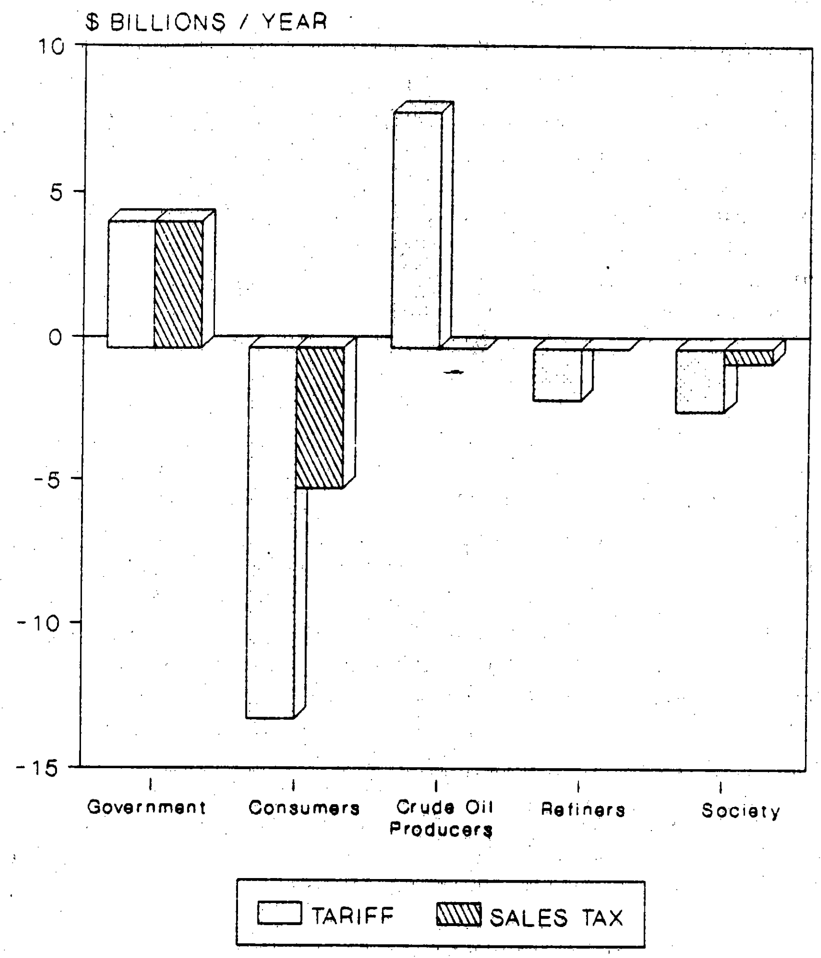
	$5 Tariff	Sales Tax of $1.85
Change in Price of (Dollars Per Barrel)		
Crude Oil	+$2.60[2]	$0.00
Gasoline	+$5.00	+$1.85
Changes in Government Revenue		
Revenue from Tariff or New Sales Taxes	+5.6	+4.8
Revenue from Existing Gasoline Taxes	-1.3	-0.5
Net Change in Revenue	+4.4	+4.4
Cost to Consumers of Gasoline	12.9	4.9
Gain to Crude Oil Producers	8.1	0.0
Gain to Refiners	-1.8	0.0
Net Social Cost	2.2	0.5

---

1 Totals may not equal the sum of individual elements due to independent rounding. The values of tariffs, taxes, and price increases are reported to the nearest $.05 per barrel.

2 When a $5 per barrel tariff is imposed on crude oil and on gasoline, domestic refiners' demand for crude oil is satisfied by domestically produced crude oil once the price rises by $2.60 per barrel. As a result, the price of crude oil increases by only that amount.

FIGURE II
$5 Tariff on Crude Oil and Gasoline: Comparison of Tariff and Equivalent Sales Tax



of the refiner's output would be covered by tariffs, refiners would suffer a loss of $1.8 billion per year. Net social cost would come to $2.2 billion per year, or 51 cents for every dollar of revenue raised.

In order to raise the same $4.4 billion increase in revenue, gasoline taxes would have to be raised by $1.85 per barrel. Such an increase would cost consumers $4.9 billion per year, or $1.12 per dollar of revenue raised. Net social cost would be $500 million per year, or about $0.12 per dollar of revenue. A tax on gasoline would impose social costs only about 23 percent as great as those imposed by a tariff on gasoline and crude oil. In terms of consumer costs, the cost of the tax would be about 38 percent of the cost of the tariff.

C. Maximum Revenue Tariffs

In Table 3 and Figure 3, we see that the maximum revenue from a tariff on imports of crude oil and all refined products occurs when the tariff is set equal to $12.20 per barrel, though the price of gasoline would rise only $10.95 per barrel. This tariff would generate a net increase in government revenue of $18.4 billion per year, but would cost consumers $70.9 billion, or $3.85 for each dollar of new revenue raised. The net social cost of this tariff would be $12.0 billion per year, or about $0.65 per dollar of revenue. In contrast, the comparable tax on refined products--a tax of $3.05 per barrel--would only cost consumers $19.6 billion per year and the net social cost would be only $1.1 billion. Thus the net social cost per dollar of revenue raised would only be about $0.06.

Table 4 shows that if a tariff were imposed only on crude oil and gasoline, revenue would be maximized if the tariff was set equal to $15.10. As with the smaller gasoline/crude oil tariff, crude oil imports would be eliminated. With a tariff of $15.10, the price of crude would rise by only $7.05 before this occurred. Net revenue raised by this tariff would come to $7.9 billion per year, but this revenue would be

TABLE 3

Comparison of Annual Costs and Benefits of a Revenue Maximizing Tariff on Crude Oil and All Refined Petroleum Products and a Sales Tax on Refined Product That Will Raise the Same Revenue
(Billions of 1986 Dollars, Unless Otherwise Noted)[1]

	Tariff of $12.20	Sales Tax of $3.05
Change in Price of (Dollars Per Barrel)		
Crude Oil	+$12.20	$0.00
Gasoline	+$10.95[2]	+$3.05
Refined Products, Other Than Gasoline	+$12.20	+$3.05
Changes in Government Revenue		
Revenue from Tariff or New Sales Taxes	+21.2	+19.2
Revenue from Existing Gasoline Taxes	-2.7	-0.8
Net Change in Revenue	**+18.4**	**+18.4**
Cost to Consumers of		
Gasoline	27.6	8.0
Refined Products, Other Than Gasoline	43.3	11.6
Total Cost to Consumers	**70.9**	**19.6**
Gain to Crude Oil Producers	**40.7**	**0.0**
Gain to Refiners	**-0.3**	**0.0**
Net Social Cost	**12.0**	**1.1**

[1] Totals may not equal the sum of individual elements due to independent rounding. The values of tariffs, taxes, and price increases are reported to the nearest $.05 per barrel.

[2] While a tariff of $12.20 per barrel is imposed on gasoline as on all imported refined products, domestic demand for gasoline is satisfied by domestic production at a price of gasoline that is $10.95 per barrel above the baseline value. Therefore, the price does not rise by more than this amount.

FIGURE III
Revenue-Maximizing Tariff on Crude Oil and Refined Product:
Comparison of Tariff and Equivalent Sales Tax

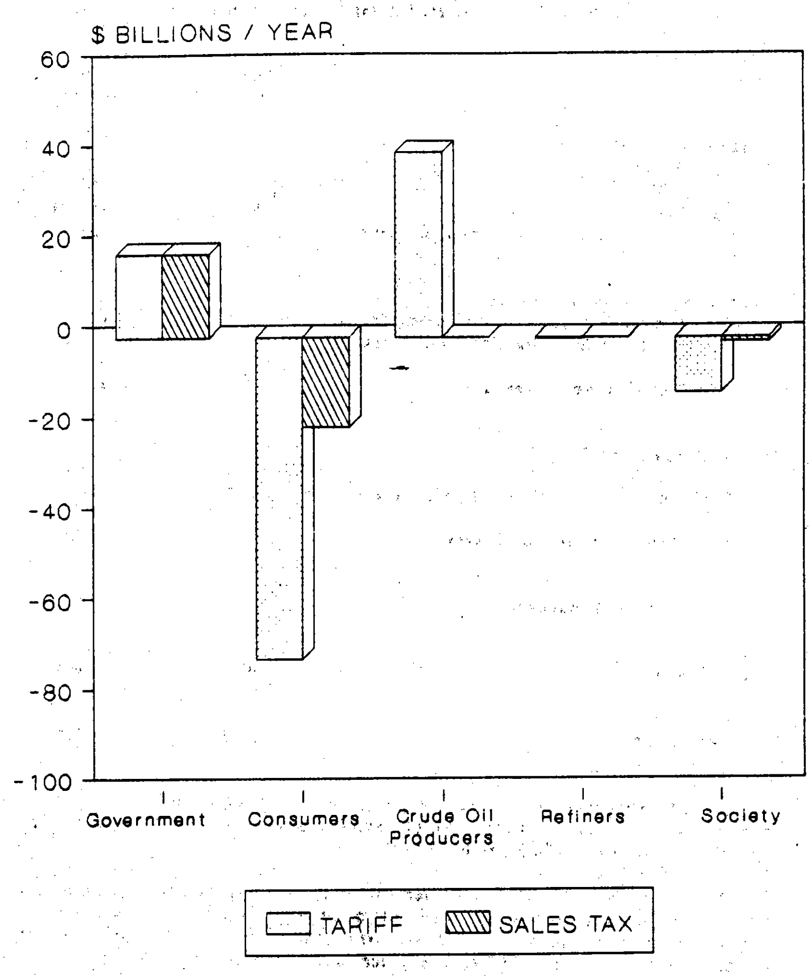


TABLE 4

Comparison of Annual Costs and Benefits of a Revenue Maximizing Tariff on Crude Oil and Gasoline and a Sales Tax on Gasoline That Will Raise the Same Revenue
(Billions of 1986 Dollars, Unless Otherwise Noted)[1]

	Tariff of $15.10	Sales Tax of $3.45
Change in Price of (Dollars Per Barrel)		
Crude Oil	+$7.05[2]	$0.00
Gasoline	+$15.10	+$3.45
Changes in Government Revenue		
Revenue from Tariff or New Sales Taxes	+11.7	+8.8
Revenue from Existing Gasoline Taxes	-3.8	-0.9
Net Change in Revenue	+7.9	+7.9
Cost to Consumers of Gasoline	37.2	8.9
Gain to Crude Oil Producers	22.6	0.0
Gain to Refiners	-1.7	0.0
Net Social Cost	8.3	1.0

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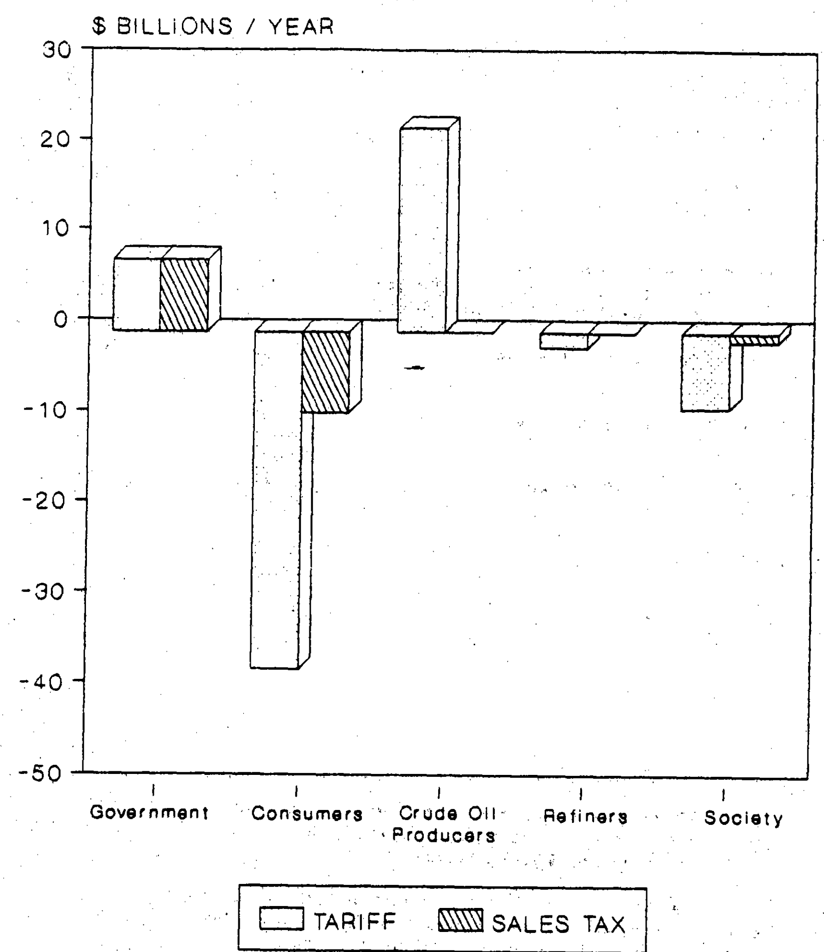
[1] Totals may not equal the sum of individual elements due to independent rounding. The values of tariffs, taxes, and price increases are reported to the nearest $.05 per barrel.

[2] A tariff of $15.10 per barrel is imposed on crude oil and on gasoline. However, domestic refiners' demand for crude oil is satisfied by domestically produced crude oil once the price rises by $7.05 per barrel. As a result, the price of crude oil increases by only that amount.

FIGURE IV
Revenue-Maximizing Tariff on Crude Oil and Gasoline: Comparison of Tariff and Equivalent Sales Tax



earned at a cost to consumers of $37.2 billion per year, or $4.69 per dollar of revenue raised. The net social cost of this tariff would amount to $8.3 billion, or more than $1 per dollar of revenue raised. By comparison, a sales tax of $3.45 per barrel would raise the same revenue but do so at a fraction of the cost: Cost to consumers would be $8.9 billion per year, or $1.13 per dollar of revenue raised, while net social cost would be $1.0 billion per year, or $0.13 per dollar of revenue.

Thus, as with the $5 tariffs, we find that maximum revenue tariffs impose greater costs than equivalent taxes on refined products. In terms of consumer cost, the cost of either tariff is about four times the cost of the tax. In terms of net social cost, the ratio is more than eight to one.

D. World Petroleum Price Changes

Our estimates of the costs of tariffs and taxes have been made under the assumption that world petroleum prices would not fall appreciably in response to a reduction in U.S. demand for imported oil. Such a reduction in U.S. demand would result from the increased prices that consumers would have to pay if tariffs or taxes were imposed. This assumption was made because there is little reliable information available on which to base an assumption about how prices might change. We recognize, however, that if the change in the price of imported crude oil were great enough, this could change the results of this study. With a large change in import price, a tariff could be less costly than an equal-revenue excise tax.

In the Appendix, we examine the likely change in the world crude oil price that would result from a change in U.S. petroleum demand.[38] Based on analysis developed there, we conclude that any change in the world crude oil price resulting from any of the tax or tariff alternatives considered in this study will be sufficiently small that the

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[38] See Appendix, Section VIII.

overall cost of any tariff will be greater than the cost of an equal-revenue excise tax.

V. Conclusion: Tariffs Are An Inefficient Way to Raise Government Revenue

In this paper we have compared the tariffs on crude oil and refined petroleum products with sales taxes in terms of their efficiency in raising additional government revenue. We have not considered tariffs on just crude oil or just one or more refined products because such tariffs would not raise significant government revenues. In our four scenarios, we have consistently found that sales taxes are more efficient than tariffs, both in terms of the costs borne by consumers and the net costs imposed on the U.S. economy as a whole. The four tariff scenarios we have considered impose costs on consumers of between $2.54 and $4.69 per dollar of additional government revenue raised. In contrast, the four comparable sales tax scenarios impose consumer costs of only between $1.05 and $1.13 per dollar of revenue. The net social cost per dollar of revenue ranges between $0.22 and $1.05 for the four tariff scenarios, while the net social cost is only $0.05 to $0.13 per dollar of revenue if a sales tax is used.

These figures make it clear that a tariff is not an efficient way to raise additional government revenues. It would be much cheaper, both in terms of the costs to consumers and in terms of the costs to the U.S. economy, to impose additional taxes on refined petroleum products. This does not mean, however, that such additional taxes would be appropriate. There are other alternatives that could be employed to raise additional government revenue, and some of these may be less costly than a sales tax on refined petroleum products. Further, we have not determined whether it is, in fact, desirable to increase government revenues. Therefore, while we can conclude that a petroleum tariff is not a desirable source of any needed additional revenue, we cannot go further and identify a desirable source of revenue.

APPENDIX

ANALYTICAL MODEL: DEVELOPMENT AND RESULTS

APPENDIX TABLE OF CONTENTS

APPENDIX LIST OF TABLES

I. INTRODUCTION

This appendix provides a detailed presentation of the analytical model and results of this study. Section II develops the theoretical model of the U.S. refining industry. The baseline equilibrium, i.e., the initial prices and quantities through which the demand and supply equations must pass, is constructed in Section III. Section IV discusses the elasticities of demand and supply, as well as other parameter values, used in constructing the demand and supply equations presented in Section V. Section VI develops the methodology used in calculating tariff-generated changes in consumer and producer surplus. In Section VII, the equilibria associated with the various tariff alternatives are reported. Section VIII examines the robustness of the results with respect to alternative parameter value assumptions, alternative baseline price assumptions, and tariff-induced changes in world petroleum prices. Finally, the results obtained in this study are contrasted with those of previous studies in Section IX.

II. REFINERY MODEL

In order to accurately assess the impact of tariffs levied on both crude oil and refined products, an integrated model is developed for the two vertically related industries, crude oil production and petroleum refining. This involves modeling the refining industry not only as a supplier of refined products but also as a demander of crude oil.

We model refined petroleum production as requiring two inputs: crude oil and another factor, v. Empirically, we find that there is little domestic variation in the ratio of petroleum output to crude oil inputs from one year to the next. We accordingly assume this ratio is equal to a constant, r. The noncrude factor, v, is assumed to be not substitutable for crude oil and to be subject to decreasing returns to scale. The production function is therefore of a modified Leontief type in that

$$Q_r = \min\, [rQ_c, f(Q_v)] \;, \qquad f'>0,\; f''<0 \;. \qquad (1)$$

where Q_r is the quantity of refined product, Q_c is the quantity of crude oil inputs,[1] and Q_v is the quantity of the noncrude input.

With this production function, profit can be expressed as

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[1] At this point, the term Q_c includes natural gas liquids (NGL) which are also used as a raw material in the production process. In Section VI, NGL's are broken out separately when specifying coefficients for the crude oil demand equation. In the analysis, the quantity of NGL used as an input to refineries is constant, although the price is assumed implicitly to vary directly with the price of crude oil.

$$\Pi = P_r Q_r - P_c Q_c - P_v Q_v$$

$$= P_r Q_r - P_c Q_r / r - P_v f^{-1}(Q_r) \; . \qquad (2)$$

By differentiating the Π function with respect to Q_r, setting the resulting expression equal to zero, and solving for Q_r, we obtain the supply function for refined products as a function of input and output prices. Since the quantity of crude oil employed in the refinery process, Q_c, is directly related to Q_r by the constant r, the demand function for crude oil is also obtained.

In order to get a supply function that is linear in prices, $f(Q_v)$ is specified to have the functional form,

$$Q_r = a + (bQ_v)^{1/2} \; .[2] \qquad (3)$$

Then

$$\Pi = P_r Q_r - P_c Q_r / r - P_v (Q_r - a)^2 / b \; , \qquad (4)$$

and

$$\Pi' = P_r - P_c / r - 2P_v (Q_r - a)/b = 0 \; . \qquad (5)$$

The supply schedule is then found by solving for Q_r, or Q_{rs} in order to indicate that this is a supply relationship,

$$Q_{rs} = a + (b/2P_v) \, P_r - (b/2rP_v) \, P_c \; . \qquad (6)$$

Define α and β so that this can be rewritten as

$$Q_{rs} = \alpha + \beta \, P_r - (\beta / r) \, P_c \; , \qquad (7)$$

The demand for crude oil (Q_{cd}) is then

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[2] In addition, there are an infinite number of other functional forms for which a linear supply schedule would be a reasonable approximation.

$$Q_{cd} = Q_{rs}/r$$

$$= (\alpha/r) + (\beta/r) P_r - (\beta/r^2) P_c . \quad (8)$$

To simplify the analysis, a constant product mix is assumed. Specifically, it is assumed that each barrel of refined products supplied is composed of μ barrels of gasoline and $(1-\mu)$ barrels of other (nongasoline) refined product. The supply functions for the two products are then simply

$$Q_{gs} = \mu Q_{rs} \quad (9)$$

$$Q_{os} = (1-\mu)Q_{rs} , \quad (10)$$

and the price of refined product is simply the weighted sum of the two product prices:

$$P_r = \mu P_g + (1-\mu)P_o . \quad (11)$$

From equation (7), the own-price supply elasticity for refined products can be found

$$\eta = \beta P_r/Q_{rs} , \quad (12)$$

so that, once magnitudes for this elasticity and the parameter r are found, the coefficients on both the price of refined product and the price of crude oil in equation (7) are determined. A subsequent fitting of the equation through the baseline equilibrium prices and quantities yields a value for the constant term.

III. BASELINE EQUILIBRIUM

The model is prospective in the sense of assuming a baseline equilibrium that corresponds to roughly the midpoint of the 1990's. To do this, annual projections of prices and quantities for the period 1990-1999, taken from the Department of Energy's Annual Energy Outlook 1989, are averaged to arrive at baseline prices and quantities for the three different goods considered: crude oil, gasoline, and other (nongasoline) refined products.[3]

The baseline prices are presented in Table A-1, with observed prices for 1988 also presented for comparison.[4] While there is only one price for crude oil and one price for other refined products, separate gasoline prices are

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[3] U.S. D.O.E. (1989a). Unless otherwise noted, all prices in this report are expressed in 1988 dollars per barrel.

[4] The crude oil price used in the D.O.E. projections represents the cost of imported crude to U.S refiners and is reported in dollars per barrel. [U.S. D.O.E. (1989a), Table A1, p. 45.] The prices for gasoline and total refined product are prices paid by consumers and are reported in dollars per million BTU. [Ibid.] For gasoline, a conversion factor of 5.253 million BTU per barrel has been applied in order to convert the price to dollars per barrel. [U.S. D.O.E. (1987a), p. 261.] Similarly, a conversion factor of 5.41 million BTU's per barrel is used to convert the price for all refined product. [Id., Table 117, p. 263.] Other (nongasoline) refined product price is imputed from the per-barrel prices for gasoline and all refined products, and from the fact that, in terms of total consumption for the period 1990-99, the proportion of gasoline to all refined product was projected to be approximately 0.406. [U.S. D.O.E. (1989a), Table A8, p. 51.]

TABLE A-1

BASELINE EQUILIBRIUM PRICES[1]
(1988 dollars per barrel)

	1988 Actual	1990's Baseline
Crude Oil	$14.70	$20.30
Gasoline:		
To Refiners	$26.70	$34.90
To Consumers	$36.70	$44.90
Other Refined Products	$24.30[2]	$30.80

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1 Unless otherwise noted, source is U.S. D.O.E. (1989a).

2 The price of all refined product in 1988 was $5.48 per million BTU, while that for gasoline was $6.98. [U.S. D.O.E. (1989a), Table A3, p. 47.] Upon converting to dollars per barrel, the prices were $29.65 and $36.65. In that year, an average barrel of refined product consumed in the U.S. consisted of 43.15% gasoline. [Id., Table A8, p. 51.] A price for nongasoline refined product can then be imputed to be $24.34 per barrel.

presented for refiners and for consumers. This is done because the state and federal governments levy excise taxes averaging about $10 per barrel on gasoline.[5] Thus, the price paid by consumers exceeds the price received by refiners by $10 per barrel.[6]

Baseline quantities, along with observed quantities for 1988, are reported in Table A-2.[7] The baseline quantity for domestic crude oil production and gasoline consumption are simply averages of figures reported in the <u>Annual Energy Outlook, 1989</u>. Demand for other refined products is not reported, and so must be calculated indirectly as the difference between total refined products and motor

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[5] Tax rates on motor gasoline considered here are those levied by the federal government (9.1 cents per gallon) and by the various states as of 1988. [U.S. D.O.E. (1988b), p. 365.] The average value was computed by multiplying the various state taxes by the quantities of gasoline sold in those states. Where a state tax was expressed in percentage terms, rather than in cents per gallon, we assumed the price of gasoline to be $1 per gallon. We assume that sales tax rates will remain unchanged for the period of our analysis, except when additional excise taxes on gasoline are examined as an alternative to import tariffs.

[6] With the exception of existing and proposed sales taxes, we assume that the prices paid by consumers are equal to the prices received by refiners. Thus, implicitly, our refining sector not only refines crude oil but also provides the transportation and marketing services needed to get the gasoline and other refined products to consumers.

[7] Unless otherwise noted, all quantity figures come from U.S. D.O.E. (1989a), Table A8, p. 51. Furthermore, all quantities are in million barrels per day (mbd) unless otherwise noted.

TABLE A-2

BASELINE EQUILIBRIUM QUANTITIES[1]
(million barrels per day)

	1988 Actual	1990's Baseline
Crude Oil:		
Demand	13.1	13.7
Supply	8.2	6.5
Imports (Net)	4.9	7.2
Gasoline:		
Demand	7.3	7.3
Supply	6.9[2]	6.9
Imports (Net)	0.4[2]	0.4
Other Refined Products:		
Demand	9.7	10.6
Supply	8.7[3]	9.3
Imports (Net)	1.1[3]	1.3

[1] Unless otherwise noted, source is U.S. D.O.E. (1989a).

[2] U.S. D.O.E. (1989b), Table 3.4, p. 47.

[3] Net imports of all refined products in 1988 were estimated to be 1.506 mbd. [Id., Table 3.1b, p. 39.] Since net imports of gasoline were .39 mbd, net imports of nongasoline imports were approximately 1.11 mbd. Domestic production is then estimated to be the difference between this and total domestic demand.

gasoline consumed. Crude oil demand is equal to domestic crude oil production plus imports minus exports.[8]

The D.O.E. projections do not provide data on domestic production of gasoline and other refined products individually. Instead, the only number reported is total domestic production of refined products. In order to get separate baseline quantities for the domestic production, it is necessary to specify a mix of the two products in production. For purposes of this report, a product mix of 42.5 percent gasoline and 57.5 percent nongasoline is assumed. This ratio preserves the mix of product imports observed in 1988, roughly 25 percent gasoline and 75 percent other.[9]

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[8] In addition, two minor adjustments are incorporated for changes in inventories: Net Withdrawals and the Strategic Petroleum Reserve Fill Rate.

[9] Alternatively we could have assumed that the ratio of gasoline production to production of all refined products was the same in the baseline as in some recent period. For example, this ratio was approximately 44 percent in 1988. However, if this number had been adopted, gasoline production would have exceeded gasoline demand in the baseline, and a tariff on gasoline would have had no effect. In an environment in which gasoline tariffs are being widely discussed, it seems preferable to construct a baseline that allowed such a tariff to have some effect.

IV. PARAMETER VALUE ASSUMPTIONS

The analysis of this study relies on a partial equilibrium, comparative static model of international trade with linear demand and supply equations assumed for simplicity. The equations incorporate elasticities which reflect changes in quantities demanded or supplied five years after a price change is introduced.

With one exception, the elasticities of demand and supply are calculated from the low and high world oil price scenarios reported by the Department of Energy (D.O.E.) in the Annual Energy Outlook, 1989.[10] In general, since the world oil price in the two scenarios first diverged in the year 1989, an elasticity was calculated as the percentage difference in quantity in 1993, divided by the average percentage difference in the two prices over that five year period.[11] The elasticities so computed are reported in Table A-3.

The one exception to the methodology described above is the estimation of the own-price supply elasticity of refined product.[12] In order to estimate this parameter, it

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[10] U.S. D.O.E. (1989a), Appendices B and C, respectively.

[11] The elasticities could have been constructed with the percentage change in the price in the fifth year if the difference in the prices of the two scenarios had been constant once they first diverged. However, in the two scenarios, the prices diverge by different amounts in different years. Hence, we look at the average difference over the five year period.

[12] Alternatively, due to the underlying production technology assumed, the cross-price supply elasticity with

TABLE A-3

ASSUMED MAGNITUDES OF DEMAND AND SUPPLY ELASTICITIES

	Assumed Value[1]	
Crude Oil Supply	+ 0.33	(@ P_c=\$16.30)
Refined Product Supply	+33.74[2]	(@ P_r=\$27.90 & P_c=\$18.70)[3]
Gasoline Demand	- 0.37	(@ P_g=\$38.50)
Other Refined Product Demand	- 0.38	(@ P_o=\$26.50)

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[1] Computed from D.O.E. alternative price scenario projections unless otherwise noted. [U.S. D.O.E. (1986a).]

[2] Computed from simulations using the D.O.E.'s Refinery Yield Model.

[3] The RYM model used was calibrated to 1987 prices. Accordingly, the comparable price for all refined products, P_R, is \$5.95 per million BTU, or equivalently, \$32.20 per barrel. [U.S. D.O.E. (1989a), Table A3, p. 47.] However, this represents the price to consumers, and so includes gasoline excise taxes. Since the average barrel of refined product in 1987 contained 43.25% gasoline, and the average gasoline tax was approximately \$10 per barrel, the average tax paid on a barrel of refined product by consumers was \$4.32. Therefore, the price of a barrel of refined products to refiners in 1987 was \$27.90 (in 1988 dollars). The 1987 crude oil price (in 1987 dollars) was \$18.70. [Ibid.]

is necessary to know how the quantity of refined products supplied by domestic refiners would change as the price of refined product changes but the price of crude oil does not. Since the Annual Energy Outlook projections involve simultaneous changes in both crude oil and refined product prices, an alternative source for this elasticity estimate was sought. However, since crude oil is used only as an input into refineries, and is also the most significant component of refinery cost, one can expect little empirical variation in refined product prices that is not simultaneously accompanied by variation in crude oil prices. Perhaps for these reasons there have been few studies that have estimated a value for this elasticity, and, of those that have, no attempt was generally made to control for the crude oil price.

At our request, the Division of Energy Analysis and Forecasting of D.O.E. performed runs of the 1987 version of their Refinery Yield Model (RYM), a large-scale linear programming model of the U.S. refinery industry.[13] Since the RYM is an annual model that assumes that the capital stock is fixed, the supply schedule at (or near) full capacity generated in the RYM is relatively steep for increases in output. On the other hand, for decreases in output below full capacity, the supply function is relatively flat. Because we are interested in the effects of a change in production five years after a change in price first occurs, the assumption that the capital stock is fixed is not reasonable for our purposes. Accordingly, we chose to focus on a decrease in output below that observed in 1987, rather than an increase. Specifically, in estimating the own-price supply elasticity, we sought to

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[13] In order to simplify the programming problem, only the portion of the RYM representing PAD III was used. However, since PAD III, the coastal region consisting of Texas and Louisiana, is perhaps the most significant marginal supplier of refined products to much of the nation, this portion of the RYM is probably the most relevant in studying the supply response of the U.S. refining industry.

measure the percentage change in the supply price (i.e., marginal cost) of refined product that resulted when output was decreased by 5%, holding all other parameters and variables (e.g., the crude oil price) constant. As reported in Table A-3, the resulting refined product supply elasticity with respect to the price of refined products is +33.74.[14]

One other parameter remains to be specified: the ratio of refined product to crude oil input, or r. This ratio is determined by the quantities in our baseline to be 1.041.[15]

---

[14] In order to impute a supply elasticity value that did not control for the crude oil price--i.e., a "gross" elasticity--from the current study, it would be necessary to know the exact manner in which the refined product price changes in response to a change in the crude oil price. For example, if the demand function is given by

$$Q = \alpha - \beta P_c + \gamma P_r ,$$

then the "pure" price elasticity would be $[\beta P_c/Q]$. If the price of refined product is observed to change by μ for each $1 change in the price of crude oil, then the gross price elasticity would be

$$\eta = -(-\beta + \gamma\mu)(P_c/Q) .$$

While there are obvious problems in defining and calculating an aggregate price for all refined products, casual empiricism would suggest that μ is in the neighborhood of unity. However, imputing a "gross" supply elasticity from an assumed pure demand elasticity is highly sensitive to the choice of a value for this parameter. For example, the gross elasticity can be calculated from equation (15) to range from +3.3 to -0.3 as μ ranges from .95 to 1.05.

[15] In the baseline equilibrium, the total quantity of refined products is comprised of 6.86 mbd of gasoline and 9.28 mbd of other refined products, while inputs equal

V. SPECIFICATION OF DEMAND AND SUPPLY FUNCTIONS

The assumptions and parameter values adopted up to this point are sufficient to fully specify the demand and supply functions needed for an analysis of crude oil and refined product import tariffs and sales taxes.[16] In establishing these relationships, it is important to recall that a sales tax and (generally) a tariff will increase the price paid by consumers of a product by the amount of the tariff or tax.[17] However, only a tariff will increase the price received by producers. Thus, while tariffs (t_c, t_g, and t_o, for tariffs on crude oil, gasoline and other refined product, respectively) appear in both demand and supply equations, sales taxes (s_c, s_g, and s_o for sales taxes on

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13.7 mbd of crude oil plus 1.81 mbd of natural gas liquids. Therefore, 16.14 million barrels per day of refined products are produced from 15.51 mbd total inputs.

[16] In arriving at the coefficients of these demand and supply relationships, the assumed elasticity values were assumed to hold at the prices and quantities at which they were estimated. Accordingly, the elasticities calculated at the baseline prices and quantities will have slightly different values than those assumed.

[17] For a tariff, this is true provided: the product is still imported after the tariff is introduced; imports are perfect substitutes for domestic production; and the world price of imports is not affected by the quantity of imports demanded by the United States. The latter two provisions are general assumptions of this study. The first provision holds for most tariffs considered. However, for those tariffs in which imports are choked off, the price of domestically supplied product rises less than the tariff amount. The price of foreign supplied product would go up by the full amount of the tariff.

crude oil, gasoline and other refined products, respectively) appear only in demand equations.

Crude Oil Supply

Given the assumed elasticity of crude oil supply and the baseline values for crude oil price and quantity, the supply function for crude oil by domestic producers becomes

$$Q_{cs} = 3.6872 + 0.1376P_c, \quad (13)$$

or when a tariff is imposed,

$$Q_{cs} = 3.6872 + 0.1376(P_c + t_c) \quad (14)$$

where P_c is the world price of crude oil, which is assumed to remain unchanged, and t_c is the tariff on crude oil imports.

Supply of Refined Product

Given the assumed baseline prices and quantities as well as the supply elasticity, the domestic supply of refined products can be found:

$$Q_{rs} = -225.0165 - 17.7676P_c + 18.4961P_r \ . \quad (15)$$

However, since the price of refined product is simply a weighted average of the prices of gasoline and other refined products,

$$P_r = .425P_g + .575P_o, \quad (16)$$

equation (15) becomes

$$Q_{rs} = -225.064 - 17.7676P_c + 7.8608P_g + 10.6352P_o \ . \quad (17)$$

In these equations, as before, prices are world prices received by producers rather than prices paid by consumers, where there is a difference between the two.

Introducing the effect of possible tariffs on the prices refiners receive for either gasoline or other refined products, and the effects of a tariff or a sales tax on the price refiners must pay for crude oil,[18] the relationship becomes

$$Q_{rs} = -225.165 - 17.7676(P_c + t_c + s_c) + 7.8608(P_g + t_g) + 10.6352(P_o + t_o). \quad (18)$$

Since the quantities of gasoline and of other nongasoline product are constant fractions, .425 and .575 respectively, of the total supply of refined product, the individual supply functions are

$$Q_{gs} = -95.6950 - 7.5512(P_c + t_c + s_c) + 3.3409(P_g + t_g) + 4.5200(P_o + t_o) \quad (19)$$

and

$$Q_{os} = -129.4700 - 10.2164(P_c + t_c + s_c) + 4.5200(P_g + t_g) + 6.1153(P_o + t_o) . \quad (20)$$

Demand for Crude Oil

Crude oil plus natural gas liquids (NGL's) are assumed to be a constant fraction of the total supply of refined product, i.e.,

$$Q_{rs} = 1.041(Q_{cd} + NGL) , \quad (21)$$

---

[18] We also assume that changes in the price of crude oil will be reflected in the price of natural gas liquids (NGL's), since NGL's are used as a substitute for crude oil, and since their supply is constant in this analysis.

where NGL is constant at 1.81 mbd. Thus, using equation (18), the demand for crude oil is seen to be simply

$$
\begin{aligned}
Q_{cd} &= (Q_{rs}/1.041) - NGL \\
&= -218.0000 - 17.0474(P_c + t_c + s_c) \\
&\quad + 7.5445(P_g + t_g) + 10.2072(P_o + t_o) \ . \qquad (22)
\end{aligned}
$$

Demand for Gasoline

Fitting an equation through the baseline price and quantity, consistent with the assumed demand elasticity, the demand for gasoline is found to be

$$Q_{gd} = 10.3398 - 0.0686(P_g + t_g + 10 + s_g) \ , \qquad (23)$$

where, as in other equations, P_g is the price received by refiners for gasoline, t_g is the tariff on gasoline, and $(10+s_g)$ is the existing plus any additional level of excise taxes on gasoline.

Demand for Other, Nongasoline Refined Product

Fitting a linear equation for the demand for refined products other than gasoline through the baseline price and quantity, consistent with the assumed demand elasticity, one obtains:

$$Q_{od} = 15.1575 - 0.1473(P_o + t_o + s_o) \ . \qquad (24)$$

VI. METHODOLOGY FOR CALCULATING GAINS AND LOSSES

In estimating the distributive impact of a proposed tariff or sales tax, we estimate the effect on consumers, producers, and government revenue. Two types of producer surplus, that for crude oil producers and for refiners, and two types of consumer surplus, that for consumers of gasoline and for consumers of other refined product, are relevant here.[19] The sum of the changes in the welfare of all of these groups represents the net societal gain or loss, or, since it is typically negative, the deadweight loss.

An import tariff on a given good has the obvious effect of raising the price of imports by the amount of the tariff. In addition, unless the tariff reduces imports of the good to zero, the price of the corresponding domestically produced good will increase by the same amount.[20] On the other hand, a sales tax causes the price of both imported and domestically produced goods to rise by the amount of the tax regardless of its impact on imports.

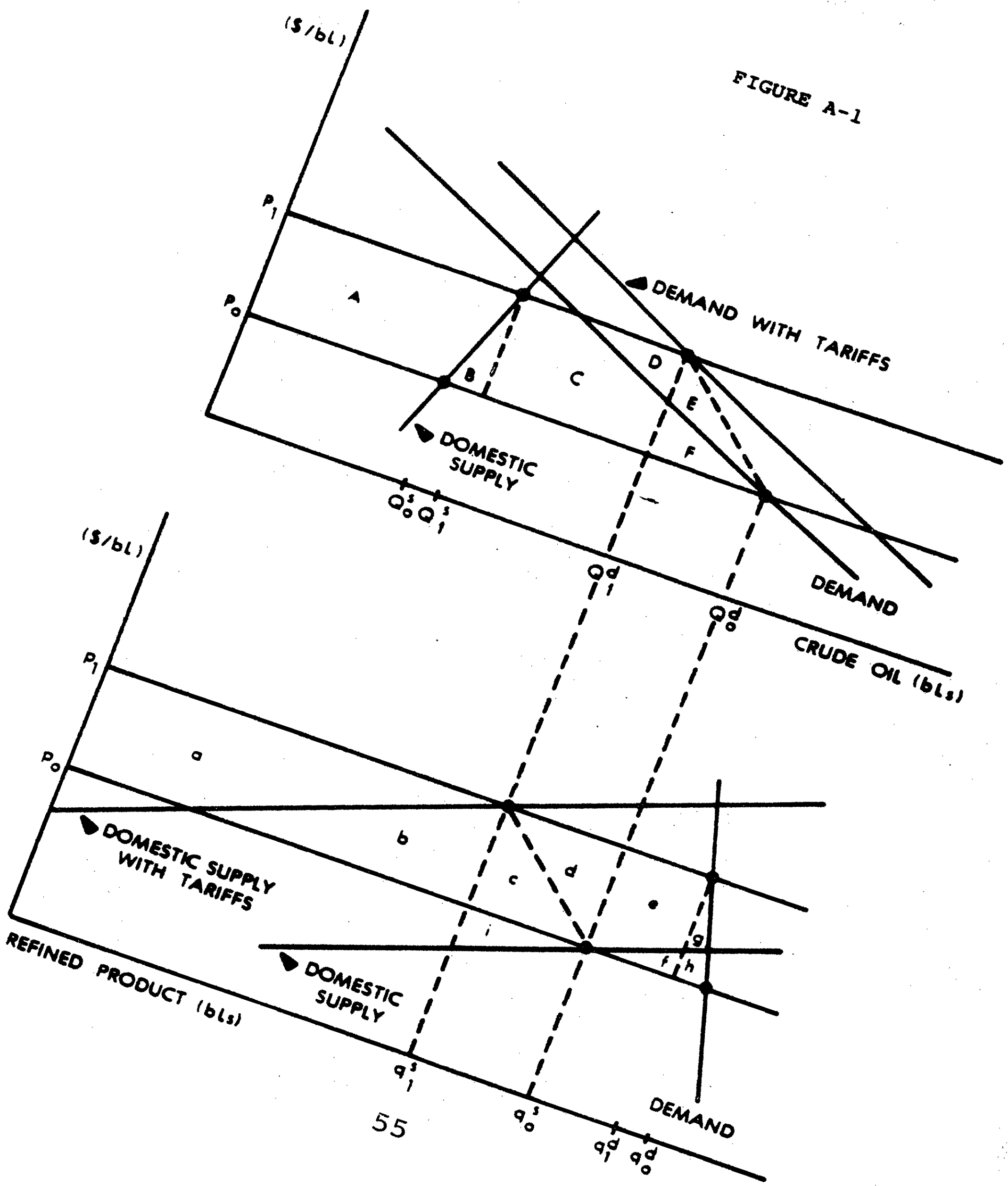
The impact of petroleum import tariffs and sales taxes on two vertically related industries, crude oil production and petroleum refining, are depicted in Figure A-1, where the upper panel corresponds to the upstream industry (crude oil), and the lower panel corresponds to the downstream

---

[19] Consumer surplus arising from the "consumption" of crude oil by refiners is subsumed into refiners' producer surplus.

[20] Implicit in this statement is the assumption that the domestically produced good is a perfect substitute for the imported good, which is an assumption made in this analysis. If the goods are imperfect substitutes, the domestic good would not generally rise by the same amount as the tariff.

FIGURE A-1



($/bl)
P_1
P_o
A
B
C
D
E
F
DEMAND WITH TARIFFS
DOMESTIC SUPPLY
DEMAND
Q_o^s Q_1^s
Q_1^d
Q_o^d
CRUDE OIL (bls)
($/bl)
P_1
P_o
a
b
c
d
e
f
g
h
i
DOMESTIC SUPPLY WITH TARIFFS
DOMESTIC SUPPLY
DEMAND
REFINED PRODUCT (bls)
q_1^s
q_o^s
q_1^d q_o^d

industry (refined products). Thus, a tariff on crude oil causes the price to rise from P_0 to P_1 in the upper panel, while a tariff on refined products causes the price to rise from p_0 to p_1 in the lower panel. When a tariff is levied on an upstream good such as crude oil, it raises the costs of downstream producers (refiners), causing the supply curves of those producers to shift up. Such a shift is shown in the lower panel of Figure A-1. Similarly, if a tariff is levied on a downstream good such a gasoline, it raises the marginal revenue product of the upstream good, causing the demand schedule for the upstream good to shift out. This is shown in the upper panel of Figure A-1.

Government Revenues

With a tariff, the government gains revenues equal to the amount of each tariff times the level of imports of that product after the tariff is imposed. Consider the case of a tariff on crude oil and refined product, as depicted in Figure A-1. The tariff revenue collected on crude oil imports would correspond to the sum of the areas C and D in the upper panel. The tariff revenue collected on refined product imports would correspond to the sum of c, d, e and f in the lower panel.

With a sales tax, government revenue is equal to the amount of the tax times the quantity consumed. Thus, if a sales tax on refined products is depicted in the lower panel of Figure A-1 by the increase in the price paid by the consumer from p_0 to p_1, government revenue would be equal to areas a, b, c, d, e and f.

One of the two refined products, gasoline, is currently subject to significant excise taxes, amounting to approximately $10 per barrel. If a tariff or additional taxes on gasoline causes domestic consumption to fall, this would reduce the revenues collected from existing excise taxes. The decline in excise tax revenue, which is not shown in Figure A-1, would be equal to the amount of the current tax (approximately $10 per barrel) multiplied by the decline in consumption.[21,22]

Crude Oil Producer Surplus and Refined Product Consumer Surplus

The calculation of three of the four surplus measures is straightforward. For example, crude oil producer surplus is simply the increased price received for that quantity of oil that would have been sold at the lower price, plus the revenue in excess of cost received on additional barrels produced because of the higher price. This area is denoted as area A in the upper panel of Figure A-1, which depicts the pre- and post-tariff (or -tax) equilibria in the market

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[21] The analysis has not taken into account revenue generated from current sales taxes on diesel fuel. While diesel fuel taxes are often lumped with gasoline sales taxes, diesel fuel is, in this analysis, a component of other refined product. In ignoring this tax, our results: (1) underestimate the revenue obtainable with a hike in the gasoline sales tax to the extent that it would, in all likelihood, be accompanied by a comparable hike in the diesel fuel tax, and (2) overestimate the revenue obtainable with any tariff that encompasses other refined product, since such a tariff would have the effect of lowering consumption of, and hence tax revenues generated from, diesel fuel.

[22] Currently there are tariffs imposed on most petroleum imports: approximately $0.05 per barrel on crude oil, $0.50 per barrel on gasoline, and up to $0.10 per barrel on some of the other refined products such as distillate and residual fuel oils, kerosene, and naphthas. Since these tariff levels are small relative to those under consideration in this study, and since even the largest of these existing tariffs--that on gasoline--does not significantly affect the revenue and deadweight loss estimates reported below, they have not been incorporated into the analytical model.

for crude oil. Similarly, the change in consumer surplus is calculated in the traditional way. For each of the two refined products under consideration, there would be a diagram corresponding to the lower panel of Figure A-1, in each of which the change in consumer surplus would be represented as the sum of areas a, b, c, d, e, f, g, and h.

Refiners' Producer Surplus

The measurement of the change in refiners' surplus is somewhat more complicated, since a tariff can potentially affect either refiners' revenues or costs, or both. To arrive at a measure of refiners' surplus, assume that the change in refiners' producer surplus is equivalent to the change in profit. Further, in order to simplify the analysis, assume there is only one refined product, which is denoted by the subscript r. Therefore, as in equation (2) above, profit can be written as

$$\Pi = P_r Q_r - P_c Q_c - V(Q_r)$$

$$= P_r Q_r - P_c Q_r / r - V(Q_r) \; , \qquad (25)$$

where natural gas liquids are subsumed for the moment into Q_c. Then, any change in prices arising from tariffs and/or sales taxes, denoted by ΔP_c and ΔP_r, affects profit:

$$\Delta\Pi = [P_r(\Delta Q_r) + (\Delta P_r)Q_r']$$

$$- \; [P_c(\Delta Q_r) + (\Delta P_c)Q_r']/r$$

$$- \; [V(Q_r')-V(Q_r)] \; , \qquad (26)$$

where Q_r' represents the post-tariff (or post-tax) quantity of refined product. Note that the first bracketed term is the change in revenues arising from the tariff, while the second and third terms are the increases in costs attributable to crude oil and other variable inputs, respectively. While the first two terms are readily estimable from observed prices and quantities, the last is more problematic.

Now, profit maximization implies

$$\partial\Pi/\partial Q_r \quad = \quad P_r - (P_c/r) - v(Q_r) \quad = \quad 0 \ , \tag{27}$$

where v(Q) denotes the derivative of V(Q). Note that upon solving equation (27) for P_r, the inverse supply schedule is found, and similarly, by solving for P_c, the inverse demand schedule for crude oil input is found.

Since the term $[V(Q_r')-V(Q_r)]$ can be expressed as the integral of v(Q) between Q_r and Q_r', then, upon substituting for $v(Q_r)$ from equation (27), this term can be simplified to:

$$\begin{aligned}[V(Q_r')-V(Q_r)] \quad &= \quad \int_{Q_r}^{Q_r'} v(x)\ dx \\ &= \quad \int_{Q_r}^{Q_r'} [P_r(x) - P_c(x)/r]\ dx \ , \end{aligned} \tag{28}$$

where $P_r(Q_r)=P_r$, $P_r(Q_r')=P_r'$, $P_c(Q_r)=P_c$, and $P_c(Q_r')=P_c'$. Since both the inverse supply schedule (for refined product) and the inverse demand schedule (for crude oil input) are linear in Q_r,[23] this equation can be further simplified to:

$$[V(Q_r')-V(Q_r)] \quad = \quad [(P_r+P_r') - (P_c+P_c')/r](\Delta Q_r)/2 \ . \tag{29}$$

Upon substituting equation (29) into equation (26), we obtain

---

[23] If the refined product supply function is linear in P_r, then the inverse supply function must be linear in Q_r. Similarly, if the crude oil demand function is assumed to be linear in P_c, the inverse crude oil demand function must be linear in Q_c. Moreover, since Q_c is a constant proportion of Q_r, it must also be linear in Q_r.

$$
\begin{aligned}
\Delta\Pi = \; & [P_r(\Delta Q_r) + (\Delta P_r)Q_r'] \\
& - [P_c(\Delta Q_r) + (\Delta P_c)Q_r']/r \\
& - [(P_r+P_r') - (P_c+P_c')/r](\Delta Q_r)/2 \\
= \; & [(\Delta P_r)-(\Delta P_c)/r](Q_r+Q_r')/2 \\
= \; & [(\Delta P_r)(Q_r+Q_r')/2] - [(\Delta P_c)(Q_c+Q_c')/2] \, . \qquad (30)
\end{aligned}
$$

Therefore, the change in producer surplus can be interpreted as the difference between: (1) the change in the product price times the average quantity sold, pre- and post-tariff; and (2) the change in the input price times the average quantity of the input purchased, pre- and post-tariff. Ignoring natural gas liquids, the change in producer surplus can be simply represented as the difference between two areas in Figure A-1: the area in the upper panel bounded by the two price lines, the vertical axis and a line segment connecting the two points denoting crude oil demand pre- and post-tariff, subtracted from the area in the lower panel bounded by the two price lines, the vertical axis, and a line segment connecting the points denoting supply pre- and post-tariff.[24]

Social Cost or Deadweight Loss

The sum of the gains and losses accruing to all segments of society--consumers, crude oil producers, refiners and the government--yields a measure of the loss to society as a whole, commonly referred to as the deadweight loss. On the basis of the gains and losses outlined above, the deadweight loss arising from a tariff on crude oil and refined products can be depicted in Figure A-1 as the sum of areas B, E and F in the upper panel plus areas g and h,

---

[24] In Figure A-1, the first area is the sum of areas A, B, C, D, E and F. The second area is the sum of a, b, and c.

minus area c, in the lower panel. Upon further manipulation, this becomes simply area B in the upper panel and areas g, h, and i in the lower panel.[25] On a more conceptual level, this loss can be broken down into the following components:

1) excessive domestic production of crude oil arising as a result of the artificially high crude oil price (area B);

2) under-utilization of resources used in domestic refineries, due to reduced refinery activity, attributable in turn to the artificially high crude oil price (area i);

3) reduced consumption of refined products, attributable to the artificially high prices for refined products (areas g and h).

---

[25] Due to the assumed constant ratio of crude oil input to refined product, it can be shown that the sum of areas E and F in the upper diagram equals the sum of areas c and i in the lower diagram. More specifically, using similar triangles, the increase in costs attributable to the tariff on crude oil upon increasing output from q_1^s to q_0^s can be represented identically as 2(E+F) in the upper panel and (c+d+2i) = 2(c+i) in the lower panel. Therefore, E+F = c+i.

VII. PREDICTED OUTCOMES WITH VARIOUS PETROLEUM IMPORT TARIFFS

In this section, the results are reported for the various tariff and tax alternatives referenced in the text. First, we present the quantity and surplus calculations for four single tariffs, i.e., a tariff on just crude oil, gasoline, other (nongasoline) refined product, or all refined product. Next, the equilibrium quantities are reported for four combined tariffs, defined here as a tariff on crude oil and at least one refined product. Finally, the equilibrium quantities are presented for four refined product sales taxes that are used as comparisons to the combined tariff alternatives.[26]

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[26] We do not consider the imposition of a sales tax on crude oil, either alone or in combination with a tax on refined product. While the social costs of raising a given amount of revenue from taxes on crude oil and refined products could be reduced slightly by imposing a very small tax on crude oil and reducing the tax on refined product, the effect is very small as is the tariff on crude oil. For example, as shown below, a tax of approximately $1.95 per barrel on refined products will raise $12 billion of government revenue per year. [See Table 1 of the text.] If a crude tax of $0.05 per barrel was imposed and the tax on refined products reduced by about $0.04, the same revenue would be raised and the social cost resulting from the tax scheme would be reduced by about $10 million per year. However, if the tax on crude were higher than $0.10 per barrel, the social cost would be higher than if taxes were placed only on refined products.

This result differs from that of Melo, Stanton, and Tarr (1988). For a discussion of their results and our reason for believing our result is more realistic, see Section IX below.

Single Tariffs

Consider first a $5 tariff on imports of crude oil. This would have the immediate effect of raising the domestic price of crude oil for both domestic producers and refiners. Since the domestic prices of refined products are determined in the world market and would be unaffected by this tariff, refiners' could be expected to respond to this cost increase by decreasing output and, hence, crude oil demand. As is reported in Table A-4, a $5 tariff would reduce demand sufficiently so as to cause imports to fall to zero. Since, in the new equilibrium, domestic demand and supply of crude oil are equated at a price that is roughly $0.40 higher than before, any tariff equal to or greater than this amount would yield zero revenue for the government, but nevertheless raise domestic price by $0.40. As is seen in the same table, this tariff would reduce net producers' surplus, as well as social welfare, by approximately $600 million per year without any offsetting benefit in the form of tariff revenue.[27]

Consider next a $5 tariff on gasoline imports. The immediate effect would be to increase the domestic price for both refiners and consumers. Refiners could be expected to increase production, and consumers could be expected to reduce consumption, causing imports to decline. Indeed, since gasoline imports constitute only 6% of total demand in the baseline equilibrium, a tariff of as little as $0.15 would be sufficient to choke off gasoline imports. [Table A-5.] Once again, with zero imports, no tariff revenues would be forthcoming. However, with the domestic price $0.15 higher, consumers would incur a loss of $300

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[27] The maximum tariff revenue that could be generated from this type of tariff would be approximately $275 million at a tariff level of $0.20 per barrel.

TABLE A-4

$5 TARIFF ON CRUDE OIL IMPORTS
(Domestic Price of Crude Oil Increases by $.40 per barrel)

OUTPUT COMPARISON [mb/d]

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	6.5
Supply	6.5	6.5
Import	7.2	0.0
Gasoline:		
Demand	7.3	7.3
Supply	6.9	3.7
Import	0.4	3.6
Other Refined Product:		
Demand	10.6	10.6
Supply	9.3	5.0
Import	1.3	5.6

SURPLUS ANALYSIS [$billion/year]

Change In Government Revenue:		
Tariff on Crude Oil	.0	
Existing Gasoline Tax	.0	
Net Revenue Change		.0
Change in Consumer Surplus:		
Gasoline	.0	
Other Refined Product	.0	
Total		.0
Change in Producer Surplus:		
Crude Oil	+1.3	
Refining	-1.8	
Total		-0.6
Net Social Cost:		-0.6

TABLE A-5

$5 TARIFF ON GASOLINE IMPORTS
(Domestic Price of Gasoline Increases by $.10 per barrel)

OUTPUT COMPARISON [mb/d]

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	14.6
Supply	6.5	6.5
Import	7.2	8.1
Gasoline:		
Demand	7.3	7.3
Supply	6.9	7.3
Import	0.4	0.0
Other Refined Product:		
Demand	10.6	10.6
Supply	9.3	9.8
Import	1.3	0.8

SURPLUS ANALYSIS [$billion/year]

Change In Government Revenue:		
Tariff on Gasoline	.0	
Existing Gasoline Tax	.0	
Net Revenue Change		.0
Change in Consumer Surplus:		
Gasoline	-0.3	
Other Refined Product	.0	
Total		-0.3
Change in Producer Surplus:		
Crude Oil	.0	
Refining	+0.3	
Total		+0.3
Net Social Cost:		-0.04

million per year.[28]

A tariff of $5 per barrel on nongasoline refined products would have a similar effect as that for gasoline. The domestic price would rise by approximately $0.20 at which point imports would equal zero. [Table A-6.] No tariff revenue would be generated, but consumers would realize a loss of $800 million per year.[29]

Finally, a tariff of $5 per barrel on all refined products would be identical to a $5 tariff on other refined product, in that only the price of other refined product would increase as a result of the tariff.[30]

In conclusion, a tariff on any single petroleum commodity cannot be expected to generate significant revenues.

---

[28] There is no maximum tariff revenue realizable from a simple gasoline import tariff. While the government would realize some revenue if a tariff smaller than $0.12 were levied, this new revenue would be more than offset by a reduction in revenue from existing gasoline taxes, due to decreased gasoline consumption. For example, if a tariff of $0.06 were imposed, the government would realize about $4.3 million per year in tariff revenue. However, gasoline consumption would fall by about 4,000 barrels per day, causing gasoline tax revenue to fall by about $15 million per year.

[29] The maximum revenue realizable from an import tariff on nongasoline refined products is approximately $25 million at a tariff rate of about $0.10 per barrel.

[30] Although the price of gasoline would be unaffected by the tariff, domestic supply of gasoline would expand to exceed domestic demand, as refiners expanded production of its joint product. Implicit in this result is the assumption that U.S. suppliers would be able to export gasoline at the world price.

TABLE A-6

$5 TARIFF ON OTHER REFINED PRODUCT IMPORTS
(Domestic Price Increases by $.20 per barrel)

OUTPUT COMPARISON [mb/d]

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	15.9
Supply	6.5	6.5
Import	7.2	9.4
Gasoline:		
Demand	7.3	7.3
Supply	6.9	7.8
Import	0.4	-0.6
Other Refined Product:		
Demand	10.6	10.6
Supply	9.3	10.6
Import	1.3	0.0

SURPLUS ANALYSIS [$billion/year]

Change In Government Revenue:		
Tariff on Other Refined Product	.0	
Existing Gasoline Tax	.0	
Net Revenue Change		.0
Change in Consumer Surplus:		
Gasoline	.0	
Other Refined Product	-0.8	
Total		-0.8
Change in Producer Surplus:		
Crude Oil	.0	
Refining	+0.8	
Total		+0.8
Net Social Cost:		-0.05

Combined Tariffs

A combined tariff is defined here to be a tariff on crude oil and at least one category of refined products. Four combined tariffs are considered here: a $5 tariff on crude oil and all refined product; a $5 tariff on crude oil and gasoline; a revenue-maximizing, uniform tariff on crude oil and all refined product; and a revenue-maximizing, uniform tariff on crude oil and gasoline. The equilibrium quantities for each of these alternatives are presented in Tables A-7, A-8, A-9, and A-10, respectively. The results of the associated surplus calculations have been previously reported in the text and will not be repeated here.

Excise Taxes

In terms of deadweight loss, the social costs associated with the four combined tariffs discussed above appear significant, ranging from $0.22 to $0.64 per dollar of revenue raised.[31] In general, a tariff can be judged to be inferior to any tax alternative that raises the same revenue at a lower cost. The list of such alternatives is most likely large. Petroleum excise taxes are considered here for comparison purposes, not because they are expected to be among the best of such alternatives, but rather because their costs can be estimated within the same analytical framework employed to estimate the costs for petroleum tariffs.

For each combined tariff discussed above, a sales tax is considered that: (1) yields the same net government revenue, and (2) impacts the same refined product prices.

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[31] Similarly, the consumer cost per dollar of revenue can be calculated to range from $2.54 to $2.93. However, since consumers generally also have stakes in the fortunes of both government and business, this measure by itself is incomplete.

TABLE A-7

$5 TARIFF ON CRUDE OIL AND ALL REFINED
PRODUCT IMPORTS: EQUILIBRIUM OUTPUT COMPARISON
(Domestic Price of Gasoline Increases by $4.55 per barrel)

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	13.8
Supply	6.5	7.2
Import	7.2	6.6
Gasoline:		
Demand	7.3	6.9
Supply	6.9	6.9
Import	0.4	0.0
Other Refined Product:		
Demand	10.6	9.9
Supply	9.3	9.4
Import	1.3	0.5

TABLE A-8

$5 TARIFF ON CRUDE OIL AND GASOLINE
IMPORTS: EQUILIBRIUM OUTPUT COMPARISON
(Domestic Price of Crude Oil Increases by $2.60 per barrel)

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	6.8
Supply	6.5	6.8
Import	7.2	0.0
Gasoline:		
Demand	7.3	6.9
Supply	6.9	3.8
Import	0.4	3.1
Other Refined Product:		
Demand	10.6	10.6
Supply	9.3	5.2
Import	1.3	5.4

TABLE A-9

REVENUE-MAXIMIZING TARIFF ON CRUDE OIL AND ALL REFINED PRODUCT IMPORTS: EQUILIBRIUM OUTPUT COMPARISON

($12.20 Tariff; Domestic Price of Gasoline Increases by $10.95 per barrel)

	Baseline	**Post-Tariff**
Crude Oil:		
Demand	13.7	12.9
Supply	6.5	8.2
Import	7.2	4.7
Gasoline:		
Demand	7.3	6.5
Supply	6.9	6.5
Import	0.4	0.0
Other Refined Product:		
Demand	10.6	8.8
Supply	9.3	8.8
Import	1.3	0.0

TABLE A-10

REVENUE-MAXIMIZING TARIFF ON CRUDE OIL AND GASOLINE IMPORTS: EQUILIBRIUM OUTPUT COMPARISON

($15.10 Tariff; Domestic Price of Crude Oil Increases by $7.05 per barrel)

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	7.4
Supply	6.5	7.4
Import	7.2	0.0
Gasoline:		
Demand	7.3	6.2
Supply	6.9	4.1
Import	0.4	2.1
Other Refined Product:		
Demand	10.6	10.6
Supply	9.3	5.5
Import	1.3	5.1

For example, in the case of a tariff on crude oil and gasoline, a sales tax on gasoline was found that generated the same net government revenues. Consequently, four excise taxes are considered here: an excise tax of approximately $2 on all refined products (which raises the same revenue as a $5 tariff on crude oil and all refined product); an excise tax of approximately $1.90 on gasoline (corresponding to a $5 tariff on crude oil and gasoline); an excise tax of approximately $3.10 on all refined products (corresponding to a revenue-maximizing tariff on crude oil and all refined product); and an excise tax of approximately $3.45 on gasoline (corresponding to arevenue-maximizing tariff on crude oil and gasoline).[32] The equilibrium quantities for each of these excise tax alternatives are presented in Tables A-11, A-12, A-13, and A-14 respectively. The results of the associated surplus calculations have been previously reported in the text and so are not repeated here.

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[32] It is unlikely that an informed policymaker would choose either of the two revenue-maximizing tariffs, given the high associated social cost. For example, the net social cost per dollar of revenue increases from $0.22 for a $5 uniform tariff on all petroleum to $0.64 for the $12.15 uniform tariff that maximizes revenue. Since the revenue yields for these two tariffs are $12 billion and $18.5 billion respectively, the cost can be seen to rise by 200% upon increasing revenues by 50%.

TABLE A-11

EXCISE TAX ON ALL REFINED PRODUCT YIELDING SAME NET GOVERNMENT REVENUE AS $5 TARIFF ON CRUDE OIL AND ALL REFINED PRODUCT IMPORTS: EQUILIBRIUM OUTPUT COMPARISON ($1.95 Excise Tax)

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	13.7
Supply	6.5	6.5
Import	7.2	7.2
Gasoline:		
Demand	7.3	7.1
Supply	6.9	6.9
Import	0.4	0.3
Other Refined Product:		
Demand	10.6	10.3
Supply	9.3	9.3
Import	1.3	1.1

TABLE A-12

EXCISE TAX ON GASOLINE YIELDING SAME NET GOVERNMENT REVENUE AS $5 TARIFF ON CRUDE OIL AND GASOLINE IMPORTS: EQUILIBRIUM OUTPUT COMPARISON
($1.85 Excise Tax)

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	13.7
Supply	6.5	6.5
Import	7.2	7.2
Gasoline:		
Demand	7.3	7.1
Supply	6.9	6.9
Import	0.4	0.3
Other Refined Product:		
Demand	10.6	10.6
Supply	9.3	9.3
Import	1.3	1.4

TABLE A-13

EXCISE TAX ON ALL REFINED PRODUCT YIELDING SAME NET GOVERNMENT REVENUE AS REVENUE-MAXIMIZING TARIFF ON CRUDE OIL AND ALL REFINED PRODUCT IMPORTS: EQUILIBRIUM OUTPUT COMPARISON
($3.05 Excise Tax)

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	13.7
Supply	6.5	6.5
Import	7.2	7.2
Gasoline:		
Demand	7.3	7.1
Supply	6.9	6.9
Import	0.4	0.2
Other Refined Product:		
Demand	10.6	10.2
Supply	9.3	9.3
Import	1.3	0.9

TABLE A-14

EXCISE TAX ON GASOLINE YIELDING SAME NET GOVERNMENT REVENUE AS REVENUE-MAXIMIZING TARIFF ON CRUDE OIL AND GASOLINE IMPORTS: EQUILIBRIUM OUTPUT COMPARISON THAT MAXIMIZES NET GOVERNMENT REVENUE ($3.45 Excise Tax)

	Baseline	Post-Tariff
Crude Oil:		
Demand	13.7	13.7
Supply	6.5	6.5
Import	7.2	7.2
Gasoline:		
Demand	7.3	7.0
Supply	6.9	6.9
Import	0.4	0.2
Other Refined Product:		
Demand	10.6	10.6
Supply	9.3	9.3
Import	1.3	1.4

VIII. ROBUSTNESS OF RESULTS

Sensitivity Analysis of Parameter Value Assumptions

In order to assess the significance of the estimates of gains and losses reported above, it is useful to perform a sensitivity analysis. An analysis of this type is designed to determine the sensitivity of the estimates to changes in the underlying parameter assumptions. The four most critical parameter values are: the crude oil supply elasticity, the refined product supply elasticity, and the demand elasticities of gasoline and other refined products. For each parameter, the model is solved at a value corresponding to 50% and 150% of the assumed value. For example, the crude oil supply elasticity is varied by .165 around its assumed value of .33. Since the assumed demand elasticities for gasoline and other refined products were derived from the same source and were moreover almost identical in magnitude (e.g., .37 and .38 respectively), they were varied simultaneously in this analysis.

A representation of four tariff/tax alternatives were used in this analysis: a $5 tariff on all petroleum, a $5 tariff on crude oil and gasoline, the revenue-maximizing tariff on all petroleum, and the excise tax on all refined products that yields the same revenue as a $5 tariff on all petroleum.

In terms of revenue yield and net social loss, the analytical results can be seen in Table A-15 to be only mildly affected by the choice of the crude oil supply elasticity. The greatest effect is seen in the case of the revenue-maximizing tariff, in which a 50% change in the elasticity causes a 15-25% change in both the revenue estimate of $18.4 billion and the net social cost estimate of $12 billion.

In all but one case, the analytical results are shown to be almost invariant to a 50% variation in the refined

TABLE A-15

SENSITIVITY ANALYSIS:
CRUDE OIL SUPPLY ELASTICITY

A. $5 Tariff on All Petroleum

	Low	Base	High
Elasticity Value:	.17	.33	.50
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$5.00	$5.00	$5.00
Gasoline	$4.55	$4.55	$4.55
Other	$5.00	$5.00	$5.00
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.3	.7	1.0
Gasoline	.1	.1	.1
Other	.1	.1	.1
Change in Demand for: (Million barrels per day)			
Crude Oil	.2	.2	.2
Gasoline	-.3	-.3	-.3
Other	-.7	-.7	-.7
Welfare Analysis: (Billion dollars per year)			
Consumers	$-30.5	$-30.5	$-30.5
Crude Oil Producers	$15.5	$15.8	$16.1
Refiners	$.1	$.1	$.1
Government Revenues	$12.6	$12.0	$11.4
Net Social Gain/Loss	$-2.4	$-2.7	$-3.0

TABLE A-15

SENSITIVITY ANALYSIS:
CRUDE OIL SUPPLY ELASTICITY--Continued

B. Revenue Maximizing Tariff on All Petroleum

	Low	Base	High
Elasticity Value:	.17	.33	.50
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$15.30	$12.20	$10.15
Gasoline	$13.75	$10.95	$9.15
Other	$15.30	$12.20	$10.15
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	1.1	1.7	2.1
Gasoline	-.5	-.4	-.2
Other	-.7	-.5	-.3
Change in Demand for: (Million barrels per day)			
Crude Oil	-1.2	-.8	-.5
Gasoline	-.9	-.8	-.6
Other	-2.3	-1.8	-1.5
Welfare Analysis: (Billion dollars per year)			
Consumers	$-87.0	$-70.9	$-59.8
Crude Oil Producers	$49.3	$40.7	$34.6
Refiners	$-.4	$-.3	$-.2
Government Revenues	$23.1	$18.4	$15.3
Net Social Gain/Loss	$-15.0	$-12.0	$-10.0

TABLE A-15

SENSITIVITY ANALYSIS:
CRUDE OIL SUPPLY ELASTICITY--Continued

C. $5 Tariff on Crude Oil and Gasoline

	Low	Base	High
Elasticity Value:	.17	.33	.50
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$2.60	$2.60	$2.60
Gasoline	$5.00	$5.00	$5.00
Other	$.00	$.00	$.00
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.2	.4	.5
Gasoline	-3.1	-3.0	-3.0
Other	-4.2	-4.1	-4.0
Change in Demand for: (Million barrels per day)			
Crude Oil	-7.0	-6.9	-6.7
Gasoline	-.3	-.3	-.3
Other	.0	.0	.0
Welfare Analysis: (Billion dollars per year)			
Consumers	$-12.9	$-12.9	$-12.9
Crude Oil Producers	$8.0	$8.1	$8.1
Refiners	$-1.8	$-1.8	$-1.7
Government Revenues	$4.5	$4.4	$4.2
Net Social Gain/Loss	$-2.2	$-2.2	$-2.3

TABLE A-15

SENSITIVITY ANALYSIS:
CRUDE OIL SUPPLY ELASTICITY--Continued

D. Excise Tax on Refined Product Yielding Same Revenue as $5 Tariff on All Refined Product

	Low	Base	High
Elasticity Value:	.17	.33	.50
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$.00	$.00	$.00
Gasoline	$2.05	$1.95	$1.85
Other	$2.05	$1.95	$1.85
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.0	.0	.0
Gasoline	.0	.0	.0
Other	.0	.0	.0
Change in Demand for: (Million barrels per day)			
Crude Oil	.0	.0	.0
Gasoline	-.1	-.1	-.1
Other	-.3	-.3	-.3
Welfare Analysis: (Billion dollars per year)			
Consumers	$-13.3	$-12.6	$-12.0
Crude Oil Producers	$.0	$.0	$.0
Refiners	$.0	$.0	$.0
Government Revenues	$12.6	$12.0	$11.4
Net Social Gain/Loss	$-.7	$-.6	$-.6

product supply elasticity. [Table A-16.] For the case of a $5 tariff on crude oil and gasoline, the choice of a lower elasticity value increases the net social cost from $2.2 to $2.8 billion.

The analytical model's results appear to be most sensitive to variations in the assumed refined product demand elasticities. [Table A-17.] In the case of a revenue-maximizing tariff, the maximum attainable revenue varies by 30-50% around the model's estimate of $18.4 billion, from $13.2 to $28.2 billion per year. Similarly, the net social loss varies by about 25% about the model's estimate of $12.0 billion, from $9.6 to $16.1 billion per year. While the assumption of lower demand elasticities, i.e., in the neighborhood of .19, would appear to significantly increase the revenue yield, the net social loss would be greatly increased as well.[33] Moreover, there

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[33] For the deadweight loss to vary inversely with the demand elasticity is contrary to conventional wisdom (as reflected in the results obtained with the other two tariffs and the sales tax considered). This arises because the magnitude of the revenue-maximizing tariff itself varies (inversely) with the assumed demand elasticity, from a level of $17.95 for the low elasticity value to $9.05 with the high elasticity value. Nevertheless, even though the social loss is higher at the lower demand elasticity, the social cost per dollar of revenue declines from $0.65 to $0.57 upon halving the baseline elasticity. However, the social cost per dollar for the corresponding equal-revenue excise tax on refined products would also decline, from about $0.06 to $0.03 per dollar revenue.

TABLE A-16

SENSITIVITY ANALYSIS:
REFINED PRODUCT SUPPLY ELASTICITY

A. $5 Tariff on All Petroleum

	Low	Base	High
Elasticity Value:	16.87	33.74	50.61
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$5.00	$5.00	$5.00
Gasoline	$4.60	$4.55	$4.55
Other	$5.00	$5.00	$5.00
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.7	.7	.7
Gasoline	.1	.1	.1
Other	.1	.1	.1
Change in Demand for: (Million barrels per day)			
Crude Oil	.2	.2	.2
Gasoline	-.3	-.3	-.3
Other	-.7	-.7	-.7
Welfare Analysis: (Billion dollars per year)			
Consumers	$-30.6	$-30.5	$-30.5
Crude Oil Producers	$15.8	$15.8	$15.8
Refiners	$.1	$.1	$.0
Government Revenues	$12.0	$12.0	$12.0
Net Social Gain/Loss	$-2.7	$-2.7	$-2.7

TABLE A-16

SENSITIVITY ANALYSIS:
REFINED PRODUCT SUPPLY ELASTICITY--Continued

B. Revenue Maximizing Tariff on All Petroleum

	Low	Base	High
Elasticity Value:	16.87	33.74	50.61
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$12.25	$12.20	$12.15
Gasoline	$10.90	$10.95	$10.95
Other	$12.25	$12.20	$12.15
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	1.7	1.7	1.7
Gasoline	-.3	-.4	-.4
Other	-.5	-.5	-.5
Change in Demand for: (Million barrels per day)			
Crude Oil	-.8	-.8	-.8
Gasoline	-.7	-.8	-.8
Other	-1.8	-1.8	-1.8
Welfare Analysis: (Billion dollars per year)			
Consumers	$-70.9	$-70.9	$-70.7
Crude Oil Producers	$40.9	$40.7	$40.5
Refiners	$-.5	$-.3	$-.2
Government Revenues	$18.5	$18.4	$18.4
Net Social Gain/Loss	$-12.0	$-12.0	$-11.9

TABLE A-16

SENSITIVITY ANALYSIS:
REFINED PRODUCT SUPPLY ELASTICITY--Continued

C. $5 Tariff on Crude Oil and Gasoline

	Low	Base	High
Elasticity Value:	16.87	33.74	50.61
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$3.00	$2.60	$2.50
Gasoline	$5.00	$5.00	$5.00
Other	$.00	$.00	$.00
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.4	.4	.3
Gasoline	-3.0	-3.0	-3.0
Other	-4.1	-4.1	-4.1
Change in Demand for: (Million barrels per day)			
Crude Oil	-6.8	-6.9	-6.9
Gasoline	-.3	-.3	-.3
Other	.0	.0	.0
Welfare Analysis: (Billion dollars per year)			
Consumers	$-12.9	$-12.9	$-12.9
Crude Oil Producers	$9.3	$8.1	$7.7
Refiners	$-3.5	$-1.8	$-1.2
Government Revenues	$4.3	$4.4	$4.4
Net Social Gain/Loss	$-2.8	$-2.2	$-2.1

TABLE A-16

SENSITIVITY ANALYSIS:
REFINED PRODUCT SUPPLY ELASTICITY--Continued

D. Excise tax on Refined Product Yielding Same Revenue as $5 Tariff on All Petroleum

	Low	Base	High
Elasticity Value:	16.87	33.74	50.61
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$.00	$.00	$.00
Gasoline	$1.95	$1.95	$1.95
Other	$1.95	$1.95	$1.95
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.0	.0	.0
Gasoline	.0	.0	.0
Other	.0	.0	.0
Change in Demand for: (Million barrels per day)			
Crude Oil	.0	.0	.0
Gasoline	-.1	-.1	-.1
Other	-.3	-.3	-.3
Welfare Analysis: (Billion dollars per year)			
Consumers	$-12.6	$-12.6	$-12.7
Crude Oil Producers	$.0	$.0	$.0
Refiners	$.0	$.0	$.0
Government Revenues	$12.0	$12.0	$12.0
Net Social Gain/Loss	$-.6	$-.6	$-.6

TABLE A-17

SENSITIVITY ANALYSIS:
REFINED PRODUCT DEMAND ELASTICITY

A. $5 Tariff on All Petroleum

	Low	Base	High
Elasticity Value:			
Gasoline	.18	.37	.55
Other	.19	.38	.57
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$5.00	$5.00	$5.00
Gasoline	$4.60	$4.55	$4.50
Other	$5.00	$5.00	$5.00
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.7	.7	.7
Gasoline	.2	.1	-.1
Other	.3	.1	-.1
Change in Demand for: (Million barrels per day)			
Crude Oil	.5	.2	-.1
Gasoline	-.2	-.3	-.5
Other	-.4	-.7	-1.1
Welfare Analysis: (Billion dollars per year)			
Consumers	$-31.1	$-30.5	$-30.0
Crude Oil Producers	$15.8	$15.8	$15.8
Refiners	$.2	$.1	$.0
Government Revenues	$13.5	$12.0	$10.5
Net Social Gain/Loss	$-1.7	$-2.7	$-3.7

TABLE A-17

SENSITIVITY ANALYSIS:
REFINED PRODUCT DEMAND ELASTICITY--Continued

B. Revenue Maximizing Tariff on All Petroleum

	Low	Base	High
Elasticity Value:			
Gasoline	.18	.37	.55
Other	.19	.38	.57
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$17.95	$12.20	$9.05
Gasoline	$16.25	$10.95	$8.10
Other	$17.95	$12.20	$9.05
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	2.5	1.7	1.2
Gasoline	-.2	-.4	-.4
Other	-.2	-.5	-.6
Change in Demand for: (Million barrels per day)			
Crude Oil	-.4	-.8	-1.0
Gasoline	-.6	-.8	-.8
Other	-1.3	-1.8	-2.0
Welfare Analysis: (Billion dollars per year)			
Consumers	$-106.7	$-70.9	$-52.0
Crude Oil Producers	$62.5	$40.7	$29.5
Refiners	$-.1	$-.3	$-.3
Government Revenues	$28.2	$18.4	$13.2
Net Social Gain/Loss	$-16.1	$-12.0	$-9.6

TABLE A-17

SENSITIVITY ANALYSIS:
REFINED PRODUCT DEMAND ELASTICITY--Continued

C. $5 Tariff on Crude Oil and Gasoline

	Low	Base	High
Elasticity Value:			
Gasoline	.18	.37	.55
Other	.19	.38	.57
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$2.60	$2.60	$2.60
Gasoline	$5.00	$5.00	$5.00
Other	$.00	$.00	$.00
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.4	.4	.4
Gasoline	-3.0	-3.0	-3.0
Other	-4.1	-4.1	-4.1
Change in Demand for: (Million barrels per day)			
Crude Oil	-6.9	-6.9	-6.9
Gasoline	-.2	-.3	-.5
Other	.0	.0	.0
Welfare Analysis: (Billion dollars per year)			
Consumers	$-13.1	$-12.9	$-12.8
Crude Oil Producers	$8.1	$8.1	$8.1
Refiners	$-1.8	$-1.8	$-1.8
Government Revenues	$5.3	$4.4	$3.4
Net Social Gain/Loss	$-1.5	$-2.2	$-3.0

TABLE A-17

SENSITIVITY ANALYSIS:
REFINED PRODUCT DEMAND ELASTICITY--Continued

D. Excise Tax on Refined Product Yielding Same Revenue as $5 Tariff on All Petroleum

	Low	Base	High
Elasticity Value:			
Gasoline	.18	.37	.55
Other	.19	.38	.57
Change in Domestic Price of: (Dollars per barrel)			
Crude Oil	$.00	$.00	$.00
Gasoline	$2.15	$1.95	$1.75
Other	$2.15	$1.95	$1.75
Change in Domestic Supply of: (Million barrels per day)			
Crude Oil	.0	.0	.0
Gasoline	.0	.0	.0
Other	.0	.0	.0
Change in Demand for: (Million barrels per day)			
Crude Oil	.0	.0	.0
Gasoline	-.1	-.1	-.2
Other	-.2	-.3	-.4
Welfare Analysis: (Billion dollars per year)			
Consumers	$-13.9	$-12.6	$-11.4
Crude Oil Producers	$.0	$.0	$.0
Refiners	$.0	$.0	$.0
Government Revenues	$13.5	$12.0	$10.5
Net Social Gain/Loss	$-.4	$-.6	$-.9

is little evidence to suggest that these elasticities would be in this neighborhood in a five year time horizon.[34]

In conclusion, the sensitivity analysis provides strong support for the conclusions of this report. The cited alternative specifications did not in any instance change the sign of a gain or loss going to any subgroup of society or to society as a whole. Indeed, in most instances, there was no significant variation in magnitude.

Alternative Baseline Price Assumption

The baseline price level used in this study was calculated as an average of prevailing prices predicted for the decade beginning in 1990.[35] While recent MidEast tensions have increased petroleum prices dramatically, there is little reason at this point to believe that these increases will be any more than short term in duration. Nevertheless, we address in this section the impact of assuming higher baseline prices on the results of this study.

An alternative initial equilibrium based on higher petroleum prices would in all likelihood be characterized

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[34] As indicated previously, these estimates were obtained from D.O.E. projections. In a recent book, Bohi (1981) surveyed numerous studies of gasoline demand and concluded that an appropriate estimate was about .2 for the short run and at least .7 for the long run. A survey of about seventy such studies by Dahl (1986) provided comparable findings. For comparison purposes, the five year time horizon of this model can probably be reasonably characterized as being midway between short run and long run.

[35] Recently, D.O.E. updated its projections for prices and quantities for this period. [U.S. D.O.E. (1990a).] The revisions were minor and would not significantly affect the estimates provided in this study.

by: (1) reduced domestic consumption of petroleum products; (2) increased domestic crude oil production; (3) virtually unchanged U.S. refinery output;[36] and (4) reduced imports of both crude oil and refined products.[37] With these characteristics in mind, it is possible to predict how an alternative baseline assumption would affect the gains and losses of consumers, crude oil producers, refiners, and the government.

Clearly, with lower levels of imports, the government revenues that could be collected from a given tariff would be reduced in going to an alternative initial equilibrium based on higher petroleum prices. An equal-revenue excise tax would by its definition raise a correspondingly lower level of revenues.

For consumers, a higher baseline price assumption would reduce the consumer cost of an import tariff in two ways. First, as indicated above, the level of consumption of refined products would be lower. Hence, consumers would incur an increase in price on fewer units of petroleum products. Second, the tariff-generated increase in domestic prices of such products may be lower. Recall that for the uniform tariffs considered in this report, the increase in domestic price of gasoline (or all refined products) was less than the amount of the tariff. This occurred because imports were choked off before domestic prices had risen by as much as the tariff. Since, as indicated above, an initial equilibrium based on higher

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[36] Since crude oil and refined product prices would move more or less in tandem, domestic refinery output should not be significantly affected.

[37] This follows as a logical consequence of the three preceding points.

prices would involve fewer imports, price would rise less before imports were reduced to zero.[38]

The consumer cost of an equal-revenue excise tax would also be reduced in two ways by a higher baseline price assumption. First, the level of consumption of refined products would be lower. Second, because the corresponding tariff would yield less revenue at the new baseline, the tax rate per unit may be lower.[39]

Due to a correspondingly higher output, the gain to crude oil producers arising from a tariff would be greater when calculated from an initial equilibrium based on higher petroleum prices.[40] As before, crude oil producers would

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[38] An illustration can be found in the $5 tariff on all petroleum, where it was observed that the U.S. became self-sufficient with respect to gasoline. Similarly, a revenue-maximizing tariff of $12.20 on all petroleum resulted in self-sufficiency for all refined products. In both cases, as domestic prices increased, domestic demand shrunk to the point where domestic refineries satisfied domestic demand. Consequently, if the analysis were to assume higher baseline prices, both domestic consumption and imports of refined products would be lower in the new baseline than in the original baseline. The U.S. would become self-sufficient in gasoline, and perhaps in other refined products, with smaller price increases for any given tariff.

[39] This presumes, as was the case in this study, that the higher prices associated with the alternative baseline would cause the tax base of the excise tax to decrease less than the tax base of the import tariff. That is, the elasticity of demand for refined products is less than the elasticity of demand for all petroleum imports.

[40] An exception to this could conceivably occur if imports of crude oil were eliminated by the tariff in the higher price baseline but not in the lower price baseline. However, given the relative magnitudes of supply in the two

be unaffected by an equal-revenue excise tax, whatever the initial baseline assumption.

Finally, the effect of higher baseline prices on refiners' gains or losses from imposition of a tariff is indeterminate. If higher baseline prices cause the price of gasoline and/or other refined product to rise less before all imports are eliminated, refiners' gains (losses) are likely to be smaller (greater). On the other hand, if all imports of crude oil are eliminated, and, as a result, the increase in price of crude oil is smaller with higher baseline prices, refiners are likely to find their gains increased (or losses decreased).[41]

In summary, for a tariff on petroleum imports, the assumption of a higher baseline price level would reduce tariff revenues, reduce the costs to consumers, increase the gains to crude oil producers, and reduce or increase the gain or loss to refiners. For an equal-revenue excise tax, a higher baseline price would (only) reduce the cost to consumers. While the net effect (i.e., in terms of deadweight loss) is unambiguously positive for the excise

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baselines, the domestic price increase in the former would have to be significantly less than that in the latter.

[41] For example, in the case of a $5 tariff on all petroleum imports, the domestic price of gasoline rose by only $4.55. With a higher price baseline, the pre-tariff level of imports would be less, so that the same tariff would cause the domestic gasoline price to rise by even less than $4.55. If imports of other refined products were also choked off, then the increase in that price would be less than $5.00 as well. To the extent that higher baseline prices did not affect the tariff-induced increase in input prices but reduced the increase in one or more product prices, refiners' gain (loss) from the tariff would be reduced (increased). A contrasting example can be found in the case of a $5 tariff on crude oil and gasoline imports. In this case, it is crude oil imports that are choked off.

tax, the sign of the net effect for the tariff is not readily apparent.

In order to ascertain the robustness of the results reported in this study with respect to higher baseline prices, two alternative baselines were examined. World prices were assumed to be \$10 and \$20 higher than the original baseline level, corresponding to crude oil prices of approximately \$30 and \$40, respectively.[42] In examining a tariff of \$5 on all petroleum imports and a \$5 tariff on crude oil and gasoline imports, the same results were obtained:

1) Tariff revenues were reduced by approximately 50% at the \$10 higher baseline, and fell to zero at the \$20 higher baseline;
2) The deadweight loss arising from a tariff was not substantially different across baselines;
3) The deadweight loss per dollar revenue was consequently twice as high at the \$10 higher baseline;
4) The deadweight loss per dollar of an equal-revenue excise tax was essentially unchanged in going from the original to the \$10 higher baseline.

The results of this study are therefore strengthened by

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[42] Refined product prices were arbitrarily assumed to increase by the same amount, $\$10\rho$ and $\$20\rho$, where ρ represents the rate at which the world price of refined product changes with respect to the world price of crude oil. For competitive markets, this rate can be argued intuitively to be in the neighborhood of the ratio of crude oil input to refined product output, i.e., $1/r$. That is, for a cost increase to be fully passed on to consumers, a \$1 increase in the price of a barrel of crude oil should cause the price of a barrel of refined product to increase by $\$(1/r)$. While the appropriate value of r should probably be that for the world (i.e., 1.02) rather than that for the U.S., both values were used in this exercise. [U.S. D.O.E. (1988b).] The results were not significantly different.

the assumption of higher baseline prices. Not only does a tariff generate substantially less revenue as baseline prices are increased, it does so at a much higher cost per dollar relative to the corresponding equal-revenue excise tax.

The Effect of Tariffs on World Petroleum Prices

This study has assumed that world petroleum prices would be unaffected by a tariff on U.S. imports or a sales tax on U.S. consumption. That is, we have assumed that the foreign supply curve of petroleum is infinitely elastic. As a result, any tariff or tax would be fully passed through to consumers. This assumption was made because there are no reliable estimates of how the world price of crude oil might change in response to a change in U.S. demand occasioned by a tariff or tax.

However, because the United States accounts for a large share of world petroleum consumption, it is possible that the world price would decline if a tariff or tax were imposed. If this were to occur, the costs of the tariff or tax would only be partially passed through to U.S. consumers; the remainder of the tariff or tax would be reflected in the lower price received by foreign and domestic producers. As a result, the losses to consumers, as well as the gains to producers would be smaller than what has been reported here. For a given tariff or tax rate, government revenues would also increase slightly. The net social costs of the tariff or tax would be lower than what we have estimated.

In addition to reducing the costs of the two instruments we have analyzed, the presence of an upward sloping supply curve would reduce the differences between the costs of a tariff and the costs of an equal revenue excise tax. Indeed, if the world supply curve is sufficiently inelastic, a tariff may involve a lower net social cost--though not a lower cost to consumers--than the equal revenue tax. This occurs because the upward sloping supply curve implies that the U.S. can exercise monopsony power in its purchase of foreign oil, and because a tariff does a better job of extracting the available monopsony rents.

The effect of a world supply curve with less than an infinite elasticity can be analyzed within the context of the model developed in this study.[43] Specifically, we can determine how the amount of any tariff or tax that would be passed through to U.S. consumers is affected by alternative assumptions regarding the supply of crude oil and the demand for refined products in the rest of the world. For purposes of this calculation, we have for simplicity aggregated gasoline and other refined products.

Define the import supply functions for crude oil and refined products as the excess of foreign supply over foreign demand:

$$I_c = S_c(P_c) - D_c(P_c, P_r) \quad (31a$$

$$I_r = S_r(P_c, P_r) - D_r(P_r)$$

$$= mD_c(P_c, P_r) - D_r(P_r)\ , \quad (31b$$

where m is the ratio of refined product output to crude oil input. The quantity of refined product imports can be expressed in terms of a crude oil equivalent measure by dividing I_r by m. Total imports in crude oil equivalent measures is then

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[43] As with the analysis based on the assumption that the tariff or tax would be fully passed through, this analysis is based on the assumption that world petroleum markets function competitively, so that a supply curve can be said to exist. Although the crude oil market is not strictly competitive, a sizeable competitive fringe constrains OPEC's ability to set price substantially above the competitive level. Its ability to attain this constrained profit maximization level is further constrained by the fact that the OPEC members do not all have the same incentives. OPEC pricing decisions therefore represent compromises.

$$I = S_c(P_c) - D_r(P_r)/m \,. \qquad (32$$

Differentiating with respect to P_c yields

$$\partial I/\partial P_c = (\partial S_c/\partial P_c) - (1/m)(\partial D_r/\partial P_c)\rho \,, \qquad (33$$

where ρ is the derivative of P_r with respect to P_c. If we assume that a $1 increase in the price of a barrel of crude oil is fully passed on to consumers by refiners,[44] then the price of a barrel of refined products will increase by $1/m. Upon performing this substitution and introducing the foreign supply and demand elasticities, one finds

$$\partial I/\partial P_c = S_c e^s{}_c/P_c + D_r e^d{}_r/P_r m^2 \equiv w,\ e^d{}_r>0,\ w>0 \,. \qquad (34$$

Because this permits the approximation $dP_c \approx dI/w$, the amount of the tariff passed through to consumers can be calculated from the change in imports resulting from a given tariff. Specifically, the "pass-through" associated with a $t tariff would be $[(t+dP_c)/t]$, where $dP_c<0$.[45]

Using equation (34) and the estimates of the changes in U.S. demand for imported crude and refined product, we can estimate how a tariff or an equal-revenue excise tax would affect the world price of crude oil.[46] For purposes of this analysis, prices, quantities, and the ratio of refined

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[44] This would be generally true if petroleum refining were essentially a competitive industry.

[45] When world prices are unchanged by a tariff, it is commonly referred to as full or 100% pass-through. If on the other hand, a tariff caused world prices to decline by X% of the amount of the tariff, it would be termed a (100-X)% pass-through.

[46] Any such change in the world petroleum prices will affect the change in U.S. imports by affecting U.S. prices. Consequently, we have to solve iteratively for the change in world prices and changes in imports.

product to crude oil input (m) are set at values that are consistent with world production levels and baseline U.S. values assumed previously.[47] The foreign demand elasticity of refined products is assumed to be comparable to that in the U.S., and is calculated as the weighted sum of the two U.S. demand elasticities.[48]

More problematic is arriving at an estimate of the foreign supply elasticity. There is no reason to believe that U.S. and foreign supply elasticities would be comparable, given the differences in geologic features and availability of reserves. Conceptually, the elasticity of supply reflects the ability of producers to expand

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[47] For the world as a whole, the value of m appears historically to have been approximately 1.02. [U.S. D.O.E. (1987c), p. 30-31, 121.] The results are not changed appreciably if the U.S. value of 1.04 is used. [U.S. D.O.E. (1988b), pp. 30-31, 121.]

The foreign refined product price, $31.60, is calculated as the weighted sum of the baseline world prices of gasoline and other refined products. The weights, .20 and .80 respectively, are chosen consistent with observed foreign refinery mixes. [U.S. D.O.E. (1987c), p. 30-1.]

The baseline foreign crude oil supply S_c is assumed to be 67.9 mb/d. World crude oil production in 1990, 1995 and 2000 is estimated to be 66.3, 68.7, and 68.8 mb/d., respectively. [D.O.E. (1990b), p. 34-5.] Subtracting the baseline U.S. crude oil production of 6.5 mb/d from the average of world production in these three years yields foreign production of 67.9 mb/d.

The baseline foreign demand D_r for refined products is calculated from S_c and the baseline U.S. imports to be 46.0mb/d. Specifically, $D_r = [S_c - I_c] - I_r/m = 54.8-7.2-(1.7/1.04)$ in crude oil equivalent measure.

[48] To arrive at a demand elasticity for the aggregate, refined product, the U.S. elasticities for gasoline and other refined products are summed, weighted by their apparent shares in world consumption, namely .25 and .75, respectively. This yields a value of about .43.

production given an increase in the price. Crude oil suppliers who have only limited oil reserves can be expected ceteris paribus to be less able to expand production than suppliers possessing bountiful reserves. Consequently, the supply elasticity may be expected to vary directly, and perhaps even proportionally, with the ratio of reserves to actual production of crude oil.[49]

The ratio of U.S. oil reserves to actual production is approximately 3,300 days, while that for foreign producers is approximately 18,800 days.[50] This suggests that the foreign supply elasticity may be five to six times greater than that of the U.S. It is conservatively assumed here

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[49] In the petroleum supply forecasting model of Adelman and Jacoby, current production at any point in time can be expressed as the product of reserves and some function of the profit-maximizing rate of extraction. This rate is in turn a function of price. Upon finding an expression for the average production level over the timepath, the elasticity of supply in this model can be shown to be proportional to the ratio of reserves to actual production. [Adelman & Jacoby (1979), pp. 25-28.]

Alternatively, consider the case where a country is producing x units per day at the prevailing price and has R units in reserve. Reserves are defined as the amount of crude oil economically recoverable at prevailing price ranges, i.e., at prices in the neighborhood, ϵ, of the current price, p. If only μR could be extracted in a given day once these reserves are brought on-line, production could be expected to expand by $(\mu R/x)\%$, if price were to rise by $(\epsilon/p)\%$. Therefore, in this admittedly simplistic example, the elasticity of supply is approximately $[(\mu R/x)/(\epsilon/p)]$, and can be concluded to vary proportionally with the ratio of reserves to actual production.

[50] U.S production and reserves in 1989 were estimated to be 7.7 million barrels per day and 26 billion barrels, respectively. Non-U.S. production and reserves were 51.7 million barrels per day and 976 billion barrels. [Oil and Gas Journal, December 25, 1989, pp. 44-5.]

that the foreign crude oil supply elasticity is three times that assumed for the U.S., or 1.3 at the baseline prices.

Based on these values, w in equation (4) is found to have a value of about 5.1. Upon solving for the effect of a $5 tariff on all petroleum imports, we find that the world price of crude oil would fall by about $0.30.[51] That is, the "pass-through" of the tariff would be approximately 94%. The tariff raises $12.3 billion dollars in revenue, at a net cost of $1.6 billion to society and $28.7 billion to consumers.[52] An equal-revenue excise tax of $2.00 causes world prices to fall by about $0.10, resulting in a lower net social cost of $0.6 billion and a lower consumer loss of $12.6 billion.

In general, for the analytical model of this study, an import tariff will involve a higher net social cost than an equal-revenue sales tax for pass-throughs above approximately 85%. For pass-throughs less than approximately 85%, an import tariff will result in net gains for society as a whole, although the consumer cost will remain significantly greater than that for an equal-revenue excise tax down to a pass-through of about 40%.

There is little reason to believe that world petroleum prices would fall in response to an import tariff sufficiently to make the social cost of a tariff less than that of an equal-revenue excise tax. For example, even if the foreign supply elasticity were assumed to equal that for the U.S., the resulting pass-through would be approximately 85%. As indicated above, the foreign supply elasticity is in all likelihood significantly greater.

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[51] To obtain this, the analytical model is solved iteratively with the modification that $\Delta P_c = \Delta P_g = \Delta P_o = \Delta I/5.1$, where $\Delta I \equiv \Delta I_c + [(\Delta I_g + \Delta I_o)/1.04]$.

[52] For the alternative assumption of full pass-through, the tariff was estimated to raise $12.0 billion dollars in revenue, at a net cost of $2.7 billion to society and $30.5 billion to consumers. [Table I.]

In conclusion, if world prices would change significantly in response to the imposition of a U.S. tariff or tax, then, contrary to the results obtained in this study, a tariff may in fact be more attractive than an equal-revenue petroleum excise tax.[53] However, this would occur only if the pass-through is less than about 85%. It is our belief that, in fact, the pass-through is greater than 85%.

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[53] Moreover, as pointed out previously, the latter tax is not necessarily the best alternative to a petroleum import tariff, but rather serves in this study as a comparison that can be calculated readily from the same analytical framework.

IX. COMPARISON WITH RESULTS OF OTHER STUDIES

Table A-18 provides several comparisons of the various studies that have examined the effects of additional tariffs or taxes on crude oil, on some or all refined petroleum products, or on both crude oil and refined products. Where the same study contains analyses of different levels of tariffs or taxes on the same set of products, the figures in Table A-18 are for the case that comes closest to a $5 per barrel tariff. However, since there are still differences in the tax or tariff scenarios, we base our comparison on measures that should be relatively insensitive to small changes in the size of the policy change being considered. First, we report the estimated increase in revenue per unit of tariff or tax. In looking at tariffs, this is billions of dollars in annual government revenue per dollar of tariff. For taxes, the figure is billions of dollars of government revenue per penny of tax. Second, we look at the social cost, or deadweight loss, per dollar of revenue earned.

Tariffs on Crude Oil Alone

The first section of the table compares estimates of the effect of a tariff on crude oil alone; no restriction is imposed on imports of refined products. A striking difference exists between our results--both in the current study and in our 1987 report--and those reported by de Melo, Stanton, and Tarr and by Boyd and Uri. As explained in the text, we find that any significant tariff on crude oil alone will not generate any revenue because it will simply result in the substitution of imports of unrestricted refined products for imports of crude oil. In contrast, de Melo, Stanton and Tarr estimate that a 25 percent import tariff on crude oil--which, given that their model is benchmarked to 1984, amounts to a tariff of slightly more than $7 per barrel--will generate $7.29

TABLE A-18

COMPARISON OF ESTIMATED EFFECTS OF
ADDITIONAL TARIFFS AND TAXES ON
CRUDE OIL AND REFINED PETROLEUM PRODUCTS

Source of Estimate	Revenue Per Unit Tariff or Tax[1]	Social Cost Per Dollar of Revenue
A. Tariffs on Crude Oil Alone		
Current Study	$0.00	---
Anderson and Metzger (1987)	0.00	---
Melo, Stanton and Tarr (1988)	1.02	$0.26
Boyd and Uri (1989)	0.68	-1.00[2]
B. Tariffs on Crude Oil and Gasoline		
Current Study	0.88	0.51
Anderson and Metzger (1987)[3]	1.34	0.57

[1] Revenue figures are measured in billions of dollars per year. For tariffs, they are measured as revenue per dollar per barrel of tariff. For taxes, they are measured as revenue per penny per gallon of tax.

[2] This is the sum of the change in household utility and the change in government utility, as reported by Boyd and Uri. If utility derived from the provision of government services is not included, the cost per dollar of revenue is $0.06.

[3] When it was assumed that the world price of crude oil and gasoline depended on the quantity demanded by the U.S., the estimated increase in government revenue was $1.64 billion per year per dollar of tariff and the social cost was $0.44 per dollar of increased revenue.

TABLE A-18

COMPARISON OF ESTIMATED EFFECTS OF
ADDITIONAL TARIFFS AND TAXES ON
CRUDE OIL AND REFINED PETROLEUM PRODUCTS--Continued

Source of Estimate	Revenue Per Unit Tariff or Tax[4]	Social Cost Per Dollar of Revenue
C. Tariffs on Crude Oil and All Refined Products		
Current Study	2.41	0.22
U.S. Department of Energy (1986)	1.95	N/A
Congressional Budget Office (1986)	1.91	N/A
D. Excise Tax on Gasoline		
Current Study	0.99	0.12
Uri and Boyd (1989)	0.54	0.87[5]
U.S. Department of Energy (1986)	0.85	N/A
Congressional Budget Office (1986)	0.76	N/A
E. Excise Tax on All Refined Products		
Current Study	2.57	0.05
Melo, Stanton and Tarr (1988)	N/A	0.01

[4] Revenue figures are measured in billions of dollars per year. For tariffs, they are measured as revenue per dollar per barrel of tariff. For taxes, they are measured as revenue per penny per gallon of tax.

[5] This is the sum of the change in household utility and the change in government utility, as reported by Uri and Boyd. If utility derived from the provision of government services is not included, the cost is $1.87 per dollar of revenue.

billion in government revenue.[54] Similarly, Boyd and Uri estimate that government revenue would be increased by $3.41 billion per year by the imposition of a $5 per barrel crude tariff.[55]

We believe that the differences between our results and those of the other authors can be ascribed to the more detailed and accurate modelling of the crude oil and refining sectors in our work. In particular, our model of the petroleum industry includes two sectors: crude oil and refined petroleum products. By contrast, the two other studies include natural gas and crude oil in the same sector.

The other important assumption in explaining the difference between our results and those of the other two studies is found in our assumption that imported petroleum is a perfect substitute for domestic petroleum, whether in the form of crude oil or refined. For example, if domestic products and imports are imperfect substitutes,[56] crude oil imports might not be eliminated with the imposition of a $5 tariff on crude oil. However, we believe that domestic and imported refined products are sufficiently close substitutes that the estimates obtained under the perfect substitute assumption are reasonable approximations to what would be observed. Similarly, while there are numerous different "types" of crude oil, the assumption is probably nevertheless reasonable for our purposes since: (1) for many (if not most) types of foreign crude oil, there exists a comparable domestic counterpart; and (2) within the relevant five year time horizon, capacity can be

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[54] Melo, Stanton, and Tarr (1989), p. 436.

[55] Boyd and Uri (1989), p. 40.

[56] In particular, it is possible that some consumers may have a preference for domestically refined products because of increased certainty of supply and smaller lead times on deliveries.

reconfigured and expanded to process different types of crude oils.

In contrast, de Melo, Stanton, and Tarr assume that domestic and imported petroleum--both crude oil and refined products--are considerably less than perfect substitutes. In their model, the degree of substitutability in demand between domestic products and imports for use as intermediate goods is determined separate from that for final consumption. For intermediate goods, the de Melo, Stanton and Tarr model expresses the degree of substitutability in terms of the elasticity of substitution.[57] Whenever two inputs are perfect substitutes, the elasticity of substitution is equal to infinity. However, de Melo, Stanton and Tarr assume the elasticity of substitution to be 2.4 for both crude oil and refined products,[58] considerably less than infinity and, moreover, less than the elasticity of substitution for three out of four nonpetroleum manufacturing sectors in their model.[59] In the case of final demands, the combination of the assumptions made about own elasticities of demand and the structure of the demand system used by de Melo, Stanton, and Tarr implies that domestic refined

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[57] The elasticity of substitution is defined as the percentage change in the ratio of quantity of domestic crude oil used to the quantity of imported crude oil used, divided by the percentage change in the ratio of the two prices. Note that the ratio of the prices is expressed in an inverse manner relative to the ratio of the quantities. That is, if the quantities are expressed as the ratio of domestic product to imports, then the prices would be expressed as the ratio of imports to domestic product. As a result, the elasticity of substitution is positive.

[58] Melo, Stanton, and Tarr (1989), p. 434.

[59] Tarr (1989), p. 5-4. The exception is automobiles, where the elasticity of substitution is assumed to be 2.01.

products are complements, not substitutes, for imports.[60] That is, an increase in the price of imports will cause the demand for domestically produced refined products to contract, not expand. We see no reason to believe such a condition is at all realistic.

Because we estimate that there would be no revenue earned from a crude oil tariff, we do not compare our study with those of others on the basis of social cost per dollar of revenue. However, it is interesting to note how much this statistic differs between the other two studies. While de Melo, Stanton, and Tarr find that society loses about $0.26 per dollar of revenue realized, Boyd and Uri find that society actually is better off by a dollar for each dollar of revenue earned.[61]

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[60] Specifically, given the structure of the demand equations used by Melo, Stanton, and Tarr, any time the own price elasticity of demand for a good is less than -1.0, the cross-elasticity of demand between that good and any other good, including imports or domestic production of the same good, is less than zero. [Tarr (1989), p. 5-10).] Melo, Stanton, and Tarr assume that the own price elasticities of demand are -0.92 for both domestic and imported refined products (as compared to our use of -0.37). [Melo, Stanton, and Tarr (1989), p. 434.]

[61] Boyd and Uri report that welfare declines by approximately about $208 million per year, or $0.06 per dollar of revenue raised. [Boyd and Uri (1989), p. 42.] However, this figure is based solely on changes in welfare accruing directly to households. In their model, government also accrues utility; and the government utility increases by $3.6 billion per year when the tariff is enacted. Since the utility generated by the government must ultimately be the value consumers place on the provision of government services, it would appear to be more appropriate to include changes in government welfare in evaluating the effects of a tariff or tax.

While it is possible that a tariff can increase U.S. welfare by causing the price that must be paid to foreign producers to fall--i.e., an optimal tariff may exist--it is virtually impossible for the social gain from the tariff to be as large as the revenue collected by the government. In the context of the conventional partial equilibrium analysis, this could only occur if the import supply curve were perfectly inelastic.[62] The Boyd-Uri analysis is based on a computable general equilibrium model. While the crude oil import supply equation used in the model is not reported, the authors do report sufficient information to suggest that a perfectly inelastic import supply curve is not the explanation for their results.[63]

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[62] With a perfectly inelastic import supply curve, the price paid to foreign producers would fall by the amount of the tariff and nothing else would change in the domestic economy.

[63] Another seeming anomaly in the Boyd-Uri paper arises in comparing the reported change in the quantity of imported crude oil and the reported increase in the price of domestic crude oil. Boyd and Uri report that the price of domestic crude oil would rise by only 0.064 percent if a $5 tariff was imposed on imported crude oil. This would seem to imply either that domestic and imported crude oil are very poor substitutes or that the price of imported crude oil only rises slightly in response to the tariff, i.e., the world price falls by almost as much as the tariff. However, the authors acknowledge that domestic and imported crude oils are "near perfect substitutes." [Boyd and Uri (1989), p. 38.] In addition, the assumed elasticity of demand for crude oil imports and the reported change in the quantity of imports are inconsistent with the notion that the price of imported crude oil does not rise significantly.

Tariffs on Crude Oil and Gasoline

The second section of Table A-18 provides a comparison of our current estimates of the effects of a $5 per barrel tariff on both crude oil and gasoline (but not on other refined products), with our analysis of the same tariff in our 1987 study. Our current estimates of the net increase in government revenue resulting from the tariff are about one-third smaller than what we estimated previously. Two factors primarily account for this difference. First, in our current study we estimate that the $5 tariff on crude and gasoline would reduce revenues from pre-existing gasoline taxes by $1.25 billion per year or $0.25 billion per dollar of tariff. We did not consider the loss of revenue from such existing taxes in our earlier work.

Second, on the basis of more precise information on the U.S. refinery operations, we have modeled domestic refiners' demand for crude oil as being much more responsive to changes in the prices of inputs and outputs than we did in our earlier work.[64] As a result, while we previously estimated that the U.S. would import 1.1 mbd of crude oil after the imposition of the $5 tariff, we now show all imports of crude oil being eliminated well before the domestic price of crude oil rises by the amount of the tariff. Our current estimate of the revenue generated by

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[64] In our earlier model, the imposition of a $1 tariff on crude oil would have caused refiners' demand for crude oil to fall by 2.41 million barrels per day (mbd), holding the price of refined products and everything else constant. In the current model, the same $1 crude oil tariff would cause demand to fall by 17.04 mbd. A $1 tariff on both crude oil and gasoline would reduce demand for crude oil by 9.5 mbd in the current model, compared to a reduction of 1.12 mbd in the earlier model. [Anderson and Metzger (1987), p. 71.]

the tariffs is accordingly lower than in our earlier work.[65]

Indeed, the current study's refinery sector model--in which a value of 33.74 is assumed for the refined product supply elasticity--is one of the most significant departures from the analysis contained in the earlier study. This departure is primarily attributable to an improved understanding of the refining process, together with the superior elasticity estimate obtained from D.O.E.'s Refinery Yield Model. This elasticity value, while admittedly large, appears reasonable given the characteristics of the industry: Petroleum refining is essentially a processing or manufacturing activity that has for the most part two inputs: capital (in the form of plant and equipment) and crude oil. In a five year time horizon, it is expected that the former can be modified and/or expanded so as to increase capacity without appreciably raising average and marginal costs. That is, the industry's supply curve (holding crude oil and capital prices constant) should be relatively flat, consistent with the assumption of a high elasticity value.

Tariffs on Crude Oil and All Refined Products

Part C of Table A-18 compares estimates of the revenue that would be generated from the imposition of a tariff on crude oil and all refined products.[66] Our estimates of the

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[65] Estimated imports of gasoline in the current study are somewhat higher than in the earlier one, i.e., 3.7 mbd as compared to 3.1 mbd. While this partially offsets the reduction in imports of crude oil, the total quantity of imports subject to the $5 per barrel tariff is lower in the current model (3.1 mbd) than in the earlier one (4.2 mbd).

[66] Since neither the study by the Energy Information Administration nor that by the Congressional Budget Office

revenue realized per dollar of tariff appear to be somewhat higher than those reported by the Energy Information Administration in the Department of Energy (D.O.E.) or by the Congressional Budget Office (C.B.O.).[67] This appears to be the result of higher levels of imports in our baseline. While imports of crude oil and refined products come to 9.0 mbd in our baseline, the D.O.E. study has baseline imports of only 6.7 mbd. The C.B.O. study appears to have used similar figures.

This difference may be the result of the periods covered by the different baselines. While the D.O.E. baseline is for 1990 and the G.A.O. figures cover the period 1987 to 1991, our baseline is an average for the period 1990 to 1999. Since imports are expected to rise over time, it is not surprising that our baseline has a higher level of imports.[68]

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provide estimates of the welfare effects of the tariffs they analyze, we have nothing with which to compare our estimate of the social costs that would result from such a tariff.

67 In addition to estimating changes in government revenues, these two studies consider the effects of the tariffs on economy-wide unemployment and inflation rates, as well as the resulting changes in government expenditures. Such changes in government expenditures are not included in our comparisons nor are they considered in the current study. However, we note that the authors of these studies estimate that such increases could substantially reduce the deficit-reducing effect of such tariffs. [C.B.O. (1986), pp. 15-17; and U.S. D.O.E. (1986), pp. 43-44.]

68 According to the Annual Energy Outlook 1989, imports of crude oil and refined products would be 7.0 mbd in 1990 if the price of crude oil is $18 per barrel. [U.S. D.O.E. (1989), p. 75.] Since higher prices result in lower

Another difference between our study and the other two concerns the tax revenues included in the analysis. Our study considers only changes in tariff revenues and in state and federal gasoline taxes. The D.O.E. and C.B.O. studies include estimates of the effect on the revenue from the Windfall Profits Tax and on general corporate and personal income tax revenues.[69] Since the Windfall Profits Tax was repealed in 1988, there are no longer any effects to include.[70] Neither of the other studies consider the effect on state gasoline tax revenues.

Excise Tax on Gasoline

Different estimates of the effects of increasing excise taxes on gasoline are reported in section D of Table A-18. In terms of revenue earned per penny-per-gallon tax, three of the four estimates do not differ greatly. The greatest difference is between our study which estimates revenue of almost $1 billion per year for each penny per gallon increase and the results of Uri and Boyd who estimate that each one cent increase in the tax will only generate about $540 million in revenue per year. An even greater difference between the current paper and the work of Uri and Boyd is found by comparing the estimates of social cost per dollar of revenue raised. While our estimates show a relatively small social cost of $0.12 per dollar of revenue raised, Uri and Boyd estimate $0.87 of utility is lost for

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levels of imports, this figure compares quite favorably with the 6.7 mbd figure in the D.O.E. baseline, where a price of $20 per barrel is assumed. [U.S. D.O.E. (1986), p. 39.]

[69] C.B.O. (1986), pp. 15, 17; and U.S. D.O.E. (1986), p. 44.

[70] Energy Users News, August 29, 1988, p. 2.

each dollar of revenue raised.[71] Because Uri and Boyd's results come from a complex general equilibrium model and all of the details of the model are not included in the published article, we have not been able to determine what is causing their seemingly anomalous results. However, we note that the 21 percent increase in the price of "Gasoline and Other Fuels" as a result of a tariff on gasoline which amounts to less than 15 percent of total cost seems very surprising.[72]

Excise Tax on All Refined Products

The final section of Table A-18 compares our analysis of the effects of imposing an excise tax on all refined products with that of de Melo, Stanton, and Tarr. Since de Melo, Stanton, and Tarr express their tax as a 15 percent ad valorem tax, we cannot determine the revenue that would be realized per penny of tax levied. However, we note that in both studies the social cost per dollar of revenue earned is lower than the estimated cost of any of the other tax or tariff options considered.[73]

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[71] As in their analysis of the effects of a tariff on crude oil (see footnote 61 above), Uri and Boyd report changes in welfare based only on the direct changes in the welfare of consumers. Thus, the authors report that welfare declines by approximately $15 billion per year, or $1.87 per dollar of revenue raised. [Uri and Boyd (1989), p. 368.] However, when the $8 billion per year increase in government utility is included in the analysis, we get the $0.87 per dollar figure reported in the text.

[72] The tariff analyzed was $0.15 per gallon in 1984, when the price of gasoline was less than $1.00 per gallon.

[73] The one exception is Boyd and Uri's estimates of the costs (or benefits) of a crude oil tariff. However, as discussed above, there are questions about the reliability of these estimates.

General Versus Partial Equilibrium Models

While the analyses of Boyd and Uri and of de Melo, Stanton, and Tarr are based on general equilibrium models, both of the analyses by the current authors employ a partial equilibrium model. It is therefore useful to briefly consider the relative advantages and disadvantages of these two types of models. One of the main advantages of a general equilibrium (GE) approach is the ability to capture the interactions among industries.[74] If one good is used as an input in the production of another, imposition of a tax or tariff on the first good can have significant effects on the profitability of producing the second good. While such effects are not generally captured by partial equilibrium models, they will be captured by a general equilibrium approach.

Inter-industry effects are certainly important in evaluating policy changes in the petroleum industry. Some refined petroleum products are used by almost every industry. However, the most important interrelationships would appear to be those between the crude oil and refining industries.[75] Because we model both of these sectors in our partial equilibrium analysis, these relationships are captured in our work. Indeed, since we are able to focus on these two industries, these relationships may well be more completely and accurately captured in our work than in a typical GE model. For example, rather, than combining crude oil and natural gas production as occurs in both of the general equilibrium studies, we can look just at crude

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[74] Tarr (1989), pp. 2-5; Boyd and Uri (1989), pp. 30-31.

[75] Virtually all crude oil is consumed by the petroleum refining sector. In only two of the twelve sectors in the model used by Melo, Stanton, and Tarr--Agriculture and Mining--do purchases from the petroleum products sector amount to more than three percent of total expenditures. [Tarr (1989), pp. A-27 - A-28.]

oil.[76] Further, we can differentiate between gasoline demand and the demand for other refined products. This level of market differentiation does not appear to exist in the existing general equilibrium models. Also, with a partial equilibrium approach, many of the computational complexities are avoided and fewer parameters must be determined. As a result, the analyst can better understand the model's dynamics and can concentrate attention on the more important parameters. It is therefore not clear that the GE models provide a better estimate of the likely inter-industry effects of petroleum tariffs or taxes.

The other advantage of general equilibrium models, according to proponents of these models, is that they can capture the effects of changes in exchange rates that may

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[76] The fact that natural gas is included in the same sector as crude oil may explain why Melo, Stanton, and Tarr find that the least-cost way to raise a given amount of government revenue is to impose taxes on the oil and gas sector and subsidize the production of refined products. This result differs considerably from our finding that social costs are minimized with a very small tax on crude oil and a larger tax on refined products. It appears to arise because the inclusion of natural gas production in the oil and gas sector means that when a tax is imposed on the oil and gas sector, a tax is levied on users of natural gas in addition to refiners. In our case, we are dealing only with a tax on crude oil which is used almost exclusively as an input into petroleum refining. Whether it is desirable to include natural gas along with crude oil as being subject to any import tariff depends on what policy change is actually being considered. We are unaware of any discussion of placing a tariff on imports of natural gas. Further, natural gas imports are a relatively small percentage of total consumption--5.6 percent in 1987--and come predominantly from Canada. [U.S. D.O.E. (1988a), p. 155.] Particularly given the United States Canada Free Trade Agreement, it seems unlikely that new tariffs would be imposed on natural gas.

occur when tariffs or taxes are changed.[77] Basically, the argument here is that when a tariff is imposed, less of a good is imported. As a result, fewer U.S. dollars are used to pay foreigners for imports of the good. Because the supply of U.S. dollars involved in foreign trade is reduced, foreigners may be willing to pay more in terms of foreign currency to attract dollars. As a result, we can purchase more foreign goods with the same number of dollars. This increase in U.S. welfare can, at least partially, offset the direct costs of the tariff which are captured in the partial equilibrium analysis. As a result, a partial equilibrium analysis may overstate the social cost of a tariff.

However, there does not appear to be a consensus in the economics profession as to how changes in exports and imports affect the exchange rate between two countries.[78] Thus estimates obtained from partial equilibrium analyses that assume no change in the exchange rate may provide a useful comparison to general equilibrium estimates based on specific assumptions about the way in which exchange rates are determined.

Furthermore, partial equilibrium analysis will not overstate the costs of those tariffs considered in the current study that do not have the potential to result in currency appreciation. For example, a tariff on crude oil and gasoline would appear to result in more dollars being used to purchase imports rather than fewer.[79] This occurs

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[77] Tarr (1989), pp. 2-5 - 2-6.

[78] See Tarr and Morkre (1984), footnote 3, p. 23.

[79] Without tariffs, we estimate that the U.S. would spend $73.6 billion per year on imports of crude oil and refined petroleum products. If a tariff of $5 per barrel is imposed on crude oil and gasoline, but not on other refined products, this figure would rise to $100.8 billion. With a maximum revenue tariff on crude oil and gasoline, we

primarily because this tariff makes it more profitable to import refined products rather than to refine imported crude in this country. As a result of importing high-valued product rather than lower-valued crude, a tariff on crude oil and gasoline is likely to lead to a depreciation, rather than an appreciation, of the U.S. currency.

While it is not clear that imposing tariffs on crude oil or refined petroleum products would result in welfare gains because of dollar appreciation, we have attempted to estimate the maximum potential effect of exchange rate changes in order to be certain that such effects do not have the potential to alter our basic conclusion that tariffs are less efficient than taxes as a way to raise revenue. In doing this, we have employed a method developed by Morkre and Tarr for evaluating the maximum potential effect of currency changes in a partial equilibrium model.[80] The results of this analysis are contained in Table A-19. For example, we estimate that a $5 tariff on crude oil and all refined products could conceivably induce exchange rate changes that would improve U.S. welfare by $700 million per year.[81] While this effect would reduce the net social cost of the tariff from $2.7

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estimate that annual expenditures on imported crude oil and petroleum products would amount to $84.4 billion.

[80] See Tarr and Morkre (1984), pp. 26-27.

[81] The magnitude of the exchange rate effect is determined by the change in the value of imports. Absent any tariffs, the U.S. is estimated to spend $73.6 billion per year on imports of crude oil and refined products. If a $5 tariff is imposed on crude oil and all refined products, the value of imports, before the tariff duty is added, falls to $55.2 billion per year. Thus, imposition of the tariff results in a gain of $18.4 billion in the balance of trade. The Tarr-Morkre estimate of the change in welfare is equal to 0.038 times this gain or about $700 million.

billion per year to around $2 billion, the effect is not nearly great enough to reverse the finding that a sales tax, which would only impose social costs of about $640 million per year--or $450 million if the maximum adjustment for the welfare effects of exchange rate changes is assumed--is a far more efficient way to raise revenue.

<u>Summary</u>

In this section, we have compared our results to those obtained in other studies that have examined the costs of imposing tariffs or taxes on the petroleum sector. Where the findings of these other studies have differed significantly from our own, we have sought to explain them. In some cases, it appears that the explanation is to be found in the more accurate modelling of the refining industry in our partial equilibrium analysis. In other cases, the limited information provided about the specification of the general equilibrium models used by other researchers has made it impossible to determine what has generated the differences. Nevertheless, for some of such studies, we have identified inconsistencies that call into question their results. Finally, we have shown that our primary finding--that sales or excise taxes are a more efficient source of revenue than a tariff--is not altered by consideration of exchange rate effects.

TABLE A-19

EFFECT OF EXCHANGE RATE CHANGES ON ESTIMATED SOCIAL COSTS OF TARIFFS AND EXCISE TAXES ON CRUDE OIL AND REFINED PETROLEUM PRODUCTS[1]

	Social Cost of Tariff or Tax (Billions of Dollars per Year)	
	Without Exchange Rate Effects	Including Exchange Rate Effects
$5 Tariff on Crude Oil and All Refined Products	$2.7	$2.0
Excise Tax on All Refined Products Equivalent to $5 Tariff on Crude Oil and All Refined Products	0.6	0.4
$5 Tariff on Crude Oil and Gasoline	2.2	3.2
Excise Tax on Gasoline Equivalent to $5 Tariff on Crude Oil and Gasoline	0.5	0.4
Tariff on Crude Oil and All Refined Products That Raises Maximum Revenue	11.9	10.5
Excise Tax on All Refined Products Equivalent to Maximum Revnue Tariff on Crude Oil and All Refined Products	1.1	0.8
Tariff on Crude Oil and Gasoline That Raises Maximum Revenue	8.2	8.6
Excise Tax on Gasoline Equivalent to Maximum Revenue Tariff on Crude Oil and Gasoline	1.0	0.9

[1] The effects shown here are the maximum effects that could result from exchange rate changes due to the tariff or tax. The effects could easily be smaller.

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