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Reducing U.S. Vulnerability to World Oil Supply Disruptions

*By Stephen P. A. Brown**

Through 1978, Iran accounted for approximately 10 percent of the world's oil production, with output of 5 million to 6 million barrels per day. The overthrow of the Shah in early 1979 led to a 10-week period in which Iran produced almost no oil. The consequences of such a disruption in the world's oil market are painfully familiar. Lines at gasoline stations have become the most widely recognized symptom of stress in petroleum markets, but major disruptions also lead to higher petroleum prices and reduced production and consumption throughout the economy.

The United States has reduced its consumption of oil in the past few years, but the U.S. economy is still vulnerable to disruptions in the world's oil market. Past disruptions have resulted from political disturbances that were largely independent of market conditions. Much of today's production is in countries with potentially unstable political systems (Table 1), and an interruption of greater severity than the disturbances of the past decade is certainly possible.[1]

The unreliability of a significant share of the world's oil production raises concern in industrial nations such as the United States because energy conservation and switching from oil to alternative fuels require time and expensive adjustments in a nation's capital stock. Thus, it is not possible to maintain long-run consumption and production levels when the supply of oil is abruptly curtailed. In theory, vulnerability could be reduced by negotiating long-term contracts with countries having stable political systems. These contracts might specify prices and quantities to be delivered under various contingencies. However, such international contracts are not enforceable and, therefore, not written.

The United States can employ foreign policy to reduce the probability of supply disruptions, but economic policy can only lessen the consequences. Policies that would be effective in reducing

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1. U.S. Department of Energy, Office of Oil Policy Analysis, "The Energy Problem: Costs and Policy Options," Staff Working Paper by Jerry Blankenship, Mike Barron, Joseph Eschbach, Lindsay Bower, and William Lane (Washington, D.C., 1980).

Table 1
CRUDE OIL PRODUCTION IN MAJOR PETROLEUM-PRODUCING COUNTRIES

Area	1978	1979	1980	1981
	Annual averages[1] (Thousands of barrels per day)			
Algeria	1,161	1,154	1,012	797
Iraq	2,563	3,477	2,514	984
Kuwait[2]	2,131	2,500	1,656	1,155
Libya	1,983	2,092	1,787	1,160
Qatar	487	508	472	411
Saudi Arabia[2]	8,301	9,532	9,900	9,923
United Arab Emirates	1,831	1,831	1,709	1,508
Arab members of OPEC[3]	18,457	21,094	19,050	15,938
Indonesia	1,635	1,591	1,577	1,610
Iran	5,242	3,168	1,662	1,371
Nigeria	1,897	2,302	2,055	1,394
Venezuela	2,166	2,356	2,167	2,094
Total OPEC[4]	29,805	30,928	26,890	22,776
Canada	1,313	1,496	1,424	1,222
Mexico	1,209	1,461	1,937	2,320
United Kingdom	1,082	1,568	1,622	1,798
United States	8,707	8,552	8,597	8,556
China	2,082	2,122	2,114	2,018
USSR	11,185	11,460	11,770	11,827
Other	4,782	5,111	5,098	5,275
World	60,165	62,698	59,452	55,792

1. January-November averages for 1981.
2. Includes about one-half of the production in the former Kuwait-Saudi Arabia Neutral Zone. In November 1981, total production in this region amounted to approximately 279,000 barrels per day.
3. Arab members of the Organization of Petroleum Exporting Countries (OPEC) include Algeria, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, and the United Arab Emirates.
4. OPEC total includes production in Algeria, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, United Arab Emirates, Indonesia, Iran, Nigeria, Venezuela, Ecuador, and Gabon.

SOURCES: U.S. Department of Energy, Energy Information Administration.
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vulnerability fall into one of two categories: encouraging an accumulation of oil inventories (stockpiling) and reducing imports in normal periods.[2] The discussion in this article is limited to a comparison of the methods for reducing imports.

Reduced oil imports are synonymous with higher oil prices. In the past, U.S. energy policy has sought to insulate consumers from higher oil prices—but at the cost of increased vulnerability to world oil supply disruptions. Because imported oil is subject to disruptions, the true economic cost of its use is greater than its price. If energy policy resulted in imported oil being accorded its true economic cost, U.S. oil consumption and imports would fall while domestic production would rise. An examination of policies to reduce imports reveals that those most effective in reducing vulnerability to import disruptions recognize higher prices in normal periods as the solution, not the problem.

Analytics of the problem

Imported oil has an economic cost to the United States that is in excess of its purchase price, for it is subject to unexpected disruption. This nonprice cost arises because the economic loss experienced during disruptions increases with the level of imports in normal periods. As U.S. oil imports rise, the short-run maintenance of national income becomes more dependent on the maintenance of oil imports. Furthermore, increased U.S. imports will raise the share of world oil production contributed by potentially unstable producers. It follows that the nonprice costs of imported oil are an increasing function of the quantity of imports.

From the U.S. perspective, the economic cost of an additional barrel of imported oil is the sum of the world oil price, the risk associated with greater vulnerability to supply disruptions, and the impact of higher U.S. imports on the world oil price. To the extent that the nonprice economic costs of oil imports are ignored, U.S. oil consumption and imports will be too high while domestic production will be too low.

The economic loss arising from an oil supply disruption is the value of production lost as a result of the disruption. The loss of production can be severe because energy conservation and switching from oil to alternative fuels are costly and time-consuming. Hence, the short-run response of oil-using firms to unexpectedly higher oil prices is reduced production. These direct effects constitute the primary loss during a disruption. In addition, a general cooling-off of the economy may occur during the adjustment of relative prices necessitated by the disruption. However, such secondary macroeconomic losses occur during the adjustment to the disruption only to the extent that monetary and fiscal policies cannot be sufficiently fine-tuned.

The optimal import level is achieved at that quantity for which the contribution of an additional barrel of imported oil to current production just equals its economic cost. At the optimal level of imports, the nonprice cost of imported oil (P^* less P' in Figure 1) has been estimated by the U.S. Department of Energy at $4 to $8.[3]

2. It might seem that policy could insulate the United States from disruptions without reducing imports by requiring oil importers to purchase oil from stable suppliers only. The intent of such restrictions would be to reduce the share of world production contributed by unstable suppliers and to establish a position with those suppliers most likely to be producing during a disruption. In fact, neither objective would be accomplished.

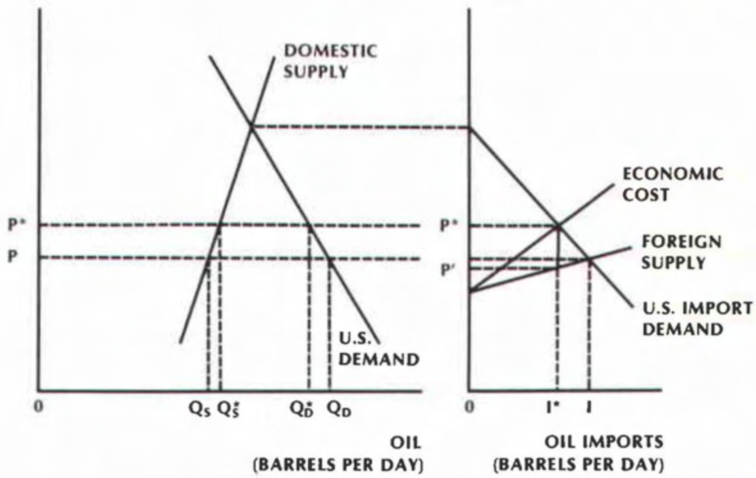
   Oil is a fungible commodity, and a reduction in U.S. purchases from any particular country would not diminish that country's share of the world market. Another buyer would replace the United States. In addition, the absence of contracts makes the distribution of oil during a disruption independent of any relationships that may exist during normal periods. The United States has joined 20 other countries as a member of the International Energy Agency. These countries, which account for 56 percent of the world's petroleum consumption, have established a set of rules for sharing oil during a disruption. These rules do not take into account historical relationships between producing and consuming countries. Furthermore, any oil that is not allocated by such agreements will be sold in the market to the highest bidder.

3. Michael J. Barron of the Division of Energy Security, Office of Policy, Planning and Analysis, U.S. Department of Energy, provided the author with this updated estimate in a private communication in March 1982. A model of the world oil market, microeconomic and macroeconomic loss functions, subjective estimates of the probabilities of various supply disruptions, and an Energy Information Administration estimate of the elasticity of import demand with respect to import prices were utilized. For a complete description of the methodology used, see Department of Energy, "The Energy Problem."

   A number of other estimates of the nonprice cost of imported oil have been made. Most of them are higher than $4 to $8. An advantage of the Department of Energy estimate is that the nonprice cost is determined at the optimal level of imports, not the current level of imports. Another advantage of the

FIGURE 1

Determining Optimal U.S. Consumption, Production, and Imports of Oil



Net U.S. import demand for oil is the difference between domestic oil consumption and production at various world oil prices. At the equilibrium world oil price, the quantity of oil imports demanded equals the quantity supplied by foreign producers. Assuming that the price of imported oil reflects its cost to the United States, P is the equilibrium price, Q_D is total U.S. consumption, Q_S is domestic production, and $(Q_D - Q_S)$, or I, is imports.

The economic cost of oil imports is not limited to price, however. The additional costs of increasing imports include greater exposure to economic loss resulting from disruptions of foreign oil supply plus more expensive terms of trade for oil. If the full economic costs of imports are considered, P' will be the import price, and P^* its economic cost and the price of domestic oil. Domestic consumption is Q_D^*, domestic production is Q_S^*, and imports are $(Q_D^* - Q_S^*)$, or I^*.

As described in the article, an unleashed free market would lead to the desired prices. Otherwise, an import tariff of $(P^* - P')$ can be imposed.

A free market policy

The free market approach consists of encouraging private sector preparation for the possibility of disruptions by establishing a policy of not interfering in the free market pricing and allocation of oil in the event of a disruption. The risk of temporarily higher oil prices sometime in the future would induce oil consumers to hedge by stockpiling oil, signing long-term purchase agreements with domestic suppliers, and undertaking oil conservation measures.

Long-term supply agreements with domestic producers are an attractive investment, given the possibility of oil supply disruptions. Recognizing that they are forgoing the possibility of higher profits during a disruption, producers signing long-term supply agreements will expect compensation in higher prices during normal periods. Because purchasers expect to avoid the costs of uncertain oil

estimate is that the various components of the cost are determined jointly—not independently—eliminating the double-counting of costs that is implicit in the summing of independently estimated components. For a summary of estimates of the nonprice costs of imported oil, see Harry G. Broadman, "Review and Analysis of Oil Import Premium Estimates," RFF Discussion Papers, no. D-82C (Washington, D.C.: Resources for the Future, December 1981).

supplies, they will be willing to pay a premium to obtain long-term contracts. Under long-term contracting, domestic oil prices will rise until the domestic oil price just equals the economic cost faced in utilizing its substitute, imported oil. As domestic oil prices rise, domestic oil production will increase, contributing to a decline in imports (Figure 1). Interestingly, vertical integration in the form of domestic well ownership by oil-using firms appears to be a good substitute for long-term contracts. Long-term contracts with stable foreign producers would also be desirable but must be presumed unenforceable.

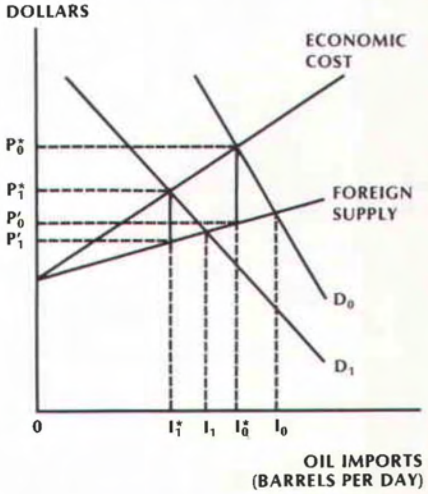
Higher domestic oil prices and the economic costs of imported oil encourage oil conservation (Figure 1). Though the conservation investments discussed here would raise the cost of production in normal periods, they would result in lower *expected* costs of production over the life of the investment. Oil-conserving investments will be made until their marginal cost just equals the value of the domestic oil they save. Since oil consumption is greater and has a greater price elasticity than domestic oil production, oil conservation measures can be expected to contribute more than domestic production to reducing oil imports. Investment intended to increase the short-run elasticity of demand for oil during disruptions is probably of an insignificant quantity, because the most attractive substitutes for oil generally entail lower operating costs and higher capital costs.[4]

One task at which the private market excels is the continual reevaluation of the equilibrium nonprice cost of imports. For example, natural gas deregulation, changed taxes on domestic oil production, changed demand for imports, and the revised probabilities of disruptions will alter the profitability of preparing for a disruption (Figure 2). The incentive of profits will provide rapid and automatic adjustment to new market conditions. In contrast, the political process will be rather slow and haphazard in reacting to changes in the equilibrium divergence between the economic cost and price of imports, raising the continual possibility of inappropriately weak or strong intervention measures.

4. For a detailed discussion, see Douglas R. Bohi and W. David Montgomery, "Tariffs and the Economic Costs of an Oil Disruption," RFF Discussion Papers, no. D-82B (Washington, D.C.: Resources for the Future, December 1981).

FIGURE 2

Effect of Reduced Demand for Oil Imports on Equilibrium Nonprice Costs

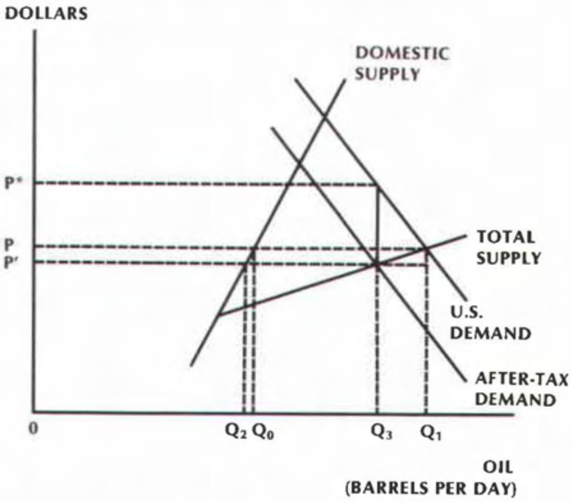


The decontrol of natural gas prices decreases U.S. demand for oil by increasing the supply of gas. Decreased oil demand translates into decreased demand for oil imports. Similarly, elimination of the oil windfall profit tax increases the domestic supply of oil and makes it more elastic. These changes in domestic oil supply translate into a decreased and more elastic demand for oil imports.

Decreased import demand reduces the optimal economic cost of imports from P_0^* to P_1^*, optimal imports from I_0^* to I_1^*, the optimal import price from P_0' to P_1', and the divergence between the economic cost and price of imports from $(P_0^* - P_0')$ to $(P_1^* - P_1')$. If the divergence between the economic cost and price of oil imports is not taken into consideration, the decrease in import demand will reduce imports from I_0 to I_1.

FIGURE 3

Effects of a General Oil Tax on Domestic Consumption and Production of Oil



A general tax on crude oil consumption is shown as a downward shift in demand by the amount of the tax, $(P^* - P')$. In effect, the tax reduces the price of oil received by foreign and domestic suppliers from P to P' while increasing the price paid by consumers from P to P^*. U.S. consumption is reduced from Q_1 to Q_3, with domestic production falling from Q_0 to Q_2. Imports are reduced from $(Q_1 - Q_0)$ to $(Q_3 - Q_2)$.

The free market appears quite capable of preparing for world oil supply disruptions through stockpiling and an efficient reduction in imports. However, some costs of imported oil would be ignored. The most important of these arises from the absence of an incentive for individual decisionmakers to consider the impact of their oil consumption on world oil prices. And to the extent that it is impossible to fine-tune monetary and fiscal policy accurately in response to an oil supply disruption, indirect macroeconomic losses will occur. Energy users have no reason to take these costs into account either. The exact magnitude of the resulting inefficiencies is unknown but most likely is small.

Reluctance to rely on the market to prepare for the possibility of disruptions has not centered on reservations about the ability of the market to take efficient measures, however. Objections have been raised about the impact an unfettered market would have on the distribution of income during a disruption. High oil prices are thought to have graver consequences for both the Northeast and lower-income families than do Government allocation rules. As a result, world oil supply disruptions in recent history have been accompanied by domestic price controls on petroleum and petroleum products and by refinery output mix controls. These policies have caused shortages, which have led to Government allocation rules at both the industrial and the consumer level. In the past, these allocation rules have undermined the effectiveness of oil-conserving investment in maintaining individual-firm production during a disruption. Furthermore, a distaste for "profiteering" has led to legislation limiting private oil stockpiling. In the wake of this intervention, free market preparation for oil supply disruptions has been virtually eliminated because decisionmakers have reason to believe that during a future supply disruption, similar controls would prevent them from benefiting from any such preparation.

Tariffs, taxes, and subsidies

Reluctance to rely on the free market to reduce imports leads to the consideration of interventionist policies. The simplest methods for reducing imports are an oil import tariff, an oil use tax, and a domestic oil production subsidy. Of these three, the most direct method for reducing oil imports to a beneficial level is Government imposition of an oil import tariff equal to the equilibrium divergence between the price and economic cost of imports.

In many ways, implementation of an oil import tariff is akin to the free market response to the potential of a disruption. Under an oil import tariff the reduction in oil imports will be achieved through those consumption decreases and production increases that have the lowest opportunity cost. Also, an oil import tariff equal to the nonprice economic cost will reduce imports to the point where the economic cost of their use equals the benefit (Figure 1). An advantage an oil import tariff has over reliance on the free market is that any potential secondary macroeconomic losses arising from world oil supply disruptions and any impact of reduced U.S. imports on the world oil price can be taken into account.

However, oil import tariffs might have a palling effect on free international trade if some oil-exporting nations retaliated against U.S. action by imposing tariffs on their imports. While many oil-exporting nations are not in a position to retaliate with tariffs of their own (their governments are the primary import purchasers) and many U.S. trading partners would benefit from U.S. imposition of an oil import tariff, some of the oil-exporting nations, notably the United Kingdom and Mexico, would suffer economic losses as a result of U.S. tariffs and are in a position to retaliate with tariffs of their own. U.S. imposition of a tariff on oil imports could contribute to a worldwide movement away from free trade. Because the United States has generally favored free international trade and it is regarded that this country and the rest of the free world have benefited, the potential impact of a tariff on international trade cannot be taken lightly.

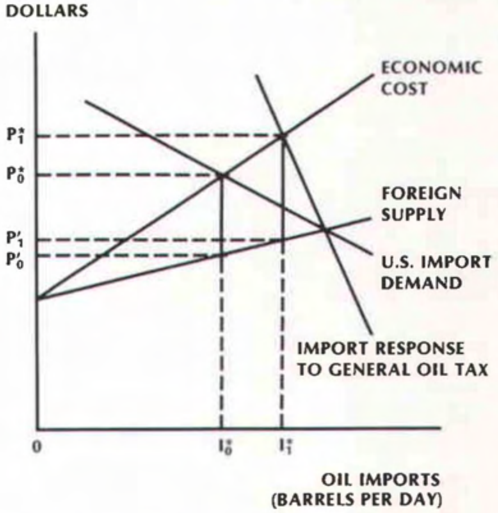
Public opposition to an oil import tariff has not arisen from the issue of free trade, however. Criticism has centered on the rise in oil prices that would accompany a tariff. Under a tariff, U.S. consumers would pay higher prices for petroleum products, and domestic oil producers would receive increased profits.

In view of the problems with an oil import tariff, less efficient methods for reducing dependence on imported oil must be considered. Oil use taxes and oil production subsidies are possible alternatives.

Given that both the level and the elasticity of U.S. demand for oil are greater than the level and elasticity of the domestic supply of oil, oil use taxation is more efficient than production subsidies in

FIGURE 4

A General Oil Tax Versus an Oil Import Tariff

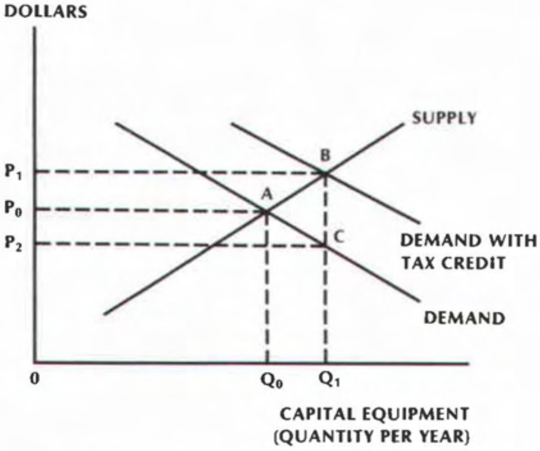


Import response to a tariff—shown as U.S. import demand—is more elastic than import response to a general oil tax. This difference arises from the differing impact of a tariff and a tax on domestic production. A tariff encourages domestic oil production while a tax discourages it. It follows that a tax is a more costly and less effective measure for reducing imports.

The optimal tariff is $(P_0^* - P_0')$ because at I_0^* the marginal economic cost of imports equals its marginal contribution to current production. It is much more difficult to see that the optimal oil tax is $(P_1^* - P_1')$. When less efficient means are used for reducing imports, the opportunity cost to current production of reducing imports is greater. Therefore, imports should be maintained at the higher level, I_1^*, with which the tax $(P_1^* - P_1')$ is consonant. Under the tax the consumer oil price is higher, P_1^* versus P_0^*; imports are higher, I_1^* versus I_0^*; and the price of imported oil is higher, P_1' versus P_0', than with the tariff. However, under the tax the price received by domestic producers is less than with the tariff, P_1' versus P_0^*; hence, domestic production is less.

FIGURE 5

Effects of an Investment Tax Credit in the Market for Capital Equipment



An investment tax credit shifts the demand for qualified equipment upward by the amount of the credit. The effective price paid by purchasers decreases from P_0 to P_2, while the price received by producers increases from P_0 to P_1. The Government makes up the difference between the effective purchase price P_2 and the producer price P_1. The quantity of equipment purchased increases from Q_0 to Q_1. However, the loss in Government tax receipts is not restricted to the equipment purchases induced by the tax credit. All purchasers of qualified equipment receive the tax credit benefits. Hence, Government revenue losses are represented by the rectangle $\overline{P_2P_1BC}$.

The economic cost of the investment tax credit program is the difference between the opportunity cost of producing the additional equipment—shown along the supply curve—and the benefit of using the additional equipment—shown along the demand curve. Hence, the triangle $\overline{ABC}$ represents the economic cost of the investment tax credit.

reducing imports. An oil use tax decreases the demand for oil. However, unlike a tariff, which stimulates domestic production, a tax discourages domestic production (Figure 3). Compared with an oil import tariff or the free market, the "optimal" oil use tax leads to not only greater imports but also higher domestic prices for petroleum products (as can be seen in Figure 4).

Rebating the tax to the producers of domestic oil would allow for an incentive structure that is identical to the import tariff. It is so transparently identical that most U.S. trading partners would view the combination of an oil use tax and a domestic producer rebate as a de facto U.S. oil import tariff.

Interestingly, taxes on domestic oil production (including the windfall profit tax) reduce the portion of any domestic price increase received by producers and nongovernmental royalty owners to an average of 26 percent at the margin.[5] Under current tax laws, neither an oil import tariff nor an unleashed free market provides much incentive to increase domestic oil production. As a result of eroded production incentives, both policies will be more similar in effect to an oil use tax than is suggested by the preceding analysis.

Investment tax credits and oil use regulations

Free market preparation for oil disruptions, an oil import tariff, and a general oil tax result in consumers facing higher oil prices in normal periods. The desire to avoid higher oil prices while obtaining some of the security benefits of reduced oil consumption has led to investment tax credits for oil conservation and to regulations restricting oil use.

The Energy Tax Act of 1978 and the Crude Oil Windfall Profit Tax Act of 1980 contain provisions offering temporary tax credits for specified residential and business investments in energy conservation, the development of new energy sources, and the substitution of other fuels for oil and gas. The present analysis is limited to the business investment tax credit provisions of these acts. Business energy use is considerably greater than residential energy use, and the analysis and conclusions with respect to residential tax incentives would be similar. Qualifying business investments, the tax

5. Philip C. Crouse, "U.S. Crude Prices: No Improvement in 1982," *World Oil*, February 15, 1982, p. 131.

Table 2
SUMMARY OF TAX CREDITS

Energy property, equipment	Tax credit (Percent)	Effective date	Expiration date
Alternative energy property (principally combustors not using oil or gas)	10	October 1, 1978	December 31, 1982[1]
Specially defined energy property (principally equipment for the recovery of waste heat)			
Cogeneration equipment			
Solid waste recycling equipment			
Equipment for producing shale oil			
Equipment for producing natural gas from geopressured brine			
Solar, wind, and geothermal energy equipment (equipment for producing usable energy from these sources)	10	October 1, 1978	December 31, 1979
	15	January 1, 1980	December 31, 1985
Ocean thermal energy conversion equipment (equipment for producing electricity from differentials in ocean temperatures)	15	January 1, 1980	December 31, 1985
Small hydroelectric facilities (hydroelectric dams under 125-megawatt capacity)	[2]11	January 1, 1980	December 31, 1985[3]
Intercity buses	10	January 1, 1980	December 31, 1985
Biomass equipment (equipment for producing usable energy from agricultural products or by-products)	10	October 1, 1978	December 31, 1985

1. In certain cases, expiration date is postponed until December 31, 1990.
2. Actual tax credit rate varies inversely with size. The rate is 11 percent for installations with capacities of 25 megawatts or less, decreases from 11 percent to zero between 25 and 125 megawatts, and is zero for 125 megawatts or more.
3. For projects for which the application has been docketed by the Federal Energy Regulatory Commission prior to January 1, 1986, the expiration date is postponed to December 31, 1988.

SOURCE: Brown and Anandalingam, *Economic Analysis of Tax Credit Incentives*.

credit percentages, and the availability dates for the tax credits are summarized in Table 2.

Investment tax credits lower the effective price of qualified equipment for the purchaser while raising the price the manufacturer receives, with the Government making up the difference. (See Figure 5.) The direct revenue loss to the Government is incurred on all units purchased—not just on units whose purchase is induced by the tax credit. Therefore, Federal revenue losses from a tax credit program are sizable compared with the other economic consequences of the program. For the most part, the revenue loss is not an economic cost. The revenue loss is largely a transfer payment from taxpayers to the manufacturers and purchasers of equipment receiving the tax credit. However, the reduction in Federal revenue requires increased Government borrowing or taxation, both of which generally have undesirable side effects.

More important, an investment tax credit causes distortion costs that are the difference between the full opportunity cost of producing the additional equipment whose purchase has been induced by the credit and the value of that additional equipment in producing goods or saving other inputs (Figure 5). The distortion costs result from not only substitution of capital equipment qualified for the credit for other inputs but also increases in the output of goods produced with the equipment.

To estimate the economic consequences of the tax credits, a number of dynamic, partial-equilibrium simulation models were constructed to represent the markets in which the energy tax credits would have an effect.[6] Construction of these models involved economic theory, engineering data, and econometric techniques.

Table 3 presents the results of exercising the models. Estimates of the distortion cost and revenue loss are biased downward because the models do underestimate somewhat the substitution and output effects. However, the models do not significantly bias the oil savings estimates. It follows that the estimates of average distortion cost per barrel reported in the table are biased downward somewhat. Furthermore, since these investments have diminishing marginal productivity in reducing oil consumption, a small increase in the tax credit rate would entail economic costs for each barrel of oil saved that would be higher than the average cost shown in the last column. Consonantly, the distortion costs avoided through a small decrease in the rate would be larger per barrel consumed than the average shown in the table.

The equilibrium nonprice economic costs of oil imports (estimated at $4 to $8) and an Energy Information Administration estimate that a $5 increase in the per-barrel price of imported oil would reduce imports by 1 million barrels per day can be used as standards of comparison in evaluating the investment tax credit program.[7] Examination of the estimates in Table 3 reveals that it is nearly certain (given the known biases in the estimates) that the investment tax credits for alternative energy property, specially defined energy property, solid waste recycling equipment, and intercity buses have a higher *marginal* cost in saving oil than the equilibrium nonprice economic cost of oil imports. It is likely that the investment tax credit for cogeneration equipment also has a higher marginal cost than its marginal benefit.

Four tax credits were found to have no consequences, and as is evident in Table 3, the one tax credit showing likely benefit has a great deal of uncertainty surrounding its estimated effect. Furthermore, oil savings, at less than 120 million barrels in the year with the greatest savings, are less than one-third of the reduction in imports that would result from a $5 increase in the oil import price.

The investment tax credit program relies too heavily on a few oil-conserving activities. An efficient reduction in imports requires a more diverse set of oil conservation and production activities (including increased production of oil from conventional sources) than those targeted by the current incentives, with less reliance on each activity.[8]

6. For a detailed description of the methodology, see S. P. A. Brown and G. Anandalingam, "Economic Analysis of Tax Credit Incentives for Business Investment in Energy Conservation and Production," no. BNL-51526, Brookhaven National Laboratory (Upton, N.Y., December 1981).

7. Department of Energy, "The Energy Problem." A current estimate of the import response to a $5 increase would probably be slightly lower.

8. Similar results are obtained in a theoretical general-equilibrium analysis. See William J. Baumol and Edward N. Wolff, "Subsidies to New Energy Sources: Do They Add to Energy Stocks?" *Journal of Political Economy* 89 (October 1981):891-913.

Table 3
SUMMARY OF ESTIMATED CONSEQUENCES OF BUSINESS ENERGY INVESTMENT TAX CREDITS

Tax credit	Present-value distortion cost	Present-value direct revenue loss	Maximum-year oil savings	Total oil savings[1]	Average distortion cost[2] (Dollars per barrel)
	Millions of dollars		Millions of barrels		
Alternative energy property (combustors not using oil or gas)	$3,855.8	$5,122.9	111	973	$ 7.74
Specially defined energy property (waste heat recovery equipment)	176.78	712.51	1.75	7.11	[3]15.13–32.90
Cogeneration equipment	45.96	156.27	2.07	7.36	[3]3.25–7.08
Solid waste recycling equipment	.28	1.13	.008	.033	11.03
Equipment for producing shale oil	*	*	*	*	*
Equipment for producing natural gas from geopressured brine	*	*	*	*	*
Solar and wind energy equipment	*	*	*	*	*
Ocean thermal energy conversion (OTEC) equipment[4]	29.35	37.60	2.01	60.2	2.74
Small hydroelectric facilities	*	*	*	*	*
Intercity buses	.05	9.78	.001	.007	14.19

1. Figures represent savings over a 30-year period in some cases.
2. Values in this column cannot be determined from other columns in the table. Rather, they are determined through the use of a present-value formula that takes into account the time path of energy or oil savings.
3. The first value is for estimated oil and gas savings; the second, for estimated oil savings alone.
4. These estimates represent the construction of one 200-megawatt OTEC facility. The estimates are from the middle case of nine cases examined. In the other eight cases, no impact on energy use was found, either because oil was the choice with or without the tax credit or because ocean thermal energy conversion was the choice with or without the tax credit. It should also be understood that OTEC technology may not be sufficiently developed for any commercial use during the period in question.

* No estimated consequence.

SOURCES: Brown and Anandalingam, *Economic Analysis of Tax Credit Incentives.*
Federal Reserve Bank of Dallas.

Regulations appear to have several advantages over investment tax credits, although the two approaches produce similar undesirable side effects. Direct losses of Federal revenues are avoided. However, energy use regulations do not stimulate domestic production. Moreover, the effects of regulations already implemented bear little resemblance to the least-cost means of reducing imports.

The most significant legislation to regulate energy use in recent years is the Powerplant and Industrial Fuel Use Act of 1978 (PIFUA). The act mandates that all baseload electric powerplants in the United States that use oil or gas must be converted for use of other fuels and that new baseload powerplants must use fuels other than oil or gas. Furthermore, all new major fuel-burning installations in industry must use a fuel other than oil or gas unless the estimated cost of doing so would substantially exceed the cost of imported oil. The Economic Regulatory Administration of the Department of Energy has ruled, for the purposes of PIFUA, that substantial cost is to be defined in a manner equivalent to placing a $1 tax on imported oil.

Other important regulatory legislation includes the Energy Policy and Conservation Act (EPCA), the Energy Conservation and Production Act (ECPA), and the subsequent National Energy Conservation Policy Act (NECPA). Under these acts, energy performance standards for buildings and appliances were established, along with fuel economy standards for automobiles. The EPCA also imposes Federal thermostat settings in nonresidential buildings.

Of these regulations, only the portion of PIFUA directed at industrial combustors offers any explicit recognition of the nonprice economic cost of imports. However, taken in isolation, PIFUA results in an insufficient reduction of oil use in new industrial combustors. Taken in conjunction with the investment tax credit for alternative energy properties, PIFUA aggravates the excessive reduction of oil use in new industrial combustors that is induced by the tax credit. Furthermore, unless exemptions are granted, the marginal cost of banning baseload generation of electricity with oil or gas under PIFUA is undoubtedly greater than $8. The EPCA, ECPA, and NECPA substitute Federal rule for individual decisionmaking.

Because the costs of compliance cannot be considered on an individual basis in the administration of Federal regulations, some users could be required to cut oil consumption by more than is beneficial. In addition, regulators may overlook beneficial reductions in oil usage. The information required to administer regulations makes impractical the achievement of economic efficiency through fine-tuning. Besides, regulations that can achieve a least-cost reduction in oil consumption will impose costs that seem inequitable.

Choosing among the policy alternatives

On balance, reliance on the free market to prepare for the possibility of an oil supply disruption appears to be the most efficient policy for reducing oil imports.[9] It is followed by an oil import tariff and a general oil tax. (See Table 4 for a summary of policy consequences.) However, unleashing market forces would require assurances that the Government will not intervene in the energy market during oil supply disruptions. Expiration of the Emergency Petroleum Allocation Act (EPAA) in 1981 may be viewed as encouraging by those favoring a market solution. But efforts to reinstate the EPAA are afoot, and many decisionmakers in industry can recall the rapidity with which the EPAA was adopted in 1973.

Though an oil import tariff is more effective than an oil use tax in reducing oil imports, its use runs the risk of decreased international trade. Given that the tariff's supply incentives are seriously eroded by the windfall profit tax, the oil use tax may prove the most attractive method for reducing imports that is currently available.

Although it is probably beneficial that the United States is drifting toward elimination of energy investment tax credits and oil use regulations, no new measures are being taken to reduce imports, and that is risky. World oil prices are currently languishing, but the world oil market was in a similar situation during the summer of 1978, before the shock of political upheaval in Iran led to a rapid

9. Most analysts recognize that least-cost preparation for the possibility of world oil supply disruptions involves both stockpiling and import reductions. For instance, see Department of Energy, "The Energy Problem"; Broadman, "Oil Import Premium Estimates"; and Thomas J. Teisberg, "A Dynamic Programming Model of the U.S. Strategic Petroleum Reserve," *Bell Journal of Economics* 12 (Autumn 1981):526-46. Current Government stockpiles do not appear sufficient to obviate either an import reduction or further stockpiling.

Table 4
SUMMARY OF POLICY CONSEQUENCES

Effect of policy	Free market	Tariff	Oil use taxation	Oil production subsidies	Investment tax credits	Oil use regulations
Provides decentralized evaluation	Yes	Some	Some	Some	Greatly reduced[1]	No[1]
Provides automatic reevaluation	Yes	No	No	No	No	No
Has domestic production incentives and increased profits for domestic oil producers	Yes[2]	Yes[2]	No[3]	Yes[2]	No[3]	No[3]
Has incentives to reduce U.S. oil consumption	Yes	Yes	Yes	No	Yes	Yes
In theory, has no extraneous distortion costs	Yes	Yes	Yes	Yes	No	Yes
Automatically provides stockpiling	Yes	No	No	No	No	No
Efficiency of policy not inhibited by "fairness" considerations	Yes	Yes	Yes	Yes	No	No
In theory, all costs of oil imports enter evaluation process	No	Yes	Yes	Yes	Yes	Yes
Avoids risk of palling effect on world trade	Yes	No	Yes	Yes	Yes	Yes
Avoids increases in oil prices	No	No	No	Yes[4]	Yes[4]	Yes[4]

1. Has massive data requirements to achieve fine-tuning to efficiency.
2. Effectiveness eroded by windfall profit tax.
3. Unless foreign oil supply to the United States is perfectly elastic, will lead to decreased domestic oil production and decreased profits for domestic oil producers.
4. Unless foreign oil supply to the United States is perfectly elastic, will lead to decreased oil prices.

doubling of the world price of oil. This is not to suggest that an oil supply disruption will occur—only that current oil market conditions do not greatly reduce the possibility of an oil supply disruption.

Given the nonprice costs of oil imports, arising from the possibility of disruptions in the supply, a reduction in imports is beneficial. However, reduced U.S. oil imports must come at the expense of decreased oil consumption or increased oil production. Effective policies for oil conservation involve higher oil prices for consumers, and increased domestic production is synonymous with higher producer prices and profits. Unfortunately, higher oil prices and increased producer profits have proved politically distasteful, and policy has reflected that distaste.

Petrochemicals: Changing Markets and Limits to Growth Alter Outlook

*By Edward L. McClelland**

Sales of chemicals and allied products, which include drugs, detergents, coatings, and agricultural chemicals, total $200 billion a year in the United States. A major segment of the industry is petrochemicals. They are derived from natural gas and crude oil and are used to manufacture plastics, man-made fibers, and synthetic rubber.

The first stage in manufacturing petrochemicals is the production of a few basic building-block chemicals, from which other products are made. The manufacture of building-block chemicals is a major activity in the southwestern economy. For example, basic petrochemicals account for 59 percent of all chemicals produced in Texas, which in turn amount to 13 percent of total value added of the state's manufacturing output. In Louisiana, basic chemicals account for 50 percent of total chemical production, which amounts to 17 percent of that state's manufacturing output.

Petrochemical manufacturing has been a fast-growing industry. Since 1947, production of basic chemicals has increased eightfold, compared with a fourfold increase in the production of all manufactures. The development of the oil and gas industry in the Southwest provided petrochemical manufacturers with abundant supplies of inexpensive feedstocks. Chemicals and synthetic materials increasingly displaced a wide range of natural materials as technology advanced.

The current recession has substantially reduced the demand for many products made from petrochemicals. A quarter of the production capacity of basic chemicals is shut down, and those plants still operating are running at about 70 percent of capacity. Several factors suggest demand for petrochemicals will remain weak and that current capacity will be more than adequate for some time. Economic recovery may be slow in many domestic petrochemical markets, and exports of chemical products are down because of recessions abroad, especially in Western Europe. There is concern that in the long run, other major oil-producing countries will build their own petrochemical industries and permanently capture significant shares of the export and domestic markets now served by U.S. producers.

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CONCENTRATION OF BUILDING-BLOCK CHEMICAL PLANTS IN LOUISIANA AND TEXAS
(Dollar amounts in billions)

Chemical	Louisiana	Texas	Commercial value of 1981 U.S. production
	Percent of U.S. capacity		
Ethylene	25	65	$7.0
Propylene	22	65	3.2
Butadiene	20	77	1.1
Benzene	16	54	2.4
Para-xylene	2	42	1.1

SOURCES: *Chemical & Engineering News.*
Chemical Marketing Reporter.
Pace Company Consultants & Engineers.
Federal Reserve Bank of Dallas.

U.S. firms hold comparative advantage

The manufacture of petrochemicals began with salvaging by-products of other industries and processing them into products of higher economic value. Before the discovery and widespread production of crude oil, a few petrochemicals were made from coal tars and from animal and vegetable residues. But the biggest advances in petrochemicals arose from the expansion of the automobile industry and the accompanying demand for more and better gasoline.

Distillation of crude oil yields gasoline and heating oils but simultaneously produces other coproducts or (in the terminology of economists) joint products, such as gas oil and naphtha, which is largely natural gasoline. These coproducts of gasoline had no ready markets, but chemical manufacturers were quick to see the potential for processing those inexpensive materials into more useful products. The growth of gasoline refining made huge supplies of distillate feedstocks available to the U.S. petrochemical industry.

Petrochemical plants were built and expanded beside refineries. That close proximity allows the free flow of primary and intermediate products between the two industries, minimizing transportation costs and increasing economies of scale. As a result, many of the refining and petrochemical industries are clustered in heavy concentrations of plants and equipment. Today, some petrochemical manufacturers are operating subsidiaries of major oil companies, and others are chemical firms that buy their feedstocks from refiners and gas processors.

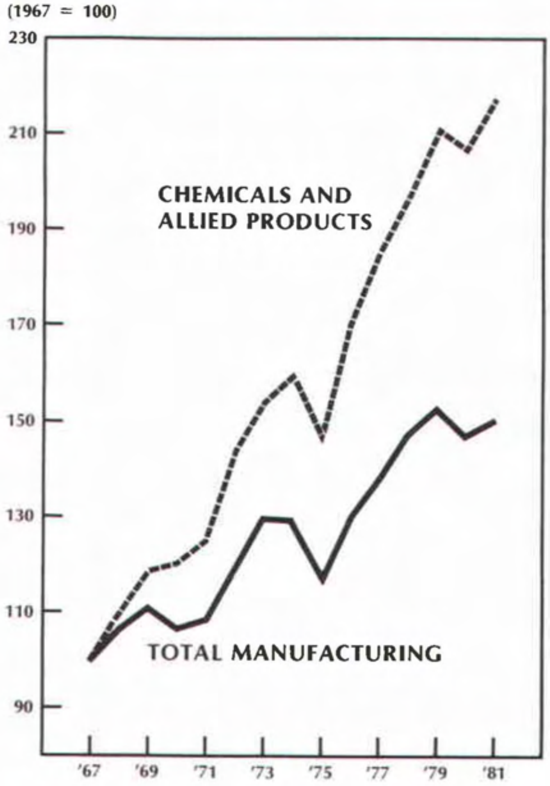
Growing demand for gasoline stimulated production of crude oil, and increased crude output resulted in a rise in the associated production of natural gas, which initially had little value. It was not until the 1940's, when the first major pipelines were built to midwestern and eastern heating markets, that natural gas gained significant value as an inexpensive, clean-burning fuel. Natural gas consists of several component products. Natural gas produced in association with crude oil is about 85 percent methane, and most of the remainder is natural gas liquids—ethane, propane, and butane. Methane is used largely for fuel, although it is an important raw material in the production of chemical fertilizers. Some natural gas liquids, such as propane and butane, are also sold for fuel but, in addition, they are used as petrochemical feedstocks. In the early 1960's, in fact, natural gas liquids displaced naphtha and gas oil as the largest source of petrochemical inputs.

At the industry level and for firms with large plants, there is often some flexibility to switch between oil-based feedstocks and natural gas liquids. Switching between feedstocks can be used to minimize production costs. But it also depends on the relative demands for petrochemicals that compete with one another in end uses, the ability of individual plants to use more than one feedstock, the relative price differences among feedstocks, and other capital and labor costs incurred by individual producers. Each plant has its own matrix of production capabilities and its own cost structure, which often make its product mix and level of output unique.

The combination of abundant supplies of oil and gas, a healthy refining industry, and expanding markets for their products gave U.S. petrochemical producers an advantage over foreign competitors. They successfully exploited the low transportation costs and economies of scale provided by this combination to keep prices low. After the sharp increases in oil prices shocked the industry in 1973, Federal regulation of oil and gas prices helped U.S. producers maintain their advantage of lower-cost feedstocks.

Until recently, U.S. prices of crude oil and natural

Chemicals and allied products in Texas have been outpacing overall manufacturing output



gas liquids were held below the world level by price controls. In 1980, for example, U.S. refiners paid an average composite price of $28.02 a barrel for crude oil. The cost of domestic oil was held to $24.23, compared with an average price of $33.89 for imported oil. Thus, for U.S. refiners and petrochemical producers, the cost advantage over the world price was nearly $6 a barrel. Crude oil prices were freed in January 1981, and by the end of that year, the price advantage had decreased to $2.33.

Petrochemical producers using natural gas liquids, however, faced another problem. Domestic reserves of natural gas dwindled throughout the 1970's. As a result, manufacturers began to build plants that were geared to process naphtha and gas oil since they believed that crude oil, which could be imported easily, would be more plentiful than natural gas in the years ahead. That outlook proved incorrect because the rise in drilling that began in 1975 and was spurred by the lifting of price ceilings on some categories of natural gas has led to increased supplies of natural gas and natural gas liquids.

In recent years, natural gas liquids have become cheaper than naphtha, as the production of natural gas has increased faster than was projected just a few years ago. With soft markets for both gasoline and petrochemicals, the major U.S. oil companies are now rethinking their chemical operations. Declining gasoline production yields less naphtha and gas oil to feed their large-scale petrochemical plants, resulting in a substantial rise in production costs.

Petrochemical markets becoming more cyclical

Along with the changes in feedstock supplies and production costs, significant changes are taking place in major petrochemical markets. One example is plastics. Sales of these materials are apparently becoming more cyclical as more uses are found for them. From 1974 to 1979—the year petrochemical output peaked—sales of plastics rose from nearly 27 billion pounds to nearly 39 billion pounds. Most of the rise was concentrated in the four major markets in which the share of total sales increased: packaging, building and construction, exports, and "other." The volume of plastics sold during the 1980 recession fell in every major market except exports.

The biggest market for plastics is packaging, where relatively inexpensive petrochemicals have been substituted for such natural materials as

DISTRIBUTION OF U.S. SALES AND CAPTIVE USE OF PLASTICS

Major market	1974	1979	1980	1974	1979	1980
	Millions of pounds			Percent of total		
Packaging	6,720	10,334	10,003	25.2	26.7	28.4
Building/construction	4,327	7,573	6,424	16.2	19.6	18.3
Exports	1,585	3,432	3,670	5.9	8.9	10.4
Consumer/institutional	3,168	3,753	3,553	11.9	9.7	10.1
Electrical/electronic	2,524	3,043	2,453	9.4	7.9	7.0
Adhesives, inks, etc.	2,150	2,794	2,387	8.1	7.2	6.8
Furniture/furnishings	1,791	1,894	1,646	6.7	4.9	4.7
Transportation	1,725	1,934	1,605	6.5	5.0	4.6
Industrial/machinery	488	517	391	1.8	1.2	1.0
Other	2,215	3,443	3,054	8.3	8.9	8.7
TOTAL	26,693	38,717	35,186	100.0	100.0	100.0

SOURCES: Society of the Plastics Industry.
Federal Reserve Bank of Dallas.

metals, wood, paperboard, and paper. These substitutions will likely continue at a slow pace. Most of the future competition for existing plastics will be with other plastic and synthetic materials, so increasing this market share will be harder to achieve. Demand for packaging materials is directly related to factory shipments and inventory accumulations, which follow the business cycle closely. Thus, increases in the share of petrochemicals sold for packaging will make the industry more cyclical.

The second largest market for plastics is building and construction materials. This market is also cyclical. For example, new housing starts fell from 2.0 million units in 1978 to 1.1 million units in 1981, and it is estimated they may recover to 1.2 million units this year. But that is only half the level for the banner year of 1973.

In addition, the housing market is undergoing significant structural change as the size of dwelling units declines. High land and mortgage costs are forcing builders to reduce the size of new houses. The median size of housing units reached a peak of 1,650 square feet in 1979 and declined to 1,570 square feet in 1980. That trend will likely continue, given the current outlook for mortgage markets and land prices. Smaller homes require smaller quantities of such petrochemical-based products as plastic pipe, insulated wiring, exterior wall surface to insulate and side, resins used in the production of plywood and particle board, paint and finishes, and nylon for carpeting.

Motor vehicle production is looked upon as a market of significant future growth for petrochemicals, even though total consumption of plastics by that industry is declining. The current outlook for domestic auto production is grim. The 6.2 million cars built during the 1981 model year constituted the smallest level of output in six years. And current auto sales have declined to the lowest level in 22 years. As a result, auto assemblies have been trimmed to an annual rate of about 5 million units, compared with a typical boom year of 10 million units.

Low auto production reduces demand for plastics and other synthetic materials. And in order to increase fuel economy, auto producers are making future models smaller. In 1975, for example, the average vehicle weighed 4,000 pounds. The average is about 3,000 pounds now and will be reduced to less than 2,500 pounds by 1990. While smaller cars require less material, use of more lightweight materials, such as aluminum and plastics, also helps achieve weight reductions. Plastics, which are currently used for decorative and nonstructural parts, account for about 200 pounds of total vehicle weight. By 1990, that will rise to 275 to 300 pounds, but engineering breakthroughs could increase the

Basic Building-Block Chemicals

Petrochemicals are chemical materials that are manufactured from such hydrocarbon feedstocks as natural gas liquids, naphtha, and gas oil. They are subclassified as "primary" petrochemical materials, petrochemical "intermediates," and petrochemical "products." Primary petrochemicals are produced directly from the raw material inputs and are the basic building blocks of downstream intermediates and products. More than 100 industrial chemicals constitute the most important primary and intermediate materials, and further processing yields more than 5,000 petrochemical products of commercial significance that are used to manufacture an even wider range of finished consumer products.

Even though the petrochemical industry is widely diversified, with the output of most materials used as inputs for additional processing, an analysis of the primary petrochemical markets at the head of the processing stream gives an indication of market conditions for all petrochemicals. Because primary petrochemicals do not enter consumer markets directly, the demand for their production is derived from the demand for products into which they are processed.

Broadly speaking, petrochemicals are any materials derived from petroleum hydrocarbons. But for this study, primary petrochemicals consist of olefins and aromatics, and most of the U.S. production capacity is in Texas and Louisiana. Olefins—ethylene, propylene, and butadiene—do not exist as such in nature and are highly reactive materials having the chemical structures of paraffin. Aromatics include any compounds that contain a benzene ring in their chemical composition. They have a pungent odor, as the name implies. The principal aromatics are benzene, xylenes, and toluene. However, toluene is used primarily in the manufacture of high-octane gasoline rather than chemical materials, and when the economics is right, it is dealkylated to make benzene.

Ethylene is the giant of petrochemicals. Production capacity in the United States reached 42 billion pounds last year, but the recession held output to 29 billion pounds. Two-thirds of all ethylene is made from natural gas liquids. While plastics are the biggest end use, antifreeze, synthetic fibers, and solvents are other major consumer products using ethylene.

Propylene is a coproduct of ethylene. However, the production capacity of propylene is half that of ethylene, and output last year totaled nearly 15 billion pounds. Half of all propylene production ends up in fabricated plastic products, and synthetic fibers account for another major share of output.

Four-fifths of all butadiene production is used by the rubber industry, and with automobile sales off sharply, output decreased to 2.8 billion pounds in 1981 from 3.1 billion pounds in 1980. Production capacity totals 4.5 billion pounds. Aside from tires and other fabricated rubber products, a significant share of butadiene is used to make synthetic fibers.

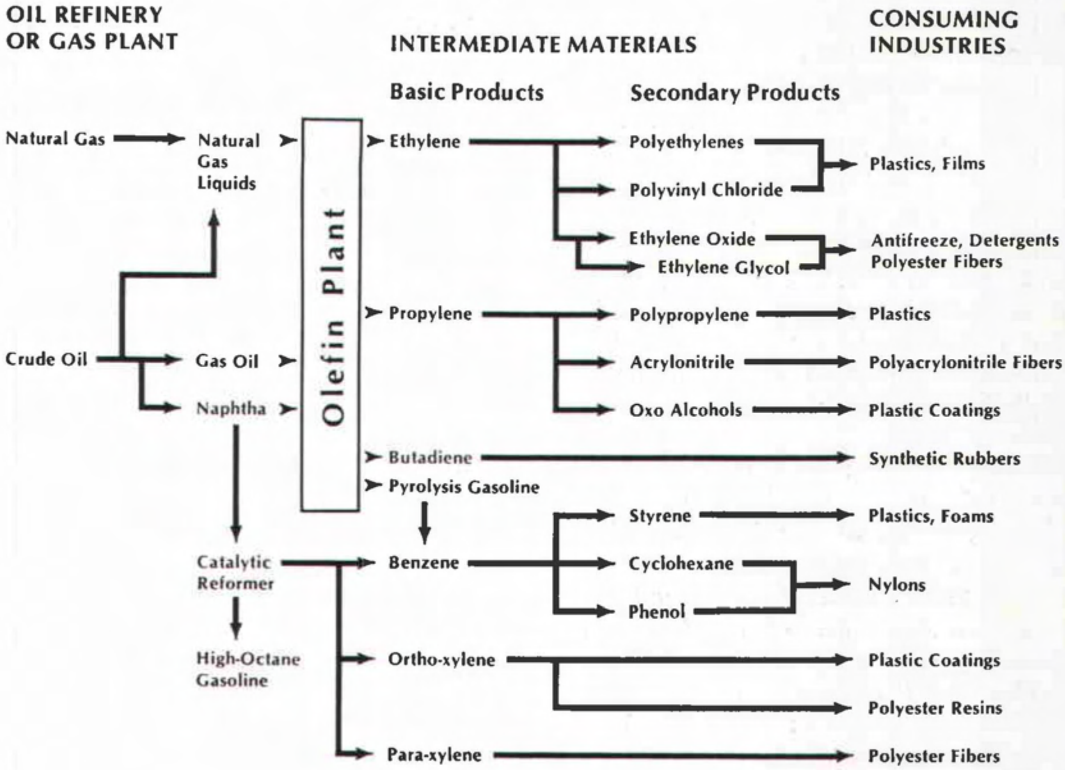
Benzene is the leading aromatic. Production last year was 1.6 billion gallons, although production capacity reached 2.6 billion gallons. Benzene is used to make polystyrene and thermosetting plastics. Of the other aromatics, several xylenes are produced in commercial quantities, but para-xylene dominates. Output of para-xylene totaled 3.8 billion pounds from a production capacity of 5.5 billion pounds. Its major end uses are polyester fibers, plastic films, and such fabricated items as plastic bottles.

total further if new plastic materials are developed to build such structural components as body frames and motor parts. It is only with such innovations that the share of petrochemicals used by the motor vehicle industry will increase.

Foreign competition looms as a limit to growth

Because domestic petrochemical manufacturers have had a competitive advantage over foreign producers in the way of cheaper feedstocks, export sales have grown at a rapid rate. From 1975 to 1980, the value of exports increased 25 percent a year, compared with a 21-percent rate of growth in total factory shipments and a 22-percent rate of growth in imports. A tenth of the production of basic petrochemicals is sold in export markets. Growth in export sales could help offset some of the slump in the automobile and housing markets. Shipments of exports slowed last year to a rate of increase of about 2 percent, and there is little likelihood they will rebound to the average rate of growth over the prior five years.

Stages in the Production of Petrochemical Products



In the short run, two factors have a substantial influence on export sales: foreign demand and the strength of the U.S. dollar. The economies of most of this country's major foreign trading partners will likely begin weak recoveries this year and outperform the U.S. economy. That should boost U.S. exports slightly, but sales may be tempered somewhat by the strength of the dollar. Continued high interest rates in this country relative to its trading partners would hold up the value of the dollar and make U.S. exports comparatively expensive.

In the long run, domestic chemical producers face stronger competition in international markets. Foreign countries producing oil and gas are beginning to build their own petrochemical industries. Countries in the Middle East have abundant supplies of oil. This may lead them to become major refiners, which would provide inexpensive feedstocks they could use to capture a significant share of the petrochemical market. However, transportation costs to consumer markets would add to the cost of their products, and major buyers might not rely heavily on supplies from that politically unstable part of the world.

More serious competitive challenges come from closer to home. The Canadians are rapidly expanding their petrochemical industry to process inexpensive gas supplies developed in the western provinces. The price advantage stems from Canada's price controls on oil and natural gas. The buildup in petrochemical capacity will increase the chemical trade surplus that country has with the United States. Last year, for example, chemical exports to the United States totaled $3.0 billion, compared with imports of $2.5 billion. Ethylene capacity is being increased in Alberta to 7.2 billion pounds a year by 1985 from 1.2 billion pounds currently. The increase will directly affect most U.S. manufacturers, particularly those in Texas and Louisiana, since three-quarters of Canada's ethylene output is sold in the United States. Therefore, the Canadian expansion will likely limit the growth of U.S. capacity for some time to come.

The Canadians will hold a strong competitive edge because the price of their supplies of natural gas liquids is held below the world price level. It is estimated that ethane may cost about 12 cents a pound in Alberta in 1986, compared with more than 20 cents in the United States, according to *Chemical Week*. That advantage will be offset somewhat by traditionally higher capital and transportation costs in Canada. Construction costs, for example, are 30 to 40 percent higher in Alberta than on the Gulf Coast. There are also some tariffs on Canadian products, but producers north of the border will still be able to deliver petrochemicals to users in this country at well below U.S. prices.

The development of oil and gas fields in Mexico also represents another source of substantial potential competition for U.S. petrochemical producers. And located close to the heart of the Gulf Coast petrochemical complex, the Mexican oil company, Pemex, may eventually be able to deliver petrochemicals very cheaply to U.S. users. Last year, Mexico had 64 petrochemical projects proposed, planned, or under construction, compared with 60 projects for the United States.

Despite the rise in foreign competition, domestic producers still retain a strong market position. The United States remains the largest integrated market in the world for chemicals and synthetic materials. The domestic industry has well-developed downstream processing facilities, and the current capacity of plants and equipment gives U.S. manufacturers the highest economies of scale. And the industry's strong technological base enables it to develop new higher value-added products. Therefore, even though domestic manufacturers face growing competition, many will be able to adjust to the coming changes in market conditions.