Chapter 8

Regional and National Economic Impacts

Contents

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INTRODUCTION

This chapter examines the types, timing, and distribution of economic impacts associated with both development of a synthetic fuels industry using national coal and oil shale resources, and improved automobile fuel efficiency. identifying and assessing these impacts are difficult because: impacts are not distributed evenly in time or across regions, so that people may not receive benefits in proportion to the adverse consequences they experience; impacts are not translatable into directly comparable terms (e.g., dollars); the evaluation of impacts is subjective, based on perceptions of the uncertain benefits and costs of new technologies; and impacts are cumulative and may be difficult to monitor or attribute solely to a particular technology choice.

This chapter assesses the broad economic impacts of synfuels and changes in auto technology. Chapter 9 further analyzes employment effects and discusses other social impacts of these technological developments. Decisions about synfuels and making cars more efficient will require tradeoffs in terms of energy use, economic growth, and social welfare and equity. There will be both beneficial and adverse social consequences for the Nation as it moves towards energy independence.

ECONOMIC IMPACTS OF AUTOMOTIVE CHANGE

Overview

The economic impacts of improving automotive technology result primarily from two factors: the large investments that will be required for associated capacity, and changes in the goods and services purchased by the auto manufacturers. Large investments increase financial risk, exhaust profits, and influence the ability of firms to raise outside capital. Changes in goods and services used by manufacturers affect suppliers and, in turn, local economies. As automotive fuel economy increases, the structure and conduct of the auto industry and the relationship of the domestic auto industry to the general economy change. Radical increases in demand for fuel economy, induced either by changes in consumer preferences or by Government mandates, would lead to greater industry change, most likely in the form of acceleration or exacerbation of current trends.

Changes in the auto industry stem from both technological developments and new market trends, including strong competition from foreign manufacturers. Large increases in demand for fuel economy, and for small cars relative to large cars, encourage the industry to improve the fuel economy of all car classes and to invest in the production of small cars. These activities help domestic manufacturers to satisfy relatively new demands, but at the cost of diminished profits during at least the short term. Profits can fall when manufacturers prematurely write off large-car and other capacity investments and change their pricing strategies to replace large-car profits with small-car profits.

Meanwhile, manufacturers lose money when sales of their least efficient models decline. High fixed costs and scale economies make their profitability vulnerable to sales declines of even a few percent. Profits would therefore also fall if domestic manufacturers lost market share to foreign firms. Future opportunities to gain market share and profits will be limited by slowing market growth. *

*The U.S. auto market is nearly saturated (there were 0.73 cars for every licensed driver in 1979, according to the Motor Vehicle Manufacturers Association) and the U.S. population is growing slowly. Therefore, auto sales will grow at lower rates than in past decades, probably averaging 1 to 1.5 percent per year.

Manufacturing Structure

The U.S. automotive industry includes three major manufacturers—General Motors (GM), Ford, and Chrysler-plus a smaller manufacturer, AMC (now almost half-owned by Renault, a French firm) and some very small specialty car manufacturers. The three major manufacturers have historically been characterized by moderate levels of vertical integration and broad product lines that include trucks and other vehicles as well as automobiles. During the past few decades, GM's operations have been the most extensive both vertically and horizontally; Chrysler's have been the least extensive.

Because of the high costs of production change, U.S. auto manufacturers are becoming less vertically integrated, relying increasingly on suppliers to. make components and other vehicle parts. For example, the Department of Transportation (DOT) reported that in late 1980 alone, domestic manufacturers announced purchasing agreements with foreign suppliers for over 4 million 4-cylinder gasoline engines plus several hundred thousand units of other engines and parts. Reliance on outside suppliers, referred to as "outsourcing," relieves short-term spending pressures on manufacturers. By spending less initially to buy parts rather than new plants and equipment (in which to make parts), manufacturers can afford to make more production changes while exposing less cash to the risk of financial loss due to limited or volatile consumer demands.

On the other hand, outsourcing may cause manufacturers to lose control over product quality. Also, manufacturers may incur higher vehicle manufacturing costs in the longer term because the price of purchased items includes supplier profits as well as production costs. Because of more severe financial constraints, Ford and Chrysler tend to rely on suppliers more than GM. In the future, all domestic manufacturers may outsource more from domestic suppliers, foreign firms, or foreign facilities owned by domestic manufacturers as a means of reducing capital investments and thus short-term costs.

Manufacturers are consolidating their operations across product lines and engaging in joint ventures, primarily with foreign manufacturers. While there appears to be no up-to-date source of data aggregating these changes, trade journals and the business press report that American firms are sharing production and research activities with foreign subsidiaries, with foreign firms in which they have equity (Ford with Toyo Kogyo, GM with Isuzu and Suzuki, Chrysler with Mitsubishi and Peugeot, AMC with Renault), and with other foreign firms. Joint ventures are also increasingly common between non-American firms, which have historically been highly interconnected.

Cooperative activity among auto firms worldwide is likely to grow. Many firms will be unable to remain competitive alone, because of the growing costs and risks of improving automotive technology and increasing competition in markets around the world. The quickest way for U.S. manufacturers to respond to a mandated or demand-induced fuel economy increase would be to use foreign automotive concepts directly, by licensing designs, assembling foreign-made automobile kits, or marketing imported cars under their own names. GM and Ford, for example, assemble Japanese-designed cars in Australia and AMC sells Renaults in the United States.

Domestic companies can make profits by merely selling foreign-designed cars. They can gain additional manufacturing profits without risking additional capital if they sell cars made by companies in which they have equity. Cooperative activity (and, in the extreme, mergers and acquisitions) allows firms to pool resources, afford large investments in research and development (R&D) or in plant and equipment, gain scale economies, and spread large financial risks. It is consistent with the reduction in the number of autonomous auto producers widely predicted by industry analysts.

Although the number of automotive manufacturing entities is declining worldwide, there may be continued growth in the number of firms producing and selling in the United States. Already, Volkswagen produces cars in Pennsylvania and is building a plant in Michigan; Honda is planning to build cars in Ohio; and Nissan is building a light truck plant in Tennessee. There are now about 23 different makes of foreign cars sold in the United States, excluding "captive imports" sold under domestic manufacturers' nameplates (e.g., the Plymouth Colt, which is made by Mitsubishi).[1] Manufacturers of captive imports, including Isuzu and Mitsubishi, are already preparing to enter the U.S. market directly.

Manufacturer Conduct

U.S. auto manufacturers are fundamentally altering their product, production, and sales strategies as automobile technology and consumer demand change. Several changes in product policy include the following.

First, the number and variety of models is falling. The highest number of models offered by domestic manufacturers was 375 in 1970; 255 were offered in 1980.[2] Manufacturers might sharply reduce the number of available models to increase fuel economy quickly, by producing relatively efficient models on overtime and ceasing production of relatively inefficient models.

Second, while cars of all size classes are shrinking in number, small cars are becoming more prominent in number, share of capacity, and contribution to revenues relative to large cars. Recent changes in price strategy have led to smaller profit differentials by vehicle size and higher absolute and relative small-car prices. As individual models become more alike in size, manufacturers will differentiate models by visible options and design.

Third, manufacturers may introduce new, oil-conserving products such as very small "mini" cars (e.g., GM's P-car and Ford's Optim projects) and vehicles powered by electricity as well as alternating fuels.

Cost-reducing alterations to the physical and financial characteristics of individual firms–widely reported in trade journals, the business press, and company publications—help manufacturers adjust to declines in sales and profits and growing investment requirements. Cost-cutting efforts include reductions in white-collar employment and elimination of relatively inefficient or unneeded capacity. During the last couple of years GM, Ford, and Chrysler have sold or announced plans to sell several manufacturing and office facilities. One investment analyst estimates that sales of assets may have provided over $600 million to GM and Ford during 1981.[3]

Efforts to reduce long-term costs focus on measures to improve productivity and reduce labor costs per unit. To improve productivity, manufacturers (and suppliers) are already investigating and beginning to use new types of equipment, plant designs, and systems for materials handling, quality control, and inventory management. Industry analysts and firms also expect that improved coordination between management and labor, vendors, and Government will be important means for improving productivity and competitiveness. Finally, manufacturers maintain that reductions in hourly labor costs (wages and/or benefits) are essential for making U.S. cars competitive with Japanese cars. Whether, when, and how much labor costs are lowered depends on negotiations between manufacturers and the United Auto Workers union.

Another cost-cutting measure is reduction in planned capital spending, Spending cutbacks affect firms differently, depending on their context. For example, Chrysler reduced 1980 planned capital spendings by $2 billion, halting a diesel engine project and others.[4] GM has announced cutbacks that take the form of spending deferrals and cancellations of planned projects (with little effect on immediate cash flow, however).

Another factor which complicates the evaluation of cutbacks is that U.S. projects abroad are, and could be, used to supply the U.S. market. Foreign projects are relatively cheap where foreign partners or foreign governments share in or subsidize investments. Cost-cutting efforts are consistent with growth in the share of U.S. auto investment and production abroad, because facilities in Central and South America, Asia, and in parts of Europe generally produce at lower costs

[1] Automotive News, *1981* Market Data nook (Detroit, Crain Communications, Inc., Apr. 29, 1981).

[2] Maryann N. Keller, "Status Report: Automobile Monthly Vehicle Market Review" (New York: Paine, Webber, Mitchell, Hutchins, Inc., February 1981).

[3] Maryann N. Keller, personal communication, 1981.

[4] *Ward's* Automotive Reports, June 15, 1981.

and sell in home markets that are more profitable than the U.S. market.

Some analysts believe that if extreme pressures were placed on U.S. manufacturers to make sizable investment in brief periods of time, Ford and GM (at least) would reduce U.S. production in favor of foreign production (Chrysler has divested foreign facilities to obtain cash). U.S. manufacturers and suppliers are already operating with high fixed costs, large investment requirements, weak demand, and labor costs higher than foreign competitors. If there are sharp increases in fuel economy demand, or if there are other sources of growth in perceived investment requirements–without offsetting changes in manufacturing and demand/market share–these developments might give auto firms additional incentives to curb, if not abandon, auto production in the United States. If U.S. production were curtailed, it would affect production of new, very efficient small cars while U.S. production of larger and specialty cars would probably continue. Large and specialty cars are characterized by consumer demand that is relatively insensitive to price and in many cases limited to U.S. car buyers.

Other Firms

Suppliers

Automobile suppliers manufacture a wide variety of products, including textiles, paints, tires, glass, plastics, castings and other metal products, machinery, electrical/electronic items, and others. Changes in the volumes of different materials used to produce cars and the ways in which cars are produced are changing the demands on suppliers. In the near term, for example, GM predicts that the average curb weight of its cars will fall 21 percent, from 3,300 lb in 1980 to about 2,600 lb in 1985, with up to 67 percent more aluminum, 48 percent more plastics, and 30 percent less iron and steel, by weight. Rubber use will also fall. GM predicts that steel will comprise a relatively constant proportion of car weight, while the proportion of iron will fall and aluminum and plastics proportions may even double by 1985[5] (see table 58).

Changes in demands for materials and other supplies create pressures on traditional suppliers to close excess capacity and invest to develop or expand capacity for new or increasingly important products. They also create new business opportunities for firms whose products become newly important to auto manufacturers, such as semiconductor and silicone producers. The degree of hardship on individual traditional suppliers depends on how much of their business is automotive and on their resources for change. Like the auto manufacturers, suppliers operate in the context of a cyclical market which can cause their cash flow to be unstable. Table 59 indicates the dependence of different supplier groups on automotive business as of 1980.

The steel and rubber industries have already been adversely affected by changing auto demands together with stronger import competition. Tire manufacturers have suffered with the rise in popularity of radial tires (which are replaced less frequently than bias ply tires and require different production techniques) and the fall in rubber use per vehicle. Between 1975 and 1980, over 20 tire plants (about one-third of the domestic total) were closed, one major tire manu-

[5] "GM Sees Big Gain for Aluminum, Plastics in 'Typical' 1985," Ward's Automotive Reports, Apr. 27, 1981.

Table 58.—GM's Major Materials Usage (per typical car, 1980 v. 1985)

Materials	1980 Pounds	1980 Percent total	1965 Pounds	1965 Percent total
Iron	500	15%0	250-300	10-12%
Steel	1,900	58	1,450	58
Aluminum	120	4	145-200	6-8
Glass	92	3	60	
Plastics	203	6	220-300	8-12
Rubber	86	3	88[a]	3[a]
Other	377	11	277	11
Total	3,300	100%	2,600	100%

[a] GM projects actual rubber use to be less than SS lb in 19S5.

SOURCE: General Motors Corp., reported in *Wards Automotive* Reports, Apr. 27, 1981.

Table 59.—1980 Motor Vehicles (MVs) and Parts Supplier Trade

Industry	Percent of industry output for MVs and parts	Value of output for MVs and parts
Textiles	7 +	$4 billion+
Wood products	2 +	618 million +
Nonhousehold furniture	2.4	260 million
Paper and allied products	3	2.5 billion +
Chemical	4 –	15 billion+
Plastics, synthetic rubber, and synthetics	6 –	4 billion+
Paints and allied products	8 +	900 million +
Tire and rubber products (OEM)	13	4 billion+
Glass	11–	1.3 billion
Steel furnaces, foundries, and forgings	21–	24.6 billion
Aluminum and aluminum products	14.6	4 billion+
Copper and other nonferrous metal products	11–	6 billion+
Metal products and machine shop products	13–	22 billion
Metalworkings and industrial machinery	5.6	8 billion+
Service industry machinery	12	3 billion
Electrical and electronic equipment	5.2	8 billion
Scientific and controlling instrument	7.5	900 million

NOTES: "+" means "greater than" and "–" means "less than." "OEM" stands for "original equipment manufacturer."

SOURCE: The Automotive Materials Industry Council of the United States.

facturer (Mansfield) declared bankruptcy, and another (Uniroyal) suffered severe financial problems (see fig. 18). Several steel plants were closed during the same period. In both industries, additional plant closings and continued import competition are likely in the 1980's, although the elimination of excess and inefficient capacity is expected by Government and private analysts to leave these industries financially healthier.[6]

Machinery and parts suppliers also face import competition and product demand changes. A recent Delphi survey of auto suppliers conducted by Arthur Andersen & Co. and the Michigan Manufacturers Association (hereafter referred to as A&M) predicted that these suppliers will be investing together at least $2 billion per year in the 1980's, especially for new equipment (about 60 percent of total investment). z Machinery investments are needed both to make new types of supplied products and to help suppliers adapt to a shortage of skilled machinists. A recent study prepared for DOT by Booz-Allen & Hamilton describes the types and levels of investments associated with different types of auto activities on a new-plant basis (see table 60).[8]

Analyses by A&M, Government agencies, and industry analysts suggest that both appreciation of the types of supplier changes needed and ability to make those changes are greater among larger supplier firms than among smaller ones. Most supplier firms are small- and medium-sized, although a few large firms have large shares of the auto supply business. Among GM's total 32,000 suppliers in the United States, for example, only 4 percent have at least 500 employees while 52 percent have at most 25.[9]

Auto product change and market volatility are leading large suppliers, in particular, to diversify into nonautomotive products. For example, between 1978 and mid-1981 Eaton Corp., a major supplier, spent about $470 million to buy companies producing electronics, machinery, electrical parts, hydraulic systems, and other high-technology goods.[10] Large suppliers are also

W .S. Department of Commerce, *1981* U.S. *Industrial Outlook* (Washington, D.C: U.S. Government Printing Office, 1981).

[7]Arthur Andersen & Co. and the Michigan Manufacturers' Association, "Worldwide Competitiveness of the U.S. Automotive Industry and Its Parts Suppliers During the 1980s" (Detroit: February 1981).

[8]Booz-Allen & Hamilton, Inc., Automotive Manufacturing *Processes* (Washington, D.C: U.S. Department of Transportation, National Highway Traffic Safety Administration, February 1981).

[9]"Supplier Conference, Ford/Europe Interview Underscore Threat, " Ward's Automotive *Reports,* June 15, 1981.

[10]"Eaton: Poised for Profits From Its Shift to High Technology," Business Week, June 8, 1981.

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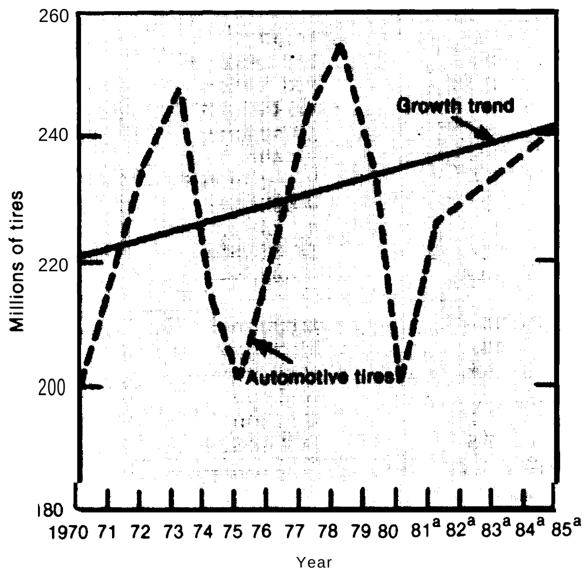
Figure 18.—Tire Industry Trends

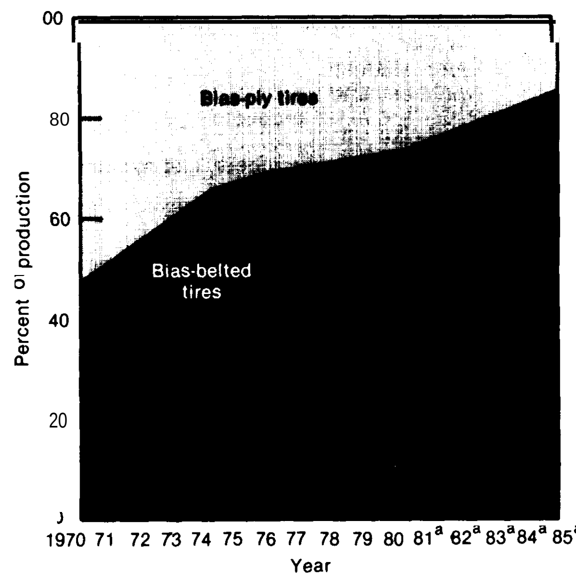
Consumption patterns for automotive tires



[a]Estimated by Bureau of Industrial Economics.

SOURCE: Trade Association data.

Product mix of passenger-car tires



[a]Estimated by Bureau of Industrial Economics.

SOURCE: Trade Association data.

Major tire manufacturer earnings fall,
July 1979 to June 1980, as the table below shows:

Company	Change in earnings
Armstrong. . . .	+ 12.1%
Cooper	negative (loss)
Dunlop	negative (loss)
Firestone	negative (loss)
General	negative (loss)
Goodrich	+ 11.2%
Goodyear	– 40.8%
Mohawk	negative (loss)
Uniroyal	negative (loss)

SOURCE: U.S. Department of Commerce, Bureau of Industrial Economics *1981 U.S* Industrial Outlook January 1981.

strengthening their international operations, diversifying away from the U.S. market. Small- and medium-size firms are likely to follow auto manufacturers in undertaking joint R&D and production ventures, while mergers and acquisitions and even closings or bankruptcies are likely. * The A&M survey predicted that decline in the numbers of suppliers will lead to increased vertical integration among suppliers, while strong import competition and other market changes will motivate increases in supplier productivity.

*According to Dun & Bradstreet, transportation equipment firms, primarily including auto suppliers, suffered financial failure at a rate of 101 per 10,000 in 1980, as compared with a rate of 42 per 10,000 for all manufacturers.

Sales and Service

Other segments of the auto industry include dealers and replacement part and service firms. The latter group, which serves consumers after they buy their cars, is called the automotive aftermarket.

Dealer sales activities are not necessarily affected by changing auto technology per se. Sales depend on consumer income and general eco-

Table 60.—Examples of Supplier Changes and Associated New Capacity Investment[a]

Characteristics	Approximate capital requirements for property, plant, and equipment
Foundries	
90 percent of auto castings use iron, 92 percent of which are sand cast, and auto manufacturers operate about 20 percent of U.S. sand casting capacity	$21 million (typical independent die cast foundry producing 15,000 tons/year)
Downsizing and production of smaller parts generates excess capacity	
Materials substitution reduces sand casting with iron and increases die casting with aluminum	
Metal stamping	
Autos have had up to 3,000 stampings and auto manufacturers produce about 60 percent of all stampings by weight	$67 million (typical captive plant producing stampings for 175,000 cars/year; independent plants are smaller and cheaper)
Materials substitution decreases carbon steel, increases high-strength steel and aluminum for stampings	
Plastics processing	
Injection molding	$31 million (typical plant producing 65 million lb parts/year)
Compression molding	$43 million (typical plant producing 60 million lb compound/year
Reaction injection molding	$19 million (typical plant producing 30 million lb parts/year)

[a]Figures for completely new facilities.

SOURCE: Booz-Allen & Hamilton, Inc.. Automotive *Manufacturing* Processes, prepared for the Department of Transportation, National Highway Traffic Safety Administration, February 1961.

nomic conditions (including the availability of credit), demographic conditions (including household size), the price of fuel, and vehicle price and quality attributes. Although consumers have responded to recent gasoline price increases by demanding relatively fuel-efficient cars, the experience of the recent recession illustrates that overall sales levels in a given year are primarily determined by consumer finances and not by vehicular technology.

There are about 300,000 automobile repair facilities in the United States[11] (see table 61). New automobile technology affects them because automobile design and content are changing. For example, problems in new, computer-controlled components will be diagnosed with computerized equipment, and plastic parts will be repaired with adhesives rather than welding. Components are more likely to be replaced than repaired on the vehicle or even at the repair shop. While automobile service firms will have to invest in new equipment and skills to service new cars, continued service needs of older cars may ease the transition,

[11] "Auto Repair Facilities Total 300,000," *Ward's* Automotive Reports, Apr. 6, 1981.

Table 61 .—1980 Auto Repair Facilities

Type of facility	Quantity
Dealers	26,000
Auto repair shops (independent and franchised)	170,000
Tire—battery-accessory outlets	18,850
Other auto and home supply stores	1,860
Gasoline stations	70,000
General merchandise stores	3,500
All others	1,430
Total	292,240
Total including facilities selling only parts, accessories	331,090

SOURCE: *Wards Automotive* Reports, Apr. 6, 1981.

However, the concurrent operation of very different types of cars requires firms to double their parts inventories to service both types. The dollar value of parts and the frequency of repairs are also likely to differ between new and old car types. Manufacturers are attempting to curb service cost growth by designing cars for easy servicing. For example, the Ford Escort and Lynx and the Chrysler K and Omni/Horizon cars were designed so that servicing during the first 50,000 miles would cost less than $150.[12]

[12] Francis J. Gaveronski, "Ford's New Escort, Lynx Designed for Easy Service," Automotive News, May 19, 1980, and "Chrysler K-car to Stress Ease of Diagnosis, Repair," Automotive News, June 16, 1980.

The effects of new repair and service practices on the structure of the aftermarket are uncertain. During the past decade, repair and service activity shifted from dealers to service centers run by general retailers (e.g., Sears) and tire retailers (e.g., Firestone) and to specialized franchised centers for tune-ups, body work, or component service (e.g., AAMCO Transmissions and Midas Muffler). Both of these trends help to moderate service cost increases because of scale economies in planning and management. However, the intimate and advance knowledge of new technologies held by manufacturers is likely to help dealers regain repair and service business. While dealers now perform about 20 percent of auto repairs, they are expected to gain a greater share by the mid-1980's. Meanwhile, scale economies in advertising and inventory management may promote consolidation among parts firms.[13]

Prospects

Further financial strain on the domestic auto industry is not likely to lead to financial failure of major manufacturer and supplier firms (except perhaps Chrysler, but Government intervention makes its future hard to predict). However, the continued viability of many smaller auto suppliers is becoming especially uncertain because automotive technology changes make products and capacity obsolete. While the industry may continue to contract, "collapse" of its leading firms is not likely because major and even intermediate-sized firms can make at least partial adjustments to automotive market changes; adjustments are already under way. Reduction in the U.S. activities of domestic firms and failure or contraction of smaller firms would, nevertheless, severely affect employment and local economies.

In contemplating the future of the industry it is important to appreciate what financial failure means. In a technical sense, businesses fail when they are unable to make scheduled payments. If this inability is temporary, firms can usually negotiate with creditors or seek protection from bankruptcy courts to relieve immediate creditor demands. In many cases, bankrupt firms are successfully reorganized, structurally as well as financially. However, some firms find that the stigma of bankruptcy makes producing and selling especially difficult. * If selling a firm's assets generates more value than using them for production by the firm, the firm is fundamentally unviable, and there are financial and economic grounds for liquidating it.

Barring Government support or merger, Chrysler is the large automotive firm most likely to fail if viability in the U.S. market entails large investments that it cannot afford. AMC has been at least temporarily rescued by the French Government-backed Renault. Because Chrysler's financial weakness has been known for years, the magnitude of the potential social and economic effects of its failure has been diminishing as Chrysler has cut back its operations and suppliers have reduced their dependence on Chrysler as a customer.

In mid-1979, when Data Resources, Inc., prepared for the U.S. Department of the Treasury a simulation of the macroeconomic effects of a Chrysler bankruptcy and liquidation, it found that only temporary macroeconomic instability was likely to result, although 200,000 people might be permanently unemployed. Dependence of workers and businesses on Chrysler has diminished since that simulation was done, although small firms for which Chrysler is a primary customer remain vulnerable. If Chrysler were to liquidate, its exit from the U.S. market would provide opportunities to domestic and foreign manufacturers to expand market share and purchase plant and equipment at relatively low cost. This could relieve financial pressures on Ford and GM.

While contraction of the U.S. auto industry may result in fewer, healthier firms, employment and local economies will suffer.** Loss of jobs will re-

[13] Maryann N. Keller, "Status Report: Auto Parts Industry Automotive Aftermarket Quarterly Review" (New York: Paine, Webber, Mitchell, Hutchins, Inc., July 29, 1980).

*When Lockheed and Chrysler appealed for Government aid, they both argued that their customers would not buy from firms in bankruptcy. This is more likely to be a problem for automobile (or aircraft) manufacturers than for their suppliers, given the difference in size of customer purchase and producer liability.

**Also, change in the amount of U.S manufacturer operations in Canada (not considered "foreign") could imply violation of our obligations under the Automotive Products Trade Act agreements with Canada.

suit predominantly from supplier-firm difficulties. Unemployment of auto industry workers may also affect the performance of the national economy. Unemployment causes a more than proportionate decline in aggregate production, because slack demand reduces average hours per worker, output per worker, and entry into the labor force, The reduction in disposable personal income (DPI) because of unemployment reduces personal consumption spending. Reduced personal consumption (and business fixed investment) spending reduces gross national product (GNP), causing DPI to fall, and so forth. Both personal and corporate tax revenues decline, while transfer payments to unemployed workers and economically depressed communities rise.

The national economy can better adjust to auto industry trauma than local and regional economies because the national economy is more diversified, and because, over time, national economic sensitivity to auto industry problems has been diminishing. Since World War II, manufacturing employment in the Midwest (and Northeast) has been declining as a percent of national manufacturing employment; it has declined in absolute volume since 1970 because job opportunities have not been growing, foreign and domestic firms have located facilities in other regions, and other industries primarily located elsewhere have been growing in their importance to the economy. * In this context of structural change, the 1975 recession seems to have been a turning point for traditional Midwest manufacturing, accelerating a trend of decline that was further aggravated by the 1979-80 oil crisis and recession.

*Electronics, computing equipment, chemicals and plastics, aerospace equipment, and scientific instruments have been the leading growth industries in the postwar period. These industries are both outlets for diversification by auto-related firms and competitors to traditional auto-related firms in automotive supply.

ECONOMIC IMPACTS OF SYNFUELS

Because large blocks of capital are required for synfuels projects, they will be visible centers of economic activity even from a national viewpoint and, in fact, for' people outside of the synfuels industry, the economic costs and benefits of synfuels may be more easily understood in terms of regional and national impacts.

Despite the absence of commercial experience, an outline of the synfuels industry emerges with comparisons to coal mining, conventional oil and gas production, chemicals processing, and electric power generation. By itself, this new industrial organization is an important economic impact, as it changes the way economic decisions are made regarding the supply of premium fuels. Furthermore, along with the technologically determined menu of resource requirements, industrial organization determines the major regional and national economic impacts of synfuels deployment.

potential regional and national economic impacts are then explored through comparisons of aggregate resource demands and supplies. Since plans call for very large mines and processing plants, and perhaps many construction projects in progress at once, the emphasis is on potential bottlenecks which could delay deployment schedules and drive up project costs. If severe resource bottlenecks do occur, the resulting inflation in the prices of these resources will spread through the economy, driving up prices and costs for a broad range of goods and services.

These resource costs add up in the next section of this chapter to financial requirements for projects and for the industry as a whole. To the extent that the Federal Government does not intervene, individual firms must compete in financial markets with all other products and all other firms for limited supplies of debt and equity capital. With the important exception of methanol and ethanol from biomass, * the large scale and long leadtimes of synfuels projects may make it difficult to raise capital, especially during the next

*Ethanol from biomass is not included in this discussion because with current technology its potential production is limited by the availability and price of feed-grain feedstocks. However, if economic processes for converting ligno-cellulose into ethanol are developed, ethanol could compete with methanol as a premium fuel from biomass.

decade, when important technological uncertainties are likely to remain. Federal subsidies or loan guarantees will speed synfuels deployment–but only by reducing capital available to other types of investments, by reducing other Federal programs, by increasing taxes, or by increasing the Federal deficit. Depending on general economic conditions, each of these different market interventions may be inflationary.

Each of these areas of regional and national economic impacts—industrial structure, potential resource bottlenecks, finance capital, and inflation as related to synfuels development–is discussed below.

The Emerging Industrial Structure of Synfuels

Synfuels are fundamentally different from conventional oil and gas because they are manufactured from solid feedstocks and because synfuels economics may lead to the replacement of conventional fuels by methanol and low- or medium-Btu gas in the future. Liquids from coal and oil shale, the feedstocks with a natural resource base sufficient to fully displace petroleum in the long run, involve economies of scale which encourage ownership concentration. The methanol option, however, provides offsetting opportunities for large chemical firms to enter the liquid fuel business and, based on biomass feedstocks, it may also allow many small producers to supply local markets throughout the Nation.

The following discussion is broken down into the four stages of synfuels production. While this breakdown is convenient, it should be understood that several stages of production may be performed on the same site in order to minimize handling, transportation, and management costs.

Mining Coal and Shale

Mining for synfuels will closely resemble mining for any other purpose except that the mines dedicated to synfuels production will be relatively large.[14] It takes approximately 2.4 million tons of coal per year to fire an 800 MWe generator and about three times that much to feed a 50,000 barrels of oil equivalent per day (BOE/D) coal synfuels plant, and about four to eight times as much oil shale (by weight) for the same output of liquid fuel produced by surface retorting. *

Capital costs for development of a coal mine depend primarily on the depth and thickness of the coal seam. Average investment cost data can be misleading, since each mine is unique, but it takes about $60 of investment per annual ton of coal mined underground (1981 dollars). With coal preparation and loading facilities, investments at the mine site may approach $100 per annual ton, or about $750 million for capacity sufficient to supply a 50,000 bbl/d synfuels plant. Western surface mining may in certain cases be substantially less expensive. ** Furthermore, substantial synfuels production may be achieved on the basis of existing excess mining capacity.***

In the absence of commercial experience, investment cost estimates are unavailable for shale mining. It is clear, however, that they can be either larger or smaller than for coal, depending on two opposing factors. First, investments costs could be much higher because of the low energy density of shale. Hence, much more material must be mined per barrel of oil equivalent. Second, shale investment costs could be lower because major shale resources lie in very thick

[14] For an extensive discussion of mining techniques and costs, see The Direct Use of Coal: Prospects and Problems of Production and Combustion, OTA-E-86, (Washington, D. C.: U.S. Congress, Office of Technology Assessment, June 1979), chs. III and IV.

*This range is determined by the Btu content of coal and shale and by the efficiencies of converting a Btu of solids into a Btu of finished liquid fuels. If we just compare shale oil and methanol (the two liquid synfuel options which are best understood and probably of least cost), conversion efficiencies are comparable, so the difference in feedstock rates is entirely a matter of the energy density of the feedstock. Coal has 16 to 30 MMBtu/T with Western coal typically on the lower end of the range. Shale, which is presently considered suitable for retorting, has 3.6 to 5.2 MM Btu/T. Hence, the ratio of shale to coal inputs can be as low as 4.2 and as high as 8.3.

**Investment cost data were obtained from National Coal Association. Federal surface mine regulations have increased investment requirements in increasing the equipment required to operate a mine and to reclaim land after coal has been removed, by increasing the amount of premining construction and equipment required to establish baseline data, and by extending the required development period.

***The National Coal Association estimates excess capacity at 100 million to 150 million tons per year. The low end of the range is calculated on the basis of the number of mines closed and the number of workers working short weeks. The high end of the range is calculated by comparing peak weekly production to average annual output per week.

seams (in some areas over 1,000 ft thick) and often relatively near the surface. Estimates for the first commercial shale project indicate that mining investments for a 50,000 bbl/d project may be substantially below $750 million. * Furthermore, if in situ retorting techniques fulfill optimistic expectations, shale mining could become relatively inexpensive as mining and retorting operations are accomplished together underground.

Mine investment is important in project planning, but its share in total investment is still usually less than a third. (Notice that in the estimated investment costs for coal-based synthetics in ch. 8, the cost of the mine was not included. It is included in ch. 4 in the discussion of total investment costs.) Beyond actual costs, the activity of mining itself is important in the synthetic fuel cycle because of its previous absence in the U.S. oil and gas industry. In fact, the entire sequence of economic events associated with extraction of coal and shale contrasts sharply with the extraction of conventional petroleum and natural gas. The key difference is that oil and gas reserves must be discovered, with potentially large rewards for the discoverer, while the location and morphology of coal and shale resources have been known for a long time.

A wildcat driller, looking for an oil or gas deposit, can rent and operate a drilling rig with a relatively small initial investment. Since the most promising prospects have already been drilled in this country, exploration typically is a high-risk gamble and, although investment is small compared with development of resources, it can still require large sums of money in frontier areas such as deep water or the Arctic. The uncertainty is a deterrent to investment, but potentially large payoffs and special Federal tax incentives continue to attract large numbers of investors and large sums of capital.[15] Furthermore, the wildcatted can induce cooperation from landowners, local government officials, and any other powerful local interests by promising royalty payments, or at least a rapid expansion of local business activity, without serious environmental impacts. Only after a substantial reservoir has been discovered is it necessary to make relatively large investments in development wells, processing equipment, and pipelines.

In mining, there is nothing comparable to the opportunity and uncertainty of discovery wells. Most of the business parameters of a potential mine site are evident to the landowner and to all potential mining companies, which means that profit margins are generally limited by competitive bidding.

As discussed below, mines also typically employ more labor per million Btu of premium fuel produced than oil and gasfields[16] and they have many more adverse environmental impacts (e.g., acid drainage, subsidence, etc). For both reasons, interests external to the firm are more likely to oppose and perhaps interrupt mining operations. Investors realize such contingencies and see them as risks for which they expect compensation.

This discussion of relative payoffs and risks is by no means complete or conclusive, but it does suggest that private investors may exploit min-

"The Denver office of Tosco Corp. estimates that mine costs for the Colony project, which is the first shale project to proceed with commercial development, could be as low as $250 million. That particular site has the advantage that large-scale open pit mining equipment can be used in an underground mine, since the seam is horizontal and the mine can be entered via portals opened in a canyon wall. This means that the reclamation costs of a surface mine can be avoided as well as the costly mine shaft of a conventional underground mine. Furthermore, the site is propitious because there is virtually no methane trapped in the shale, so safety measures are minimal. In the future, mine costs as well as conversion costs may be held down by in situ liquefaction, but this technology remains unproven.

15 In 1979, approximately $12.5 billion was invested in exploration for oil and gas in the United States. That includes (in billions), $5.4 for lease acquisition, $4.5 for drilling, $2.3 for geological and geophysical activity, and $0.3 for lease rentals. (See Capital *Investments of the World Petroleum Industry,* 1979, Chase Manhatten Bank, p. 20, and Basic *Petroleum* Data Book, American Petroleum Institute, vol. 1, No. 2, sec. Ill, table 8a). $12.5 billion is about 3 percent of total gross domestic investment ($387 billion). (See 1980 Statistical Abstract, p. 449.)

The oil and gas industry receives special tax treatment mainly in terms of expensing intangible expenditures of exploration, even though they are surely treated as capital expenses in corporate accounts.

16 Although oil and gas has been closing steadily, in 1979 it took approximately 14,500 workers (miners and associated workers) to produce a Quad of coal and about 11,500 workers to produce a Quad of oil and gas. However, the labor intensity of mining for synfuels is actually 160 to 200 percent greater than for coal alone, since only about 50 to 60 percent of the energy in coal feedstock remains in the finished synfuel product. See 1980 Statistical Abstract, p. 415, for employment data and 1980 Annual Report to Congress, Energy Information Administration, p. 5, for production data. See note 2, ch. 9 for further discussion of labor productivity.

ing prospects for synfuels much more slowly than prospects for conventional oil and gas, or that investors will accept much greater risks with conventional oil and gas prospects because of the offsetting chances of striking it rich. Synfuels capacity could still expand rapidly, but probably not without very high profit incentives to reorient investors who have traditionally been in oil and gas exploration.

Conversion Into Liquids and Gases

During the second stage of production, solid feedstocks are converted into various liquids and gases. Current synfuels project plans indicate that coal or shale conversion plants will resemble coal-fired electric power stations in the sense that both convert a large volume of solid feedstock into a premium form of energy. They will resemble chemical processing (in products such as ammonia, ethylene, and methanol from residual oil or natural gas) and petroleum refining facilities in their use of equipment for chemical conversions at high temperatures and pressures. *

Of the $2 billion to $3 billion (1981 dollars) required overall for a 50,000 BOE/D shale project, between one-third and one-half goes into surface retorts which decompose and boil liquid kerogen out of the shale rock. A larger fraction of total project costs is required to obtain methanol from coal, but with subsequent avoidance of the upgrading and refining costs.** In general (but with the exception of in situ mining shale), the conversion step alone requires investments comparable to a nuclear or coal power station of 1 GWe capacity or to outlays for a 200 to 400,000 bbl/d petroleum refinery.[17]

Factors other than economy of scale dominate the economics of syngas production, as demonstrated by the existence of many small gasification plants across the country.[18] Two factors account for this. First, gasification is only the first stage in the production of either methane or methanol, so costs of the second stage can be avoided and system engineering problems are less complex and more within the technical capabilities of smaller users. Airblown gasifiers involve the least engineering, since they do not require the production of oxygen, but only certain onsite end users such as brick kilns can use the low-Btu gas. The second reason involves transportation and end-use economics.

In many industrial applications, natural gas (methane) has been the preferred fuel or feedstock, but medium-Btu gas is an effective substitute in existing installations because it requires relatively minor equipment changes. Either low- or medium-Btu gas may be used in new installations, depending on the industrial process and site-specific variables. However, since these methane substitutes cannot be transported over long distances economically, conversion facilities must be located near the end users.

The size of the conversion facility is therefore determined by the number and size of gas consumers within a given area, and this often dictates conversion plants that are small in comparison with a 50,000 bbl/d liquid synfuels plant. Consequently, industrial gas users may choose to locate near coalfields in order to produce and transport their own gas or to contract from dedicated sources. Either approach assures security of supply and availability over many years.

Upgrading and Refining of Liquids

As discussed in chapter 6, raw syncrudes from oil shale and direct liquefaction must be upgraded and refined to produce useful products. Technically, these activities are quite similar to petroleum refining, and this affords a competitive advantage to large firms already operating major, integrated refineries. This bias toward large, established firms is reinforced in the case of direct

*Refineries typically use lower pressures than chemical plants and lower than what is expected for synfuels conversion.

** For a breakdown of methanol costs, see ch. 8.

[17]As discussed in ch. 8, all synfuels capital cost estimates are very uncertain because none of these technologies has been used commercially. Furthermore, engineering cost estimates available to OTA typically do not clearly differentiate costs by stages of production. Nevertheless, the conversion step, going from a solid feedstock to a gas or a liquid product, is undoubtedly the most expensive single step in synfuels production. For presentation of costs for electric power stations see *Technical Assessment Guide,* Electric Power Research Institute, July 1979.

[18]See National Coal Association, "Coal Synfuel Facility Survey," August 1980, for a listing and discussion of between 15 to 20 low-Btu gas facilities coupled with kilns, small boilers, and chemical furnaces.

coal liquids by the apparent cost reduction if upgrading and refining are fully integrated with conversion, thus making it difficult for smaller firms to specialize in refining as some do today. Upgraded shale oil, on the other hand, is a high-grade refinery feedstock that can be used by most refineries.

Downstream Activities: Transportation, Wholesaling, and Retailing

As long as synthetic products closely resemble conventional fuels, downstream activities will be relatively unaffected. However, medium- or low-Btu gas and methanol are sufficiently different to require equipment modifications, and they may be sufficiently attractive as alternative fuels to induce changes in location of business and structure of competition.

Depending.on the market penetration strategy, methanol may be mixed with gasoline or handled and used as a stand-alone motor fuel. As a mixture, equipment modifications will involve installation of corrosion-resistant materials in the fuel storage and delivery system. As a stand-alone fuel, methanol may have its own dedicated pipeline and trucking capacity and its own pump at retail outlets, and auto engines may eventually be redesigned to obtain as much as 20 percent added fuel economy, primarily by increasing compression ratios and by using leaner air-fuel mixtures when less power is required. *

If firms currently producing methanol for chemical feedstocks should enter fuel markets,[19] drivers stand to gain from the increased competition among the resulting larger number of major fuel-producing companies and by competition between methanol and conventional fuel. Furthermore, with coal-based methanol providing a critical mass of potential supply, drivers across the Nation may be able to purchase fuel from small local producers (using biomass feedstocks), a situation which has not obtained since the demise of the steam engine.

*See ch. 9 for further information about methanol vehicles.

[19]At the present time, approximately 1.2 x 109 gal barrels of methanol (1 1 x 1 0[6] BOE) are produced domestically, primarily from natural gas, and used almost exclusively as a chemical feedstock. See Chemical and Engineering News, Jan. 26, 1981.

Medium- or low-Btu gases are effective substitutes for high-Btu gas (methane) but, as discussed above, their relatively low energy density prohibits mixing in existing pipelines and generally restricts the economical distance between producer and consumer (the lower the Btu content the shorter the distance). Hence, deployment of these unconventional gases will require dedicated pipelines, relocation of industrial users closer to coalfields, or coal transport to industrial gas-users.

Conclusion and Final Comment

Massive financial and technical requirements for synthetic liquids from oil shale and coal encourage ownership that is more concentrated than has been typical in conventional oil and gas production. Large firms, already established in petroleum or chemicals, have three major advantages.

First, they can support a large in-house technical staff capable of developing superior technology and capable of planning and managing very large projects. Second, they can generate large amounts of investment capital internally, which is especially important during the current period of high inflation (inflation drives up interest on borrowed capital, making it much more expensive for smaller firms who must supplement their more limited internal funds).

Third, such firms already have powerful product-market positions where synthetic liquids must compete, so entry by new firms involves a greater risk that synthetic products cannot be sold at a profit. * The second and third advantages may be

*Predicting investment behavior is always difficult, but barring Federal policy to the contrary, the most likely group of potential investors are the 26 petroleum and chemical firms, each with 1981 assets of $5 billion or more (see list below). Seven chemical firms were included in this list primarily because they may be in a strong position to produce and market fuel methanol, based on their experience with methanol as a chemical feedstock.

Fortune, May 4, 1981, presents a listing of the 26 largest (in terms of total assets) petroleum and chemical firms: Exxon, Mobil, Texaco, Standard Oil of California, Gulf Oil, Standard Oil of Indiana, Atlantic Richfield, Shell Oil, Conoco, E. 1. du Pent de Nemours, * Phillips Petroleum, Tenneco, * Sun, Occidental Petroleum, Standard Oil of Ohio, Dow Chemical, * Getty Oil, Union Carbide, * Union Oil of California, Marathon Oil, Ashland Oil, Amerado Hess, Cities Service, Monsanto, * W. R. Grace, * and Allied Chemical. * Asterisk indicates firm primarily in the chemicals industry.

This conclusion about the dominance of larger companies holds despite the fact that current synfuels projects planned or under study

(continued on next page)

nullified if several smaller firms can effectively band together into consortia, but it maybe much more difficult for a consortium to build a technical staff which can develop superior technology and manage large projects during the next decade, when there will be many technical risks.

Ownership concentration is an important aspect of industrial organization in an economy organized on classical economic principles of anonymous competition, market discipline, and consumer sovereignty. Very large synfuels projects owned by very large energy corporations and consortia of smaller firms would not be anonymous, even from the viewpoint of the national economy, and they would have leverage to dictate terms in their input and output markets.

Conversely, once companies have made very large investments in new synfuels projects, they become visible targets for political action which might significantly raise costs or reduce output. Visible producers may not in fact allocate resources much differently than if there were only anonymous competitors, but at least the opportunity to manipulate markets exists where it would not otherwise—and just the appearance of doubt about the existence of consumer sovereignty can raise serious political questions.

The capital intensity of synfuels will also change the financial structure of the domestic liquid and gaseous fuel industry. Compared with investments in conventional oil and gas during the last 20 years, investment in synfuels per barrel of oil equivalent of productive capacity (barrels of oil per day) will increase by a factor of 3 to 5.[20] While all such calculations are of necessity very imprecise, the order of magnitude is confirmed by data contained in the 1980 Annual Report of Exxon Corp. As of 1980, Exxon's capitalized assets in U.S. production of oil and gas totaled $11.5 billion, and its average daily production rate (of crude oil and natural gas) was about 1.4 million BOE; so its ratio of capital investment to daily output was $8,200.[21] A 50,000 BOE/D synfuels plant at $2.2 billion implies a ratio more than five times larger ($44,000/BOE/D).

In other words, switching from conventional to synthetic liquids and gases amounts to a substitution of financial capital (and the labor and durable goods it buys) for a depleting stock of superior natural resources. A parallel substitution of investment capital for natural resources is occurring as conventional resources are increasingly hard or expensive to find and develop because of the depletion of the finite stockpile of natural resources.

As long as the United States could keep discovering and producing new oil and gas at relatively low cost, energy supplies did not impose serious inflexibilities on our economy. When we needed more we could get it without making much of a sacrifice. With synfuels, it is necessary to plan ahead, making sure that capital resources are indeed available to supply synfuels projects, and that product demand is also going to be available at least a decade into the future so that large synfuels investments can be amortized.

The current financial situation of many electric utilities in the United States illustrates the risks entailed when plans depend on long-term price and quantity predictions which may prove to be wrong. It was not long ago that utility investments were considered almost risk-free, and the industry had for decades raised all the debt it wished at low rates. Needless to say, the utility situation has now dramatically reversed as the result of sharply rising costs embodied in new, long-lived gener-

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involve many relatively small firms. For example, three of the four major parties in the Great Plains Gasification Project are primarily involved with either gas-distribution or transmission: American Natural Resources Co., Peoples Energy Corp., and Transco Cos. Inc. American Natural Resources is associated with gas-distribution firms operating in Michigan and Wisconsin; Peoples Energy Corp. is associated with Northern Natural Gas, a major distributor in the Midwest; and Transco is the parent company of Transcontinental Gas Pipeline Co., a major operator of transmission lines. The fourth partner, Tenneco, is also a major transmission company, but it was included in the group of top 26 firms listed above because of its chemical processing business. Undoubtedly, all four firms' participation is predicated upon the existence of Government subsidies and loan guarantees, but that is especially true for the three smaller firms.

[20]Comparison based on data for total costs of oil and gas wells, plus estimated costs for predrilling activities over the period from 1959-80. Capital outlays per barrel oil equivalent of reserves over the past 20 years averaged about $1.60. Depending on the synfuels option, a synfuels plant would have a comparable ratio of $5.40 to $7.00/BOE of "reserves." Well-drilling and other exploration costs were obtained from Society of Exploration Geophysicists, Annual Reports and from Joint Association Survey of the U.S. Oil and Gas Producing Industry.

[21]See 1980 *Annual* Report of Exxon *Corporation,* pp. 34, 44, 51.

ating capacity. while it may be premature to draw an analogy with synfuels, it is clear that synfuels will tie up capital in considerably larger blocks and for considerably longer periods than was true for conventional oil and gas reserves over the last 30 years.

Compared with synthetic petroleum, methanol presents two opportunities to partially offset the tendency toward industrial concentration. First, as indicated above, its present use as a major chemical feedstock provides an opportunity for large chemical firms to enter the liquid fuel business. Second, since methanol can be produced from wood and other solid biomass, small-scale conversion plants (approximately $1 O-million investments) operated by relatively small entrepreneurs may be able to take advantage of local conditions across the country. * Assuming cost competitiveness, having a mixture of small- and large-scale methanol producers may reinforce the attractiveness of downstream equipment investments (e. g., retail pumps and engine improvements), thus making it more likely that drivers will indeed have an attractive methanol opt ion.

Besides methanol, synthetic gases may attract additional large and small firms from outside the petroleum and chemical industries. Depending on the deregulated "well head" price of natural gas (relative to fuel liquids) and depending on regulatory policy regarding utility pricing, synthetic natural gas and synthetic medium-Btu gas may become profitable investments for gas utilities. Indeed, the first synthetic gas project to reach the final planning stage has substantial gas utility ownership, * * Syngas may become attractive as a methanol coproduct or as a primary product, in either case taking advantage of capital savings and higher conversion efficiencies than if methanol or gasoline is the sole product of indirect liquefaction.

*One domestic company, International Harvester, is presently developing technology to mass-produce this equipment and transport it to the purchaser's location in easily assembled modules.

* *This compares with total private domestic investment in 1980 of about $395 billion, and out of that total about $294 billion went for nonfarm investments in new plant and equipment. Also in 1980, two large blocs of energy investments were $34 billion for oil and gas exploration and production and $35 billion for gas and electric utilities.

A final comment can be made about the location of the synfuels industry. Shale oil production will be concentrated in Colorado and Utah, since that is where superior shale resources exist and since unprocessed shale cannot be shipped as a crushed rock without driving up costs prohibitively, Coal-based synfuels offer the possibility of spreading liquid fuel production over a wider cross section of the Nation. This is especially important for the Northeast and North Central section of the United States, where there remain substantial coal deposits in Pennsylvania, Ohio, and Illinois, States which have by this time depleted most of their original petroleum reserves.

Unlike their shale counterparts, coal-conversion facilities and subsequent upgrading and refining plants need not be immediately adjacent to the mine mouth, since coal's shipping costs per Btu are less than for shale. Location of facilities and, hence, their regional impacts will depend on site-specific factors and the available modes of transportation. Location of facilities to convert biomass into methanol will be determined primarily by local availability and cost of biomass feedstocks. This restriction is imposed by the dispersed location of plant material, rather than by differences in energy density (biomass feedstocks such as wood have an energy density only marginally lower than some Western coals).

Potential Resource Bottlenecks and Inflation

Technology, ownership concentration, and (in certain important cases) regional concentration, all combine to impose heavy demands on labor, material, and financial resources relative to current and potential new supplies of the same resources. If deployment plans fail to account for supply limitations, long project delays and large cost overruns can occur.

Anytime a capital-intensive industry attempts to start up quickly, temporary factor input shortages can be expected—if not more extreme "bottlenecks" or chronic shortages which generally disrupt construction schedules. Ideally, shortages and, certainly, bottlenecks can be avoided by advanced planning and giving suppliers purchase contracts years in advance if necessary to ensure availability. However, while such planning and long-term commitments minimize shortage risks, they also increase risks of loss should plans be technically ill-conceived and commitments are made to projects with actual costs much larger than planned. These two sets of risks must be weighed against each other, but at the present time technical risks clearly are more significant.

In order to predict resource bottlenecks and their impacts, the full array of supplier market dynamics must be understood. In this limited discussion, one can only begin to compare potential demands and supplies for key synfuels resources.

As a final introductory remark, it should be clear that factor price inflation drives up costs in many industries, not just for builders of synfuels plants. Industries that appear most vulnerable to inflation resulting from synfuels deployment will be identified. However, in general, a much larger study would be necessary to trace inflationary pressures through complex interindustry transactions.

Experienced Project Planners, Engineers, and Managers

As planned, the construction of oil shale and coal liquids projects requires the mobilization of thousands of skilled workers and massive quantities of equipment and materials. Of all these synfuels investment resources, the supplies of skilled engineers and project managers are the most difficult to measure, and in the final analysis, it is left up to the large investing firms to decide for each project when a critical mass of talent has been assembled. While individual firms may have excellent engineering departments, the possibility of supply bottlenecks for chemical engineering services, across the full spectrum of chemical processing industries, must be of concern because of the potential financial risks due to design errors and because of the length of time required to educate and train new people. *

t the present time, only one of the country's 10 major architectural and engineering (A&E) firms[22] has actually built a synfuels plant. * No commercial-scale plant has been built. Given this general inexperience, and making the reasonable assumption that A&E firms will not be short of work worldwide, it seems highly unlikely that synfuels construction contracts for the first round of a rapid deployment scheme will be able to hold builders to binding cost targets and completion dates. Consequently, those who would actually take investment risks may be extremely skeptical of builders' qualifications and judgment, and this may severely limit the apparent supply of qualified engineers and engineering firms.

Furthermore, if synfuels projects proceed ahead at a rapid pace despite the technical uncertainties and commercial inexperience, it could drive up the A&E costs for other large, new processing facilities which rely on the same limited group of A&E firms and the same pool of skilled workers. Of all synfuels resource markets, the possibilities

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● Well-trained engineers and project planners can still make major mistakes, but risks due to miscalculations and design errors are controlled by careful training and building up experience incrementally. Commonly accepted periods for obtaining a bachelor's degree and subsequent on-the-job training range from 6 to 10 years.

Several recent examples illustrate that errors in the design of large mining and chemical processing plants do occur and can cause severe cost overruns and project delays. Perhaps the most extreme case was the Midwest (nuclear) Fuel Reprocessing Plant built for General Electric. Construction started in 1968, with completion planned for 1970 at an estimated cost of $36 million. Unfortunately, expected time for major technical component failure in the new plant was less than the time required to achieve stable operating conditions. The project was abandoned and the company estimated that an additional expenditure of between $9o million and $130 million would have been required to redesign and rebuild.

Additional examples include a municipal solid waste gasifier in Baltimore begun in 1973 which never achieved its major goal of commercial steam production, an oil sands project in Canada which underwent extensive retrofit when the teeth of its large mining shovels were worn away in a matter of weeks by frozen oil sands, and so on. Clearly, major design errors have happened in the past and are likely in the future, with the number and severity of such errors increasing if a shortage of experienced design engineers develops,

For further information about these and other examples of design errors, see Edward Merrow, Stephen Chapel, and Christopher Worthing, A Review of Cost Estimation in New Technologies: *Implication for Energy Process Plants and Corporations*, July 1979.

[22]According to Business *Week*, Sept. 29, 1980, p. 84, the 10 major A&E firms, in order of their largest projects to date, are: Fluor, Parsons, Bechtel, Foster Wheeler, C-E Lummus, Brown and Root, Pullman Kellog, Stone and Webster, CF Braun, and Badger.

*The Fluor Corp. built Sasol I and II in South Africa and will undoubtedly sell this technology and its unique experience in the United States. However, different resource endowments can cause very different engineering economics in different countries, and thus this existing technical base may have to be adapted to the United States by investing in significant additional engineering.

for propagation of inflation from synfuels into the rest of the economy is greatest here. Petrochemicals, oil refining, and electric power generation are all industries which depend on the same engineering resources in order to build new facilities. in 1979, these three industries accounted for more than 25 percent of the total investment in new plant and equipment.[23]

Mining and Processing Equipment, Including Critical Metals for Steel Alloys

The construction of massive and complex synfuels plants will require equally massive and diverse supplies of processing equipment and construction materials. Some of this equipment must meet high performance standards for engineering, metals fabrication, component casting, and final product assembly because it must withstand corrosive and abrasive materials under high pressure and temperature.

Potential supply problems can be identified first by comparing projected peak annual equipment demand (for each deployment scenario) to current annual domestic production. While projections were not done specifically for OTA's low and high scenarios, useful information can be extrapolated from an earlier projection for the deployment of coal liquids.[24] In that analysis, which postulated 3 million barrels per day (MMB/D) of synfuels by 2000, 7 of 18 input categories were identified as questionable because projected synfuels demands account for a significant fraction of domestic production. * Supply problems for chromium, the one item in this group of seven which is not a manufactured piece of equipment, would not be caused by synfuels deployment, since synfuels requirements would amount to less than 3 percent of domestic consumption, but supplies may nevertheless be difficult to obtain because U.S. supply is imported, much of it from politically unstable southern Africa.[25]

For the six types of equipment identified, the actual occurrence of bottlenecks will depend on the ability of domestic industry to expand with synfuels demand. In all cases, including draglines and heat exchangers—where coal synfuels requirements exceed 75 percent of current domestic production even in the low scenario—there appear to be no technical or institutional reasons why, if given notice during the required project planning period, supplies should not expand to meet demand with relatively small price incentives.

In general, this optimistic conclusion is based on the fact that leadtimes for expanding capacity to produce synfuels equipment are shorter than the leadtimes required to definitely plan and then build a synfuels plant.[26] The fact that many plants would be built at the same time does not nullify this basic comparison as long as all synfuels construction projects are visible to supplier industries, as they should be. Furthermore, foreign equipment suppliers can be expected to make up for deficiencies in domestic supply if not actually displace domestic competitors.

For example, consider the case of heat exchangers. As indicated in table 62, coal synfuels

[23]For data see Statistical Abstract, 1980, p. 652.

[24]Data obtained from "A Preliminary Study of Potential Impediments," by Bechtel National, Inc., which is one part of a three-part compendium, Achieving a Production Goal of 1 Million B/D of Coal Liquids by 1990, TRW, March 1980. We can extrapolate from coal liquids to all other synfuels because subsequent research (by E. J. Bentz & Associates, OTA contractor) indicates that shale oil, coal liquids, and coal gases are all quite similar in their total use of processing equipment per unit output (measured in dollars) and in their mix of processing equipment. Furthermore, the Bechtel study remains useful, despite its age, since subsequent increments in synfuels plant costs do not add items to this list or significantly increase demand requirements for the group of seven critical items. In other words, recent escalations in plant costs are primarily related to increases in the expected prices of components and to increasing demands for certain components which are insignificant when compared with productive capacity nationwide.

*Significance in this case means that projected synfuels demand exceeds 1 to 2 percent of domestic production. Since this is a relatively low threshold, this list should stay about the same for both scenarios.

[25]The chief use of chromium is to form alloys with iron, nickel or cobalt. In the United States, deposits of chromite ore are found on the west coast and in Montana. However, domestic production costs are much higher than in certain key foreign countries. In 1977, South Africa produced about 34 percent of total world production, with the U.S.S.R. and Albania producing another 34 percent. Other major producers are Turkey, the Phillipines, and Zimbabwe. See Minerals in the U.S. Economy: Ten-Year Supply-Demand Profiles for Nonfuel Mineral Commodities (1968-77), Bureau of Mines, U.S. Department of Interior, 1979.

[26]One can never be certain about how well industrial systems will adapt to rapidly expanding demand for a limited number of highly engineered types of equipment which must be produced with stringent quality control, However, informal surveys of equipment manufacturers have not revealed substantial reasons why equipment supplies should not be responsive to moderate price incentives. See Frost and Sullivan, Coal Liquefaction and Gasification: Plant and Equipment Markets 1980 2000, August 1979.

Table 62.—Potentially Critical Materials and Equipment for Coal Liquids Development

Category	Units	(A) Peak annual requirements	(B) U.S. production capacity	(A)/(B) (percent)
1. Chromium	tons	10,400	0	—
2. Valves, alloys, and stainless	tons	5,900	70,000	8
3. Draglines	yd	2,200	2,500	88
4. Pumps and drivers (less than 1,000 hp)	hp	830,000	20,000,000	4
5. Centrifugal compressors (less than 10,000 hp	hp	1,990,000	11,000,000	18
6. Heat exchangers	ft^2	36,800,000	50,000,000	74
7. Pressure vessels (1.5 to 4 inch walls)	tons	82,500	671,000	12
8. Pressure vessels (greater than 4 inch walls)	tons	30,800	240,000	13

SOURCE: Achieving a Production Goal of *1* Million *B/D* of Coal Liquids by *1990,* draft prepared for the Department of Energy by TRW, Inc. and Bechtel National, Inc., March 1980, pp. 4-28. Although these projections apply to the achievement of 3 MM B/D of coal liquids, and not specifically to the low and high production scenarios Postulated in this report, they nevertheless Indicate rough orders of magnitude for equipment demand. See footnote 16 of this chapter for further discussion of alternative synfuels projections.

requirements for the low scenario could account for about 75 percent of current domestic U.S. production. Extrapolation from table 62 indicates that requirements for the high scenario could amount to 150 percent of current production and, as data in table 63 indicate, even in the low scenario, synfuels demand could exceed current U.S. production for "fin type" heat exchangers. However, productive capacity can expand as rapidly as machine operators and welders can be trained, which for an individual worker is measured in terms of weeks and months. Additional heat-treated steel and aluminum inputs will also be required, as well as manufacturing equipment, but in all cases supplies of these inputs should expand with demand .27

This generally optimistic assessment does not mean that temporary shortages could not occur and temporarily drive up equipment prices if prospects for synfuels deployment should improve dramatically.[28] However, as orders for new equipment skyrocket, new capacity should become available in time so that extremely high equipment prices can be avoided if project managers are willing to accept relatively brief (measured in months) delays in delivery.

Skilled Mining and Construction Labor

Construction workers and their families can move with employment opportunities, but moving is costly and especially burdensome if jobs in an area last for only a period of months. In order to induce essential migration, synfuels projects must incur high labor costs in the form of travel and subsistence payments as well as

[27]Compared with the full range of heat exchangers used in industrial and utility applications, those likely to be used in synfuels plants will operate at relatively low temperatures. Low-temperature units are made primarily out of carbon steel, low-alloy steel, and enamel steel, all of which are readily available in commodity markets where demand for heat exchangers is a small fraction of the total. Hence, material inputs are unlikely to restrain expansion of heat exchanger supplies.

It is also unlikely that skilled labor or manufacturing plant and equipment will limit supplies, because the required welding and machine operator skills can be learned in a period of weeks if necessary, and manufacturing facilities are not highly specialized. Background information about the heat exchanger industry, and synfuels technology in particular, was obtained by private communication with James Cronin, Manager of Projects, Air Preheater Division, Combustion Engineering, Wellsville, N.Y.

[28]A commonly cited example of a temporary inflationary spurt, caused by a construction boom, occurred in the U.S. petrochemicals industry in 1973-75. Over the period from the mid-1 960's to mid-1 970's, the following three price indices show a distinctive pattern for chemical process equipment:

Year	Chemical process equipment[a]	Producer goods[b]	All machinery and Equipment
1967	100	100	100
1970	81	110	111
1971	86	119	118
1972	74	135	122
1973	91	160	139
1974	139	175	161
1975	167	183	171
1976	188	194	182
1977	154	209	206

[a]Data obtained from Annual Survey of Manufacturers, Bureau of Census, U S. Department of Commerce, SIC No. 35591 005, as reported in ASM-2.
[b]Data obtained from U.S. Statistical Abstract, 1979, PP 477-79.

In words, chemical process equipment prices reversed a decline in 1973, increased by more than 150 percent through 1976, and then tapered off again in 1977. This compares with a steady upward trend from both producer goods and all machinery and equipment.

Table 63.—Peak Requirements and Present Manufacturing Capacity for Heat Exchangers (Million Square Feet)

	Peak requirements for 3 MMB/D of coal liquids (1985)"	U.S. manufacturing capacity
1. Process shells and tubes.	22.0	27
2. Fin type	9.2	8
3. Condensers	4.4	15
	36.8	50

apeak requirements indicate maximum capacity requirements if synfuels Projects are to maintain production schedules.

SOURCE: Achieving a Production Goal of 1 Million B/Do f Coal Liquids by 1990, draft prepared for the Department of Energy by TRW, Inc. and Bechtel National, Inc., March 1980, pp. 4-28.

"scheduled overtime. " * However, while the influx of people and the relatively high payments to workers may cause severe local inflation, regional and national impacts should not be significant. Confidence in this conclusion is based primarily on the fact that training in construction skills can be obtained in the period of weeks and months and that, if anything, there is an oversupply of people willing to enter these trades.[29]

Miners will be expected to move into a new area and stay permanently. Although it would seem reasonable to suppose that workers would be reluctant to mine underground, where working conditions can be unpleasant and hazardous, historical experience suggests otherwise. In the Eastern mines, with present wages about 140 percent of the national average in manufacturing, labor shortages have not been a serious problem.[30]

Basic Construction Materials

Among all synfuels resources, basic construction materials (primarily steel and concrete) are least likely to cause serious bottlenecks. The more rapid the pace of deployment, the more likely a premium price must be paid for steel and cement, but supplies of both should be highly responsive to price incentives.

Mineral resources for the manufacture of Portland cement (the class of hydrolic cement used for construction) are widely distributed across all regions of the Nation. The same is true for the sand and gravel that are mixed with cement and water to make concrete. The only constraint on supplies of cement or concrete is the time required to construct new capacity, which takes at most 3 years for a new cement plant and much less than that for a concrete mixing facility.[31] Since these times are short relative to the construction period for a synfuels project, cement shortages should not be a serious problem.

Steel supplies, on the other hand, may be insufficient in certain regions because required resources such as iron ore, scrap, and coking coal are not widely distributed. However, steel can be shipped long distances without dramatically raising costs. For example, unfabricated structural shapes and plates (e.g., 1 beams) are valued today at approximately $25 per hundred pounds FOB

*Apparently, it is important for major employers to emphasize that they do not pay premium wages and salaries for large construction projects, but instead there are various special considerations. Whatever it is called, total worker remuneration appears to provide an abnormally large incentive.

[29]Bechtel's experience at nuclear powerplant sites in Michigan, Pennsylvania, and Arizona has demonstrated that a person with limited welding experience can be upgraded to "nuclear quality" in 6 to 12 weeks of intensive training. See Bechtel, "Production of Synthetic Liquids, " pp. 4-23. Actual training periods are influenced by various institutional factors. For further discussion of labor productivity see K. C. Kusterer, Labor Productivity in Heavy Construction: Impact on Synfuels Program Employment, Argonne National Laboratory, ANL/AA-24, U.S. Department of Energy.

The supply of people willing to work on large construction projects seems to be very price-elastic. In other words, large numbers of skilled or "able-and-willing-to-learn" workers will migrate to even remote construction sites if wage incentives exceed going rates elsewhere in the Nation by 20-30 percent. Although it is difficult to confirm this conclusion in published literature, it appears to be commonly held among university-based experts as well as in the construction industry, Information was obtained from private communications with J. D. Borcherding, Department of Civil Engineering, University of Texas in Austin; Richard Larew, Department of Civil Engineering, Ohio State University; John Racz, Synfuels Project Manager, Exxon USA in Houston; and Dan Mundy, Building Construction Trades Department, AFL-CIO, in Washington, D.C.

[30]As prescribed in the new United Mine Workers/Bituminous Operators Association contract, dated June 6, 1981, underground miners presently earn $10 to $11.76 per hour and surface miners $11.15 to $12.53. This compares with the national average wage in manufacturing of $7.80 and the average wage in construction of $9.90, both calculated for March 1981. See Monthly Labor Review, May 1981, p. 84, for additional wage data. The generalization, that labor supply has not been a serious problem, is a conclusion reached but stated only implicitly in an OTA report, The Direct Use of Coal, op. cit.

[31] Information about the resource base and construction leadtimes obtained by private communication with Richard Whitaker, Director of Marketing and Economic Research, Portland Cement Association, Skokie, III,

(freight on board at the factory) and they are commonly shipped from Bethlehem, Pa., to Salt Lake City, Utah, for another $4 per hundred pounds. In other words, even if local production is insufficient to meet the needs of synfuels deployment, vast additional supplies from a national network of suppliers can be shipped into the area without driving up costs excessively .32

Final Comments

Despite OTA's conclusions that resource shortages other than engineering skills need not obstruct synfuels deployment, it does not follow that rapid synfuels deployment would not be inflationary for a broad range of resource inputs. Disregarding the prospect of Federal intervention to speed up deployment or to alleviate impacts, rapid deployment could cause bursts of inflation in an economy where certain suppliers have dominant market positions at least within regions, where skilled workers are reasonably well organized, and where people have grown accustomed to inflation. In such circumstances, it would be surprising if those with power to negotiate their revenues and incomes did not exercise it to their advantage when demand for their product and services is rapidly expanding.

Another caveat should also be made concerning the importation of processing equipment. If foreign suppliers compete successfully and become major suppliers of synfuels equipment, as they have already demonstrated in the Great Plains Gasification Project, rapid deployment could result in substantial foreign payments.[33] Depending on the general balance of payments picture, this could devalue the dollar in foreign exchange markets and thus increase the price of all imports into the United States. Perhaps offsetting this concern about balance of payments, the success of equipment imports may have a salutary effect on domestic producers by inducing them to improve their products and lower their costs.

Finance Capital and Inflation

In addition to potential shortages among resource inputs, the deployment of synfuels capacity may be restrained by the limited availability of financial capital. Such a limit has already been mentioned for small companies which cannot raise $2 billion to $3 billion and for any company trying to borrow at presently inflated interest rates.

Limits may also be imposed by financial markets that compare synfuels against all other types of investments. If synfuels projects are indeed unprofitable, the number of projects funded may be small or, if they are profitable, the number may be large. In this sense, a market-based synfuels deployment scenario should be self-correcting, with the lure of profits attracting new investment when expansion is warranted and the pain of losses driving investors away and thus curtailing deployment. Any of the previously discussed shortage possibilities, should they arise, will be perceived sooner or later by investors and the number of projects reduced as a result.

Whether or not deployment is by market incentives or Government policy, the adjustment and possible disruption of financial markets required by synfuels deployment can be discussed in terms of gross investment data. Assume that on the average, during its 5-year construction period, a $2.5-billion synfuels project requires $500 million in outlays annually. This compares with total private domestic investment in 1980 of about $395 billion, of which total about $294 billion went for nonfarm investments in new plant and equipment. Also in 1980, two large blocs of energy investments were $34 bilion for oil and gas exploration and production and $35 billion for gas and electric utilities.[34]

[32]Data obtained from American *Metal Market,* June 16, 1981, and from Bethlehem Steel, Washington Office. It should be noted that fabricated steel or steel which has been tailored to specific applications can cost as much as $75 per hundred pounds and hence ship ping costs may add much less to delivered costs (on a percentage basis).

[33]In this first major synfuels project, the Japanese low bid was substantially below apparent costs. Among other things, this indicates the competitive determination of at least one foreign supplier to capitalize on synfuels deployment. For related comments by U.S. Steel firms, see *Metals Daily,* Sept. 4, 1980; and the Chicago Tribune, Aug. 30, 1980. For a general analysis of the U.S. steel industry and its competition from abroad, see Technology *and Steel Industry* Competitiveness, OTA-M-122 (Washington, D. C.: U.S. Congress, Office of Technology Assessment, June 1980).

[34]All investment data except for oil and gas were obtained from the Survey of Current Business, Bureau of Economic Analysis, U.S. Department of Commerce, September 1981, pp. 9, S1. Oil and gas

In other words, 12 fossil synfuels plants under construction at the same time would account for about 18 percent of the 1980 investments for the production of petroleum and natural gas, about 17 percent of 1980 investments by electric utilities, or about 5 percent of the total investment in manufacturing. At this pace, assuming 5-year construction periods, approximately 2 MMB/D capacity could be installed over the next 20 years (the low scenario). Almost three times this many plants on the average must be under construction at one time, and about three times as much capital must be committed to achieve the goal of just under 6 MM B/D by 2000 (high scenario). In either case, this average would be achieved by means of a relatively gradual startup, as technologies are proven and experience is gained in construction, followed by a rapid buildup as all systems become routine.

The question remains: Can funding be reasonably expected for scenarios presented in this report? The answer depends on the future growth of GN P and the future value of liquid fuels relative to other fuels and to all other commodities. Without trying to predict the future, the question may be partially answered by showing that such a diversion of funds to energy applications has precedents in recent history.

From 1970 to 1978, investments in oil and gas grew at a rate of about 7.5 percent per year and investments in electric utilities grew at about 5 percent per year, both in constant dollars.[35] A glance back at synfuels requirements as fractions of existing energy investments shows that it would take only about 2.5 years of 7.5 percent growth in oil and gas investments or about 3.5 years of 5 percent growth in electric utility investments to provide sufficient incremental funds to support the low scenario, and about three times as many years of growth in each case to fund the high scenario.

In other words, another 5-year period of expansion in energy investments, similar to their growth in 1970-78 with oil and gas and electricity added together, could provide more than enough funds annually to reach the goal of about 6 MMB/D of synfuels by 2000 (high scenario), assuming that this higher level of investment were sustained for the next 20 years. Furthermore, if such rapid deployment were economically justified (i.e., other costs were rising sufficiently to make synfuels relatively low-cost options) there would be an economic incentive to divert funds to synfuels which had been devoted to conventional fuels.

Final Comments About Inflation and Synfuels

In an inflating economy, all price increments tend to be viewed as inflationary. However, this appearance obscures the fact that some price increases are necessary adjustments in relative prices in order to reduce consumption and to increase production. The latter will be true if synfuels place large, long-term, new demands on scarce human and material resources.

On the other hand, construction costs have grown faster than the general rate of inflation since the mid-1960's.[36] (See fig. 19.) Recently, the reverse has been true but there is reason to be concerned that rapid synfuels deployment could exacerbate what has been a serious inflationary problem. In any case, rising real costs of construction has been one of the major reasons why "current" estimates of synfuels costs have more or less kept pace with rising oil prices. (See ch. 6 for more detailed discussion.)

Finally, although most of this discussion has explored how synfuels deployment may aggravate inflation, the cause and effect could be reversed if deployment of first generation plants is too slow. That is, if the promise of synfuels remains

investment data were obtained from *Petroleum Industry Investments in* the 80's, Chase Manhatten Bank, October 1981. The total of $34 billion is broken down into $22 billion for service equipment, $6.3 billion for lease bonuses, and $3.1 billion for geological and geophysical data gathering.

35 Energy investment growth data obtained from *1978 Annual Report to Congress*, Energy Information Administration, p. 128.

36 Consumer Price index obtained from 1980 U.S. Statistic/ Abstract, p. 476. Construction Cost Index obtained from Engineering News Record, McGraw Hill, Dec. 4, 1981, Market Trends Section. The actual data series published in this journal has been converted from a base year of 1916 to a base year of 1977. There are several construction cost indices published by reputable sources, but only the ENR was reproduced here because the data available to OTA suggest that all such series reflect more or less the same trends.

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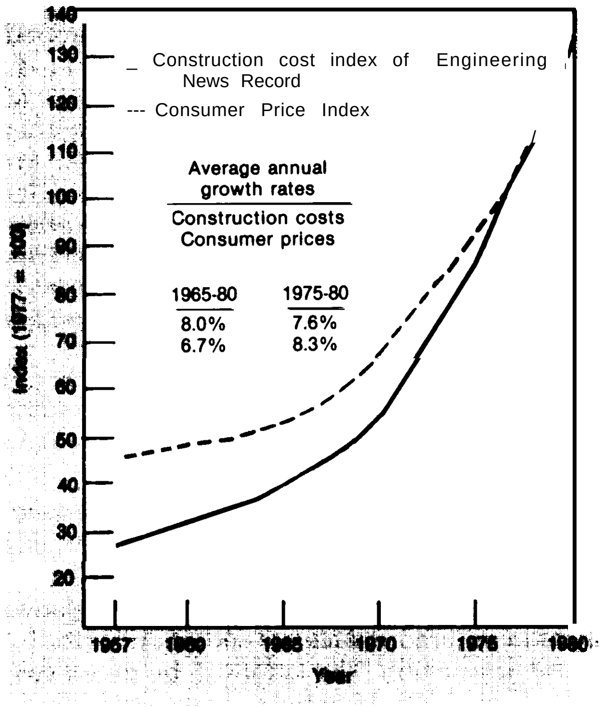
Figure 19.—Time Series Comparison: Construction Costs and Consumer Prices



SOURCE: U.S. Bureau of Labor Statistics, "Monthly Labor Review and Handbook of Labor Statistics," annual, and **"BM** and ID Investment Manual," ***Investment Engineering,*** sec. 1, part 6, item 614, pg. 1, Apr. 16, 1961.

in the distant future and conservation attempts are clearly insufficient to balance oil supply and demand worldwide, there will be no market-imposed lid on the price of oil and no reason to expect that sharp oil import price increases will not continue to destabilize domestic prices. In that case, the inflationary impacts of rapid deployment may appear to be much more acceptable.