Energy's Role in Competitiveness: Context and Strategy

J. M. Roop

February 1990

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government of any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

NTIS Price Codes, Microfiche A01

Printed Copy

Price Code	Page Range	Price Code	Page Range
A02	1- 10	A15	326-350
A03	11- 50	A16	351-375
A04	51- 75	A17	376-400
A05	76-100	A18	401-425
A06	101-125	A19	426-450
A07	126-150	A20	451-475
A08	151-175	A21	476-500
A09	176-200	A22	501-525
A10	201-225	A23	526-550
A11	226-250	A24	551-575
A12	251-275	A25	576-600
A13	276-300	A99	601-Up
A14	301-325		

ENERGY'S ROLE IN COMPETITIVENESS:
CONTEXT AND STRATEGY

J. M. Roop

February 1990

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

This study of competitiveness has three objectives. The first objective is to explain how macroeconomic and microeconomic factors can affect structural change in the U.S. economy and how energy is linked to these factors. The second objective is to provide an explanation of how many individual decision makers, in responding to higher energy prices, have changed the structure of the economy. This structural change, and the effect it has had on energy use, is estimated for the U.S. economy. A major component of these changes results from changes in U.S. trade with other countries, which gives rise to the third objective. The third objective is to develop a research design that will allow a better understanding of the role that energy plays in the competitiveness of goods in world trade.

A number of factors define energy's role in competitiveness. The first set of these factors is macroeconomic: demographics, fiscal policy and monetary policy. The second set relates to trade, trade policy and exchange rates. The third set is microeconomic; special attention is given to the decisions that affect savings and investment and, through investment, technology and productivity.

Structural change in the U.S. economy over the period 1972-1982 is analyzed using a method developed in a previous study. There are two major conclusions. The first is that structural change in the United States has substantially altered energy use in this country. Significant increases in energy use that would have resulted from growth were offset by substantial reductions through both indirect adjustment in the way that businesses use energy-intensive materials and in direct adjustments in the way that businesses use energy. The second conclusion is that the trade component of the economy accounted for a disproportionately large portion of changes in overall energy consumption.

A research project, of which this report is a first phase, has been designed that will allow energy's role in competitiveness to be better understood. The research design is as follows. Begin by analyzing the structural change in one of the major trading partners of the U.S. using a

method based on decomposition of changes in energy use into several components: changes in final demand, changes in interindustry flows, changes in energy-use intensity, and four interaction components. Second, examine trade flows between that country and the United States from both the domestic perspective and from the perspective of the other country. Third, compare the trade flow changes with changes in the industry structure of both countries, identifying the industries in which the adjustments have been most severe. Fourth, assess whether the following hypotheses are supported or rejected by the evidence: 1) the country with the relative cost advantage in energy will export those commodities that are more energy intensive; 2) where embodied energy is only an insignificant element in the costs, the country with the higher energy costs will export relatively more commodities with low levels of embodied energy; and 3) where aggregate adjustments to changes are similar between trading partners, trade flows will not be materially affected.

Repeat steps one through four until the United States' six major trading partners (Japan, Canada, Federal Republic of Germany, United Kingdom, France and Italy) have been analyzed. Examine multilateral trade flows among the seven countries, as was done bilaterally for the U.S. and each trading partner. Organize the results of these studies into a final report that assesses the role of energy in international competitiveness and focuses on the policy implications.

CONTENTS

SUMMARY	iii
1.0 ENERGY'S ROLE IN COMPETITIVENESS: CONTEXT	1.1
1.1 AN OVERVIEW OF FACTORS AFFECTING COMPETITIVENESS	1.3
1.2 MACROECONOMIC FACTORS	1.6
1.2.1 Demographics	1.6
1.2.2 Economic Policies	1.8
1.3 TRADE POLICY, TRADE, AND EXCHANGE RATES	1.12
1.3.1 Trade Policies	1.12
1.3.2 Trade	1.14
1.3.3 Exchange Rates	1.16
1.4 MICROECONOMIC FACTORS	1.17
1.4.1 Savings-Investment Balance	1.18
1.4.2 Technology and Productivity	1.22
1.5 STRUCTURAL CHANGE IN THE U.S. ECONOMY	1.25
2.0 ENERGY IMPLICATIONS OF STRUCTURAL CHANGE IN THE U.S. ECONOMY	2.1
2.1 A FRAMEWORK FOR INTERINDUSTRY ANALYSIS	2.2
2.1.1 The Economic Agents	2.2
2.1.2 The Interindustry Structure	2.4
2.1.3 Industry Energy Use	2.5
2.1.4 Data Sources	2.5
2.2 METHOD	2.7
2.3 RESULTS: AGGREGATE U.S. ECONOMY	2.10
2.4 RESULTS: TRADE COMPONENTS OF THE I/O TABLE	2.14

2.5	RESULTS: MERCHANDISE TRADE	2.18
2.6	DISCUSSION AND CONCLUSIONS	2.20
3.0	THE ROLE OF ENERGY IN COMPETITIVENESS: RESEARCH DESIGN	3.1
3.1	HYPOTHESES	3.1
3.1.1	Hypothesis 1	3.2
3.1.2	Hypothesis 2	3.2
3.1.3	Hypothesis 3	3.3
3.2	APPROACH	3.3
3.2.1	Step 1: Examine Structural Change	3.4
3.2.2	Step 2: Examine Trade Flows	3.4
3.2.3	Step 3: Compare Trade Flow Changes with Structural Changes	3.5
3.2.4	Step 4: Assess Hypotheses	3.6
3.2.5	Step 5: Examine Multilateral Trade Flows	3.6
3.2.6	Step 6: Identify Policy Implications and Develop Recommendations	3.7
4.0	REFERENCES	4.1

FIGURES

1.1	Factors Influencing Competitiveness and Structural Change	1.5
1.2	Federal Expenditures	1.9
1.3	U.S. Trade and Current Account Balances	1.15
1.4	The Savings-Investment Equality	1.18
2.1	Venn Diagram of U.S. Energy Use Changes, 1972-1977	2.9
2.2	Venn Diagram of U.S. Energy Use Changes, 1977-1982	2.11
2.3	Venn Diagram of U.S. Energy Use Changes, 1972-1982	2.11
2.4	Decomposition of Export Energy Use, 1972-1977	2.15
2.5	Decomposition of Import Energy Use, 1972-1977	2.15
2.6	Embodied Energy in Foreign Trade	2.19
2.7	Energy Intensity of Exports and Imports	2.21

TABLES

2.1	Changes in Energy Use in the U.S. Economy: Selected Years . . .	2.10
2.2	Changes in Energy Use for Exports and Imports, 1972-1977 . . .	2.16
2.3	Energy Content and Value of Exports, Imports, and Net Foreign Balance, 1972 and 1977, U.S. Manufacturing	2.17
2.4	Energy Use Calculated from Equation (2.4) for Exports, Imports and Net Foreign Balance, 1977 Technology	2.18
2.5	Inflation-Adjusted Value of Merchandise Trade	2.20

1.0 ENERGY'S ROLE IN COMPETITIVENESS: CONTEXT

The President's Commission on Industrial Competitiveness (1985, p. 6) defines competitiveness as, "The degree to which a nation can, under free and fair market conditions, produce goods and services that meet the test of international markets while simultaneously maintaining and expanding the real incomes of its citizens." With an emphasis on increasing the standard of living, it is clear that balanced trade alone is not the measure of competitiveness. Although nations may have imbalances in their trade account over periods of time, every nation must balance its account in the longer term. Trade imbalances may be symptomatic of other significant changes that are occurring in the economy, changes such as restructuring or adjustment to major shocks imposed from outside the economy, e.g., the OPEC price shocks.

The objective of this chapter is to understand the forces that have brought about restructuring and economic change in the U.S. economy and how this restructuring relates to the competitive position of U.S. goods in world trade. A primary objective is to understand the role that energy plays in these changes. There is little doubt that energy plays a role in structural change and U.S. competitiveness, but how important is that role? An answer to this question will be provided in a series of analytical reports that begins with this document. Additional documents will examine changes that have occurred in major trading partners and their bilateral trade interaction with the United States.

This report is organized as follows. Section 1.1 provides an overview of the important factors that influence the competitiveness of U.S. goods in world trade. These factors are organized into three groups--macroeconomic factors, trade-related factors, and microeconomic factors. In Section 1.2 we discuss how macroeconomic variables condition the environment within which U.S. goods are produced and the role that energy plays in this environment. The trade-related factors that are important when U.S. goods compete in world markets are discussed in Section 1.3. Section 1.4 switches from the telescope to the microscope, examining the elements of the cost of production and how these elements adjust to market forces. All of these factors--macro,

trade and micro--change the structure of the U.S. economy, and these structural changes are an important consideration in how well U.S. goods compete in world markets. Accordingly, the final section of this chapter defines structural change and explains the role that energy plays in structural change.

Because structural change is so critical to an understanding of competitiveness, Chapter 2 is devoted to an examination of structural change in the U.S. economy and energy's role in that change. Section 2.1 provides a framework for interindustry analysis that is the basis for the examination of structural change. Section 2.2 explains the method used for analysis. In Section 2.3 structural change for the aggregate U.S. economy over two periods--1972-1977 and 1977-1982--is analyzed. In Section 2.4 the trade component of the economy is examined. A final section draws conclusions from the results and provides a transition to the final chapter of this report.

Chapter 3 explains how the ongoing study effort will be organized. The discussion of Chapters 1 and 2 is first used to articulate a series of hypotheses about the role of energy in the competitive position of U.S. goods in international trade. These hypotheses provide a focus for the remainder of the study. The methods described in Chapter 2 are used to examine structural change in the economies of major trading partners on a country-by-country basis. As has been done with the United States in Chapter 2 of this report, the aggregate economy and the trade component of the United States' six major U.S. trading partners--Japan, Canada, West Germany, France, Italy and the United Kingdom--will be examined. After the structural changes that have occurred within each of these countries have been examined, trade between the United States and the country under study will be examined with an eye to affirming or rejecting the hypotheses developed in Chapter 3 of this report.

This report is the first in a series. Later reports will be bilateral studies of the United States and each of its six major trading partners (Japan, Canada, West Germany, Great Britain, France and Italy). Then the multilateral implication of structural change in all seven countries will be

examined. This phase of the study is important because there may be implications for the competitiveness of U.S. goods as a result of changes in bilateral trade patterns among competitors that do not directly affect the United States.

Work is currently under way on the first of the bilateral studies, which is tentatively entitled, The Role of Energy in U.S. Trade with Japan. Our expectation is that the sequencing of the bilateral trade reports will follow this order: West Germany, Canada, United Kingdom, France, and Italy. These six reports will be followed by a final report that assembles the policy implications of the bilateral and multilateral studies that have been identified and analyzed in earlier reports.

1.1 AN OVERVIEW OF FACTORS AFFECTING COMPETITIVENESS

A major element of a nation's competitiveness is that its goods and services meet the test of international markets. Goods and services can meet that market test in several different dimensions--price, quality, service, image (design), innovation and access. Competition may be geographically limited, which is part of the dimension of access; and there may be special niche markets. Different services may be provided in markets by product differentiation. Image often reflects a particular marketing strategy: targeting the product to one or more groups of individuals--yuppies, the elderly, etc. Innovation in markets may take a number of different turns: designing products that are consistent with health or weight-reduction concerns of the population is one such approach. Within any market segment defined by other factors, price is a major consideration.

Price is always an important factor in competition, although other attributes of the commodity or service have to be normalized in order to observe this price effect. Price is determined by costs, generally, but market conditions may force prices temporarily below costs (driving the marginal competitor from the market, thus reducing the supply). Alternatively, market conditions may provide a lucky producer with excess profits (encouraging new entrants into the market thus adding to supply and forcing

down the price). Relative prices, along with income, are considered to be the most important factors in the consumers' selection of goods and services.

Relative prices explain some of the changes that have occurred in the past 20 years in domestic markets. The economy has changed from a market dominated by American products to one in which both domestic and foreign products are readily available to consumers. In 1968, imports were 5.5 percent of GNP; exports were 6.1 percent. In 1987, exports were 9.5 percent of GNP and imports were 12.2 percent. One estimate (Choate and Linger, 1986, p. 7) suggests that 70 percent of the goods available to the American consumer have readily available foreign substitutes.

The availability of foreign goods is one facet of the structural change that has occurred in the U.S. economy. The historic response of some industries to foreign competition is to appeal for relief through protectionist legislation or executive policy actions. The steel industry successfully curtailed imports in both the 1960s and in the 1970s with the argument that the industry needed time to restructure and modernize. A similar strategy has been followed by auto makers, motorcycle producers, shoe manufacturers and textile producers (Zysman and Tyson, 1983). When import restrictions cannot be gained directly, the specter of massive jobs losses can frequently stimulate legislation (Feenstra and Bagwati, 1982, p. 245). These strategies may work for short periods of time, but they usually simply postpone the restructuring and economic change that competitive forces are suggesting ought to occur.

Figure 1.1 is a simplified schematic of the various factors that are important elements in international competitiveness. At the top of this figure are the domestic elements that influence competitiveness--fiscal policies, monetary policies, and demographics are the most important elements, and these affect economic growth and general price level changes. In the lower left are trade-related elements: trade policies, exchange rates and the balance of trade. In the lower right are the microeconomic elements: savings, investment, productivity and technology. Savings provides the wherewithal to invest; investment in plant and equipment and in human capital can improve productivity. Investment directly affects the technology set

FIGURE 1.1. Factors Influencing Competitiveness and Structural Change

available to businesses through research and development, and new technology appears when firms invest in new equipment. These factors coalesce to bring about changes in the structure of the economy.^(a) These three sets of elements interact with each other, and all elements are responsible for bringing about structural change in the economy.

Energy permeates the entire nexus of elements that affect competitiveness and structural change shown on Figure 1.1. Fiscal policies, especially taxes, and changing demographics can affect not only the type of energy used in the economy but the intensity of its use. A major component of trade is the oil imported for use in this country. Tax and trade policies affect the price we pay for all energy; the balance of trade is partially determined by

(a) For a detailed explanation of the process, see Landau (1988).

oil imports; the experience of the early 1970s indicates that oil price changes can affect domestic inflation dramatically. Trade policies adopted by the rest of the world are sometimes dominated by energy considerations (e.g., OPEC deliberations), and our domestic trade policies sometimes focus on energy (e.g., precluding exports of Alaskan crude). The adoption of new technology may have energy use implications--automation, for example, may increase the need for electricity to produce goods, while reducing their cost and making them more competitive in world markets. Investment and R&D may be dominated by energy as they were after the second oil price shock of 1979. When oil prices are high, innovation and technology development may be directed at mitigating the effects of energy's contribution to production costs. Most of the technology development undertaken by the Department of Energy's Conservation and Renewable Energy Office is directed at conserving energy, using energy more efficiently, or mitigating some of the side effects of energy consumption. Recent history indicates that energy productivity in the United States has increased dramatically,^(a) and this is one of the significant aspects of structural change in our economy. Indeed, structural change is affected by all of these major factors: macroeconomic policies, trade-related policies, and microeconomic policies.

1.2 MACROECONOMIC FACTORS

The macroeconomic factors that have an influence on the competitive position of the U.S. are identified in the top third of Figure 1.1. The major economic policies of federal, state and local governments combine with the demographics to determine the growth of real (inflation adjusted) output and the course of general price level changes.

1.2.1 Demographics

Demographics brings population growth immediately to mind, but to the story of competitiveness, it means more. One important element is the way

(a) The reciprocal of energy productivity, energy intensity, is examined at the national and end-use levels in Klan, et al. (1988).

the population ages, another is the flow of people in and out of the country, and a third is the changing distribution of the population geographically within the country.

With the baby-boomers reaching their most productive years, America faces a brief period of competitive advantage in labor force demographics (Choate and Linger, 1986, p. 40). With fewer workers entering the work force in the coming years, the rate of labor productivity is expected to grow at a faster rate than in the 1970s. The Bureau of Labor Statistics estimates that labor productivity will increase at the rate of 1.7 percent per year through 1990, with growth in output proceeding at a rate of 2.9 percent per year. John W. Kenderick expects that rate to be even higher--2.5 percent annually through 1990 (as quoted in Choate and Linger, 1986, p. 195). In addition to the labor impact of the baby-boomers, there are further consequences as a result of the continuation of immigration.^(a) This flow of immigrants has traditionally provided labor services to low-wage industries. An alternative is to create the jobs, especially assembly industry jobs in other countries where low wages are an important cost advantage; the Mexico Border Industrialization Program provides an example of such a program (Choate and Linger, 1986, p. 202; Business Week, 1988).

The energy implications of changing demographics are several. Older people spend relatively more on energy in their private lives than do younger people, although they consume somewhat less than the average household (Poyer, 1983).

Ours is a mobile society. Migrants follow the harvest from the Imperial Valley of California to the Yakima Valley in Washington and from Florida to Massachusetts. Textile and apparel manufactures, once dominated by Northeast producers, now are located primarily in the Southeast. Aluminum migrates to cheap electricity--first to Niagara hydropower, then to power from the Bonneville Power Administration and the Tennessee Valley Authority. More

(a) The U.S. accepts twice as many legal immigrants as do all other countries combined. In addition, there is a large and increasing flow of illegal immigrants. In 1985, the U.S. absorbed more than a million illegals (Choate and Linger 1986, p. 200).

recently it has moved to Surinam and Guiana, both of which have bauxite and cheap electricity. And as opportunity moves, so too does the population--generally south and west. In 80 years, the center of U.S. population moved from 6 miles southeast of Columbus, Indiana, to one-quarter mile west of De Soto in Jefferson county, Missouri. That movement is about 300 miles west and 60 miles south from 1900 to 1980. The movement has been more rapid in the last 40 years of this period (Bureau of the Census, 1986, p. 10).

Movements of both industry and people change the pattern of energy use. The movement from north to south has increased energy use during summer months since there are more cooling-degree days in the south than the north. Similarly, with more heating-degree days in the north than the south, winter peaks will grow more slowly as population shifts to the south.

1.2.2 Economic Policies

The discussion of economics emphasizes two types of economic policies: fiscal and monetary.

Fiscal Policy

Fiscal policy is used here in a broad sense: it includes the revenue and expenditure side of the government budget process, the legislative process that determines the regulatory environment of the domestic economy, as well as the legislative policy that affects trade with foreign countries. Countercyclical federal spending can provide a stimulus to the economy during recessions (when, historically, the federal government has run a deficit) and a brake on the economy (by running a surplus) as capacity and full employment are reached. Fiscal policy includes tax and expenditure policies of state and local governments; these policies have historically been countercyclical to federal policies [Gramlich, 1978; Office of the President and Council of Economic Advisers (hereinafter cited as CEA), 1987, p. 276].

Taxes, the revenue side of the fiscal policy equation, have an inordinate effect on competition, in addition to their role in generating revenues. Their absence or imposition can attract or discourage capital and, therefore, the construction of efficient, competitive plants and equipment. Taxation

can directly influence the purchase of goods and services as is the intent of sumptuary taxes (e.g., alcohol and tobacco) and can indirectly encourage or discourage specific types of investment--tax deductions for home mortgage interest payment encourage the purchase of residences, for example. The double taxation of distributed corporate earnings--once as corporate income, once as personal income--affects management decisions about the distribution or retention of profits. And taxes generate the revenue (\$854 billion for the federal government in 1987) that is part of the equation determining the deficit.

The other argument in the federal deficit equation is expenditures--the federal government spent \$1.00 trillion in 1987--shown in Figure 1.2. Defense accounted for 28.0 percent of that budget; education, health and social services another 14.4 percent; income and Social Security another 32.9 percent; and interest on the public debt required 13.8 percent. Of the 10.9 percent remaining, international affairs required 1.2 percent and all expenditures on natural resources, the environment and energy another 1.7 percent. All the other functions of government (science, agriculture, commerce, transportation, veterans benefits, justice, credit activities and general government) took the remaining 8 percent (CEA, 1988, p. 339). To put federal government expenditures into perspective, these expenditures, when translated into goods and services that are part of gross national product (GNP), account for 8.5 percent of GNP in 1987. When state and local

FIGURE 1.2. Federal Expenditures

government purchases of goods and services are added in, total government expenditures were \$923.8 billion, or about 20.6 percent of GNP (CEA, 1988, p. 248-249).

These numbers are important not only because of their direct impact, but also because the government deficit has indirect effects. The federal deficit has been \$150 billion or more every year since 1982. These deficits have been offset somewhat by state and local government surpluses--ranging from \$35 billion to \$65 billion from 1982 to 1987.^(a) Federal deficits register as dissavings in the national accounting of savings and investment. Total savings accrue through savings by households, savings by business, government surpluses and capital flows from foreigners. When the accounts are tallied at the end of the year, savings is equal to investment. Thus, any government deficit, other things equal, removes funds from the pool that would have gone to investment. And, of course, investment in the economy is what assures growth, improves productivity--of labor, energy, capital and other inputs--and lowers costs, thus enhancing the competitive position of U.S. goods in world trade.

One aspect of both federal and state policies is regulation that affects business operations. The Clean Air Act Amendments of 1970, for example, required considerable investment in pollution-abatement control equipment. These legislated requirements may have improved efficiency (if the investment replaced inefficient equipment) or may have substituted for investment in newer, more efficient, plant and equipment. There may be two components to such regulation--the direct act of compliance and the indirect requirement that the firm demonstrate its compliance with the regulation. Although the latter become less significant as they are routinized, there are nonetheless costs (both initial and ongoing operations and maintenance) associated with them that either substitute for other expenditures or add to total

(a) This is not the case for all states. Some of the "oil patch" states during this period suffered severe recession, with consequent fiscal deficits.

expenditure and costs. Some of these regulations encourage the adoption of more energy-efficient technologies; some may discourage the adoption of efficient technologies.^(a)

Monetary Policy

Monetary policy rests in the hands of two separate authorities--the Federal Reserve System (hereinafter referred to as the Fed), which has independent authority to set policy, and the Treasury Department, which is part of the executive branch of the federal government. The Treasury regulates national banks and issues currency. The Fed has four main instruments of policy: "moral suasion"; bank regulation such as setting reserve requirements; setting the interest (the "discount") rate at which banks can borrow to meet reserve requirements; and market intervention in government securities (called "open market operations") that directly affect interest rates. Although the Treasury acts independently of the Fed on some occasions (and historically there have been periods when the Fed was subservient to the Treasury), the Fed has primary responsibility for monetary policy; accordingly, the focus of this section will be on the Fed.

The Fed exercises control primarily by influencing interest rates and controlling the growth of the money supply. By selling government securities, the Fed lowers the price of those securities. This forces the interest rate up since the yield on the security is inversely related to its price. At the same time, by storing the proceeds of the sale, the Fed pulls bank reserves out of the system, which slows the rate at which the money supply can increase. Both of these actions would tend to slow economic growth and prevent price increases that result from too many dollars chasing too few goods--the classic demand-pull inflation. Alternatively, the purchasing of government securities pumps dollars into bank reserves, encouraging the expansion of the money supply. These purchases, because they withdraw securities from the market, also raise the price of securities, thus reducing interest rates. And both of these actions would encourage an expansion of

(a) Without arguing the wisdom of environmental legislation (which few would dispute), it is axiomatic that if similar legislation does not apply in competing countries, foreign costs will be lower than U.S. costs.

economic activity. This expansion of economic activity can increase energy use, since greater activity requires additional energy use.

There are additional effects through international financial flows. International repercussions to monetary policies occur when interest rates change. Domestic interest rates that are higher than interest rates in other industrialized countries encourage an influx of foreign capital to take advantage of the investment opportunity. Foreign currency must first be converted into dollars before it can be invested; this bids up the price of dollars, thus increasing the exchange rate. And exchange rates affect trade.

1.3 TRADE POLICY, TRADE, AND EXCHANGE RATES

The federal government directly determines trade policy through tariffs, quotas, customs inspections, preferential treatment, favored nation clauses, and "voluntary" restrictions. The General Agreement on Tariffs and Trade (GATT) is the major multilateral agreement among nations that affects a large fraction of merchandise trade. Another large fraction of our trade policy is formulated bilaterally; e.g., the free-trade agreement between the U.S. and Canada. These agreements, along with the policies of foreign governments (fiscal, monetary and trade), affect the level and composition of our imports and exports. The balance between these two is measured in several ways--the current account (balance of payments) and merchandise trade (balance of trade) are the most frequently cited measures. The current account includes merchandise trade, invisibles (i.e., transportation and other services), unilateral transfers, capital flows, and official reserve account transactions. The balance of payments, affected by the balance of trade, influences exchange rates.

1.3.1 Trade Policies

GATT is an agreement that provides a framework of rules for trade relations among the signatory countries (96 countries as of June 1987). The fundamental principles of GATT are these: trade without discrimination; protection through tariffs; binding negotiated tariff levels on all contracting

parties; and consultation, conciliation and settlement dispute procedures in the event that one signatory country suffers from the trade policies of another.

The countries that are signatories of GATT account for most of world trade. Strictly applied, GATT principles cover considerably less than that. None of the world trade in oil, for example, is covered. By one estimate, GATT covers only 7 percent of world trade (Choate and Linger, 1986, p. 48). Agricultural trade, although covered under GATT rules, is poorly covered.^(a) And under current rules, GATT does not cover communication, transportation or services.

As is the case in most countries, domestic trade policies are a mix of protectionism and burden-sharing. Burden-sharing is a trade tradition, which rests heavily on the settlement dispute and negotiation mechanisms of the third of three trade-related institutions: the International Monetary Fund (IMF), the International Bank for Reconstruction and Development (the World Bank) and GATT.

Since all the members of GATT are sovereign countries, settlement dispute procedures allow only for retaliatory action if the offending trade policy is not allowed under the terms of GATT. The spirit of GATT is to rely on import duties rather than the use of quotas or other quantitative limitations to imports so that the extent of the protection is made clear. The Multi-Fibre Agreement (MFA--a cartel among developed countries to limit textile and apparel imports from less-developed countries), although negotiated under the auspices of GATT, appears to be contrary to the spirit of the treaty.

Sovereign nations are not willing to allow another country or institution to dictate domestic policies. Yet to some extent, countries negotiate away part of this sovereignty when they enter into bilateral or multilateral

(a) Telephone conversation with Dan Gardner, Office of Trade Administration, U.S. Department of Commerce, January 3, 1989. See also OECD 1984.

trade agreements, and this is the essence of burden-sharing. These policies affect trade flows, and trade flows in turn have an effect on domestic economic policy.

A number of forms of trade controls currently exist. The easiest to regulate are tariffs. These are simply taxes imposed on imports (or exports) under either an ad valorem (i.e., as a percentage of the value) or specific (e.g., \$1 per item) basis. Quotas are also in wide use; these constitute an absolute limit on the number of items that can be imported or exported (and possibly the specific countries to or from which they can be shipped); e.g., the MFA. A tariff quota combines these two forms of trade control to apply a low tax to a fixed number of imports with a higher rate applied thereafter. Nontariff barriers to trade provide the third form of trade control. These operate through subsidies to import-competing suppliers, costs imposed on imports such as licensing procedures, technical barriers to trade (France, for example, had all its imported VCR's processed and inspected at one inland village for a brief time), cost-reducing subsidies to export suppliers, and quantitative restrictions on exports (e.g., current U.S. restrictions on sensitive computer components).

1.3.2 Trade

Figure 1.3 shows the current account and merchandise trade balances of the United States over the period 1950-1986 (CEA, 1987, p. 99). Over most of this history--from 1950 to 1974--both the current account and the merchandise trade balances have been positive. Only since the first OPEC crisis has the merchandise trade balance lingered in the red, and only since 1981 has the current account balance been consistently negative. Indeed, the current account deficit went from \$9 billion in 1982 to about \$160 billion in 1987. The decline in the trade balance was broad in the sense that it occurred in all sectors, but the category "manufactures" was particularly hard hit. Between 1982 and 1985 the deficit widened by \$101 billion in manufactures alone, with bilateral balances indicating a broad deterioration of U.S. trade among all countries.

Trade in energy has added considerably to this trade imbalance, although lower energy prices recently have made oil imports a small fraction of total

FIGURE 1.3. U.S. Trade and Current Account Balances (Data for 1986 are first three quarters at an annual rate; seasonally adjusted.)

imports. Oil imports peaked on a volume basis in 1977 when the U.S. imported 8.8 million barrels per day (MMbpd) (EIA, 1988a, p. 107). The volume of oil imports declined to 5.1 MMbpd in 1985, then increased significantly to 6.1 MMbpd in 1986. The dollar value of these imports changed considerably more over this period (CEA, 1988, p. 366). Import quantity peaked in 1977; at that time oil accounted for 30 percent of the total value of imports (\$45.0 billion of a total \$151.9 billion). The value of oil imports peaked in 1980 at \$79.3 billion (32 percent of total imports). With both prices and quantities of imports declining, the value of oil imports rapidly decreased to \$50.4 billion in 1985 and then to \$33.8 billion in 1986. In value terms, oil accounted for 15 percent of 1985 imports but only 9 percent of 1986 imports.

This trade imbalance for all commodities is attributable to three factors: the strong domestic performance of the U.S. economy during the current expansion; the factors that underlie the deterioration in the savings-investment balance; and the strong appreciation of the dollar (CEA, 1987, p. 101). The strong performance of the domestic economy can be attributed to

some of the macroeconomic factors mentioned previously. The deterioration of the savings-investment balance will be discussed later. The strong appreciation of the dollar falls under the domain of exchange rates.

1.3.3 Exchange Rates

International transactions are usually cleared in foreign exchange markets, which establish a price for one country's currency in terms of another. The U.S. equipment manufacturer ships machine tools to France; the French firm pays in francs; and the agent of the domestic manufacturer purchases dollars with those francs in the foreign exchange market so that the manufacturer can be paid in dollars. This trading of francs for dollars is the foreign exchange market--a loose collection of brokers and banks. Brokers deal in foreign exchange in much the same manner that other brokers deal in stocks and bonds. Since these markets establish a price of, say, the dollar against many other currencies, the exchange rate for the dollar is often measured as a weighted average of different countries' currencies, with the weights being the volume of trade with those countries.

Since the breakup of the Bretton Woods Agreement in the 1970s, the value of major Western currencies has fluctuated based on market conditions. Some currencies (such as the Korean won) have been pegged to other currencies (in Korea's case, to the dollar). An examination of the trade balance needs to take into account the exchange rate of the domestic country with many other countries. An index of the trade-weighted average of the dollar, for example, will vary as the exchange rate varies and as the volume of trade among major trading partners varies. The performance of such an index over the decades of the 1970s and 1980s is one of the major reasons for our current large trade deficit.

In 1970 the trade-weighted average of the dollar stood at 122 with March 1973 the base period (=100). This index had declined to an average of 87.4 for the year 1980 (CEA, 1988, p. 371). The Council of Economic Advisors (CEA, 1987, p. 97) argues that the dollar was undervalued and that the weakening of the dollar reflected an expectation of a greater than actual rate of inflation relative to other countries over this period of time. If this argument has weight, it could explain the rapid rise in the value of the

dollar after the Volker Fed gave a clear signal, in October 1979, that the monetary authorities had the will to wring existing inflation from the system. From 1980 to 1985 the value of the dollar rose from an average of 87.4 to 143.2, an annual rate of increase of 10.4 percent.

The effect of a depreciating dollar during the 1970s was to insulate industry from foreign competition, to allow rapid wage escalation with no loss of market share despite only modest productivity growth, and to ill-prepare industry for the early 1980s. As the dollar appreciated from 1980 to 1985, the relative prices of imported goods declined, while the relative prices of our exports increased. The market effects were devastating--one of the big-three auto manufacturers nearly went bankrupt; union wage contracts featured major give-backs in much of manufacturing; and the steel industry was totally restructured and had several major bankruptcies. As the recession of 1982 ended, demand increased, as did our appetite for imported goods.

This continued disparity between imports and exports is reflected in the national system of accounts as a discrepancy between aggregate output and aggregate consumption. Since the obverse of consumption is savings, this is also reflected in the national accounting of savings and investment. If consumption exceeds output, then the difference must be made up by an inflow of goods; equivalently, domestic savings will be less than investment, and there must be compensating financial flows to offset the difference. These choices are made at the microeconomic level.

1.4 MICROECONOMIC FACTORS

Although the accounts for savings and investment are properly macroeconomic accounts, the decisions that end up being expressed in these accounts occur at the microeconomic level. More importantly, to alter savings and investment, policies must be implemented that alter microeconomic decision making. These policies are important because they affect the level and composition of investment; these investment decisions in turn affect the creation and adoption of new technology, determine the productivity of domestic enterprise, and affect how much and what sort of energy is used.

Productivity, the mix of technology, and changes in the use of energy and other materials are some of the major elements in structural change.

1.4.1 Savings-Investment Balance

In a closed economy, savings is equal to investment identically: gross private domestic investment is equal to private savings plus business savings plus government savings plus statistical discrepancy. In an open economy where trade is allowed, net foreign investment must be added to the investment side of the equation, as shown in Figure 1.4. In 1987, this was substantial--gross private investment was \$716.4 billion and net foreign investment was -\$156.8 billion, for a total gross investment of \$559.6 billion. This was matched by personal savings of \$120.2 billion, business savings of \$553.4 billion, a government deficit of \$107.2 billion (the \$152.6 federal deficit offset by \$45.4 billion surplus of state and local governments) and a statistical discrepancy of -\$6.8 billion. The net foreign investment of -\$156.8 billion represents an inflow of foreign capital in excess of American

FIGURE 1.4. The Investment-Savings Equality

investments abroad and is equal to, except for differences in accounting and interest payments to foreigners, the trade deficit of \$119.9 billion in 1987 (CEA, 1988, p. 280). This represents a transfer of assets abroad and, thus, a future claim on income generated by those domestic investments.

Savings

The factors that affect domestic savings will vary depending on the source of the savings. Policies to encourage personal savings will vary from those designed to alter business savings.

Personal Savings. At the heart of the personal savings decision is time preference--the willingness of individuals to defer current consumption for future consumption. If personal investment opportunities can compensate for this reluctance to give up what one could have today, the incentive to do so will be greater. Similarly, if the tax system encourages savings, more personal savings will be forthcoming. Another significant factor is the cost and availability of credit that will allow current consumption by borrowing against future income. A final factor is age--the very young, characteristically, are less concerned about saving for the future than are those in their later years. Social Security may compound this incentive.

Personal savings as a fraction of disposable income has declined from its peak in the mid-1970s of over 9 percent to slightly under 4 percent in 1987. Apart from the inflationary effect (savings rates typically increase with the rate of inflation), our personal savings rates are low by historical standards. A number of arguments have been advanced (Hatsopoulos, Krugman and Summers, 1988, p. 241, and references therein) to explain this: the entrance of the baby-boomers into the labor force has shifted savings demographics to favor the dissavings associated with the young; the tax system, through various revisions, has discouraged savings; and the ease with which credit is extended, especially in the form of plastic money, has encouraged consumption over savings.

Business Savings. Gross business savings was \$553.4 billion in 1987 and comprises retained corporate earnings, the equivalent of retained earnings in proprietorships and partnerships, and depreciation allowances. The decision to retain earnings in a corporation is based on the valuation of the equities

of the company (price/earnings ratios figure in share valuations), stockholder attitudes about income and growth, and the attractiveness of corporate investment options. How attractive a corporate investment opportunity will appear depends on the weighted cost of capital, the rate-of-return criteria that figure into the capital budgeting decision, and the attractiveness of investment opportunities outside the firm. Depreciation allowances are dependent on past investments, accounting practices, and tax policy.

Government Savings. Government savings are composed of federal deficits and state and local surpluses, with the former swamping the latter in this decade. The federal deficit in 1986 was \$204.7 billion, about 4.8 percent of nominal GNP. This was offset somewhat by a surplus of \$56.8 billion in state and local governments, for a total government deficit of \$147.8. In 1987 this figure improved to a deficit of \$107.2 as a result of the federal deficit declining to \$152.6 billion or 2.6 percent of GNP (CEA, 1988, p. 280). In the 1980s, government savings has averaged about -\$100 billion per year, an order of magnitude larger than in prior decades.

Since the balance of savings and investment includes the deficit on one side and net foreign investment on the other, reducing one may very well lead to reduction of the other.^(a) And this implies a reduction in the trade deficit that the United States is currently running. Even if our economy could handle this adjustment, it would reduce the exports of our major trading partners and, accordingly, would reduce their GNP. A sudden adjustment would not be conducive to the health of the world economy, nor to multilateral trade.

Investment

Purchase of equipment and structures is typically classified as investment. But there is another type of investment, referred to as invisible

(a) On this issue there is considerable economic debate. The 1988 Cato Annual Monetary Conference, "Dollars, Deficits and Trade," addressed this issue directly during the afternoon of the first-day session. One side of the argument (that there is no relationship) was represented by William Niskanen; the other by John Williamson. Also see Dornbush (1988), McKinnon (1988) and Williamson (1988).

investment, that is also important in the set of issues that affect competitiveness of U.S. industry. These invisible investments include market development--the losses incurred in gaining market share--and research, development, and commercialization undertaken by businesses, academic institutions, and governments. All these investment choices depend on the investment decision making of firms and households.

Business Investment. In 1987 investment in traditional business categories was \$442.1 billion, of which \$308.0 billion went to producers' durable equipment and \$134.1 to structures. This was exactly 10 percent of GNP. Adjusted capital consumption allowance, the amount allocated to depreciation of the capital stock, was \$479.4 billion, about \$37 billion more than business investment. The decision logic that businesses use to determine the level and allocation of investment funds will depend on the availability and cost of the finance for the investment project, the anticipated rate of return on that capital project, expectations about how the firm will grow over time, and the options that the firm has for alternative uses of those funds. Fiscal (especially tax) policy, monetary policy, and other macro-economic factors come into play in these decisions, as does the cost of the investment project and its contribution to future output.

Business investment is a major source of energy-efficiency improvements. New equipment purchases embody the latest proven techniques that economize on the inputs to that machine, so this equipment typically produces more with less--energy, materials, etc. Generally this equipment will be more energy efficient than older equipment. But in some cases, the new equipment may use more energy because it saves on other inputs--e.g., automated machine tools that economize on labor but require higher electricity use per tool. On balance, new equipment is probably a powerful factor in reducing energy use in the industrial sector and in improving energy productivity (Klan et al., 1988).

Residential Investment. Residential investment in 1987 was \$139.1 billion. A small fraction of that went to remodel and refurbish old homes and equipment replacement, but the bulk of it was used to build new residences. Although useful for the health and well-being of the population and thereby

contributing to the productivity of the work force, such investment is not productive in the sense that business investment is. The strength of today's industry relative to Japanese competition does not depend on how many new homes are built. Yet our tax policies--deduction of mortgage interest payments--favor this category of investment.

Residential investment, however, does have a significant effect on the efficiency of residential energy use. Newly constructed buildings are generally more energy efficient than older homes, and they contain more energy-efficient equipment such as heat pumps, high-efficiency appliances, etc. This effect is documented in Klan, et al. (1988).

Invisible Investment. The components of this category, although simple in concept, are somewhat difficult to quantify. But they are important enough for the CEA's 1988 report (pp. 163-197) to devote an entire chapter to them. The first of these, and the category for which the best data exist, is research and development. In 1987, private R&D amounted to slightly more than \$60 billion, with the federal government providing nearly that amount again. The second category is investment in human capital. Our educational system alone spends about \$500 billion per year, with another \$100 billion per year for worker training, not including on-the-job and other informal training programs. The final component of invisible investment is the resources used by firms to move into new areas of business, to move up a learning curve, or to gain market share. Although not easily identified, these are investments nonetheless.

1.4.2 Technology and Productivity

Various forms of investment alter the capital stock, either by altering the technique, the physical equipment and structures, or the work force. The direct effect of these investments is to improve productivity, and one of the ways this productivity may be improved is to incorporate new technology into the production process.

Technology

Much of American history is expressed in the imagery of technology. From Whitney's cotton gin to McCormick's reaper to Henry Ford's assembly line

to the television to the transistor, progress is marked by technological advance. Part of our ethic is invention and innovation. In the future as in the past, technology will continue to be the vanguard of structural change. Choate and Linger (1986) call this the "technology wild card."

Rapid technological progress is occurring in a number of areas, including materials, microelectronics, fiber optics, biotechnology, super conductivity, and software development. These technical developments, foreseen and unforeseen, will foster new industries as technology has in the past. One particular area of technological progress in the industrial sector is the continued development of automation. The automation of production and the adoption of flexible manufacturing facilities, along with the electronic processing of orders and inventories, will allow much more rapid responses to changes in the demand for goods and, at the same time, will provide a more tailored product to clients. Automated production facilities have a distinct advantage because they economize on both material inputs (both energy and non-energy) and labor. One additional advantage of this development from the production side is that production facilities can be profitable even when operating at less than full capacity.

The widespread application of new technology will foster structural change in industries both domestically and abroad. The dramatic shift from basic materials such as steel and cement to advanced materials is one signal of the types of industrial changes that will occur (Williams, Larson and Ross, 1987). Since technology can migrate to any country or region, its adoption has accelerated the internationalization of industry. It also allows wider options for the location of service industries by substituting communications services for local access--an example of which is data entry in low-wage areas then telecommunicating the information by satellite back to the originating offices. Indeed, the Office of Technology Assessment estimates that 40 percent of all investment in new plant and equipment is in information technology.

When fully integrated into the production process, this technological revolution in microelectronics, information processing, materials science,

and biotechnology will substantially alter the current structure of our economy. The pace at which this technology is adopted will, along with other factors, determine the rate of productivity increase.

Productivity

The argument has been advanced that warnings about U.S. competitiveness have not put the emphasis where it belongs. At its core, the problem is a low savings rate, and this is manifest in a productivity problem. Production increases have been low, and most of this is explained by increases in employment. Productivity improvements, as measured by the rate of growth of output per worker, for example, declined from 1.9 percent per year over the period 1960-1973 to 0.3 percent per year from 1973-1985. This and exchange rate shifts have lowered wage growth, which is attributed to lower productivity and declining advantage in technology and quality. "Measured productivity rates do not fully take account of the decline in U.S. technological advantage" (Hatsopoulos, Krugman and Summers, 1988, p. 301). Both technology and quality are closely related to productivity.

The productivity decline can be attributed to slower capital formation, both visible (plant and equipment) and invisible (R&D, inexperience with new technology, market penetration, etc.). There is a strong relation, albeit one that poses a problem for economic theory, between capital formation and growth. There are both theoretical and empirical reasons for understating the effect of capital formation in growth accounting: 1) investment embodies technical change--more investment means newer, more productive stock of plant and equipment; and 2) contribution of capital to growth accounting relies on the measure of profit and ignores the invisible capital investment.

The major reason for a slower rate of capital formation is a higher cost of capital. The mix of labor and capital is determined by the relative price of labor and capital. Cost of capital, although difficult to measure, must take into account tax rates in addition to the interest rate. U.S. costs of capital are generally 50-75 percent higher, before tax, than Japan's. This higher cost influences the myopia of business (since it is a measure of time preference, it influences the horizon of decision making) and the amount of invisible investment that the firm will undertake.

"The short-term focus of American managers, then, is a rational response to their market situation. . . . The appropriate strategy for lengthening business planning horizons and encouraging long-term investments is not to criticize corporate cultures but to change the market incentives that shape them." (Hatsopoulos, Krugman and Summers, 1988, p. 303)

A high cost of capital limits investment, and this may be one explanation for a lagging U.S. competitiveness. Capital costs are high because of low savings rates and because a large fraction of saving goes into nonbusiness uses such as residential investment and government deficits. A number of institutional factors contribute to the low rate of personal savings--easy consumer credit, generous Social Security and pension benefits, and the availability of life and disability insurance. Through taxes, redistribution of income and method of finance, U.S. fiscal policies provide a strong incentive not to save. The three major government subsidies to current consumption are the deficit (shifts from future to current consumption), the Social Security system (similar shift from future generations to current recipients) and the tax system (drives a wedge between what the economy earns on investment and what an individual can earn--double taxation of dividends, capital gains taxed as ordinary income, etc.).

This integration of factors highlights the importance of productivity in the competitiveness of U.S. industry. The integration of new technology and the consequent improvements in productivity will bring about dramatic structural change in the economy, as the evidence suggests it has in the past.

1.5 STRUCTURAL CHANGE IN THE U.S. ECONOMY

The United States economy has changed dramatically since the early 1970s. Relative energy prices more than doubled on two separate occasions; price controls were applied, then eased, for the first time since the Korean War; legal requirements for pollution abatement were enforced; some multinational companies shifted production to lower-cost regions; and the U.S. trend toward a service-oriented economy continued. These factors manifest themselves in a number of changes in the structure of the U.S. economy. It

is the task of this section to show how these structural changes can be attributed to the changes over time of decisions or choices of different economic agents.

A variety of factors brings about changes in decisions; an example over this period is the sharp increase in world oil prices. A dramatic shock, such as world oil prices that more than doubled, sets in motion a chain of events that can substantially change the structure of the economy. As rational economic agents respond to this change, we would expect events to unfold as follows. An increase in the price of refined oil, stemming from the now higher price of crude, would be passed along both to ultimate consumers and to businesses that use refined petroleum products as intermediate materials. Businesses would substitute other fuels--coal or natural gas--for oil, thus bidding up the price of these other fuels. The price of electricity would also increase because coal is widely used to produce electricity. All fuels and electricity, now somewhat higher priced, would add to the cost of the commodities produced. When the full force of these cost changes is reflected in prices, consumers--individuals, governments, and foreigners--will find that less energy-intensive goods now have lower prices compared with more energy-intensive goods and will substitute for the relatively cheaper commodities. Imported goods that do not fully reflect these higher domestic energy prices, for one reason or another, will likewise be relatively less expensive and thus more attractive.

The change in the composition of goods purchased by consumers from domestic and foreign industry will feed back to the domestic industries producing those goods. The result will be a shift in the volume and relative position of industries--energy-intensive industries will produce relatively less; less energy-intensive industries will produce relatively more. Because the less energy-intensive industries have had the least incentive to substitute other factors for energy, their energy use will change the least, but now their fraction of total output will be relatively larger. In short, both the consumer adjustments and the substitution mechanisms operational at the firm level will have the effect of altering the mix of goods sold to

final demand and the selection of intermediate materials used in production; accordingly, the bill of final goods will change in response to a world oil price increase.

The shift in the structure of the economy is brought about by sources that can be traced to the decision making of separate economic agents. As the decisions of these agents become reflected in the economic statistics of a country, the impact of these decisions can be identified. We have developed a method that allows us to partition the sources of change into components associated with changes in final demands, changes in interindustry flows, and changes in energy intensity. The agents associated with changes in final demands are consumers, businesses, governments and foreigners. Changes in interindustry flows and factor intensities both can be attributed to decision making at the level of the firm.

With this understanding of how structural change occurs and how other factors influence these changes, we direct our attention to the changes in the U.S. economy over the period 1972-1982.

2.0 ENERGY IMPLICATIONS OF STRUCTURAL CHANGE IN THE U.S. ECONOMY

This chapter examines the effects of structural change on the aggregate United States economy over the period 1972-1982. Structural change is represented by changes in three sets of variables: changes in the input-output (I/O) structure of the economy; changes in the level and composition of final demand; and changes in U.S. energy intensity. These structural changes are identified by looking at a snapshot of the economy at three points in time: 1972, 1977 and 1982, years for which an I/O table is available. Dramatic changes also occurred in the price of energy over this same period. The analysis, then, covers a period beginning with the last pre-price-shock year (1972) and ending after the second OPEC price shock that occurred in 1979-1980.

The focus of the results will be at the aggregate level of the economy. At the aggregate level, the economy produces both goods and services. In the discussion of merchandise trade, services are ignored; i.e., the focus is on the goods-producing sector because goods constitute most of our trade. Energy consumption matched to the industry definitions used in the I/O representation is provided by slight modification of the National Energy Accounts (Faucett, 1984).

The chapter is organized into six sections. Section 2.1 provides background on changes in the U.S. economy and discusses the principal actors who were instrumental in structural change; this background provides a framework for a brief discussion of the methods used in the analysis, which is the topic of Section 2.2. Application of this method to the U.S. economic data is the topic of the Section 2.3; this discussion provides an overview of the major structural changes that have occurred over the decade 1972-1982. Section 2.4 then examines two separate components of final demand, exports and imports, as reported in the I/O tables. These results show what effect trade has had on structural change of the U.S. economy. Section 2.5 examines a time series of merchandise trade to determine how the energy intensity of

trade changes over time and then discusses these results. In Section 2.6, the results of the empirical work are summarized and some conclusions are drawn from the analysis.

2.1 A FRAMEWORK FOR INTERINDUSTRY ANALYSIS

The U.S. economy has changed dramatically since the early 1970s in response to significant external and internal shocks. These shocks were relative energy prices that more than doubled on two separate occasions; and an inflationary spiral which prompted price controls that were applied for the first time since the Korean War, then eased. These factors manifest themselves in a number of changes in the structure of the U.S. economy.

The structure of the economy was not changed directly in response to these shocks, but rather it changed as millions of different economic agents made decisions or choices. One objective of this section is to explain how structural change in the U.S. economy can be attributed to these choices. A further objective is to describe the sources of data used in the analysis (see Section 2.1.4).

Three topics are discussed in the remainder of this section: the actors--the economic agents to which change can be attributed; the structure of the economy; and a method for integrating energy into the analysis. This discussion provides background to the analytical method that is explained in the Section 2.2. Through the actors, it also linked back to the discussion of Chapter 1. Through the behavior of these actors we see how the elements that influence the competitiveness of U.S. goods in world trade can influence structural change and how these structural changes can influence energy-use patterns.

2.1.1 The Economic Agents

The two major energy price shocks, in 1973-1974 and again in 1979, caused irreversible changes in the structure of the U.S. economy and in that of other major industrialized countries. The first oil price shock reversed five decades of declining real energy prices in this country and had profound effects on different segments of the economy. As these prices began to be reflected in the cost of materials and final products, both businesses and

final consumers adjusted their purchasing patterns to reflect these higher costs. So for personal consumers, for governments and in foreign trade, final consumption adjusted so that the use of more energy-intensive goods declined and the use of less energy-intensive goods increased.

Just as final consumption patterns showed an adjustment from more to less energy-intensive goods, so too did businesses adjust their material purchases to economize on the use of now relatively more expensive material purchases. The materials that adjusted most noticeably were energy materials; businesses adjusted the intensity of energy use through conservation, equipment changes, recycling and simple housekeeping operations that reduced energy use per unit of output. So business adjustments were twofold: directly in the conservation of energy materials and indirectly in the conservation of embodied energy, i.e., by shifting from the use of energy-intensive non-fuel materials to greater consumption of those materials with relatively less embodied energy. The second oil price shock reinforced the importance of these adjustments.

The process of adjustment highlights the activities of several different actors. Business, or the managers of business, constitutes one set of agents. The resource allocation process that is part of their activity is reflected in the internal operation of the firm, the purchase of factor inputs--labor and materials, in the short-run; land, equipment and buildings over longer periods of time--and the offer of products for sale. The purchase of materials, especially, has implications for changes in the inter-industry structure of the economy over time. The efficiency with which these and other inputs are used will be reflected in productivity changes, of which energy productivity will be of special interest. The technology available has a bearing on this choice, as do the forces that otherwise shape the decision making of the agent. Clearly, then, a key figure in this tale of structural change is the business agent.

The other major set of actors falls into the category referred to as consumers. Most important among these is the individual household that engages in personal consumption, provides (not incidentally) the labor input to business, and generates the savings that finance, in part, the purchase of

plant and equipment. Another major consumer is government, with actors at the federal, state, and local levels. Foreign consumers are also of importance, since their purchases add to other consumers' purchases to make up total demand. Even businesses are part of this picture, since capital purchases (i.e., investment) are final sales, rather than intermediate materials. And, as we have seen, all of this is affected by the economic environment that is shaped by macroeconomic policy and by the factors that influence savings and investment.

2.1.2 The Interindustry Structure

The adjustments of these economic agents explain some of the changes that have occurred within the economy since 1972. Economizing on factor inputs has increased efficiency and has accelerated the rate at which energy productivity has improved. Other productivity changes have allowed increased production with less labor and material inputs. Of these adjustments, the economizing on more energy-intensive materials, i.e., the internal allocation decisions of firms, has been one direct factor that has changed the inter-industry structure of the economy. An indirect factor has been shifts in final demand.

Consumers alter their choices of goods and services in the face of a changing set of relative prices; these shifts affect the growth rates of industry. With differential growth rates over time, the relative size of these industries will change, so the contribution of any particular industry to total output will change. This change in composition can be represented in a number of ways.

The changing composition of the economy is revealed by the change in total output of each of the industry sectors of the economy; that is, by all direct and indirect purchases of goods and services represented by the I/O structure of the economy. The I/O structure is a complete representation because it takes into account changes among all the industries, rather than just an identified subset of industries. How this information is used is detailed later in the methods section (Section 2.2).

2.1.3 Industry Energy Use

Just as consumer choice influences the size of industry, managers of business make choices about energy use. Energy use in commercial and industrial establishments, including transportation uses, increased about 13 percent from 1970 to 1979, but then declined. By 1985, energy use had declined by more than 13 percent, dropping about 2 percent below its 1970 level.^(a) The significant increases in energy prices brought about by the oil price increases of 1972-1973 and 1979 are a major reason for these reductions in business energy use. But the choices of business managers effected this reduction.

2.1.4 Data Sources

The three data elements needed for the analysis that follows are: 1) energy consumption by industry, 2) the input-output structure of the economy; and 3) merchandise trade data. Each of these elements is examined in turn.

Energy

Only since the introduction of the Manufacturing Energy Consumption Survey (EIA, 1988b) in 1986 has a comprehensive survey of energy use been conducted for the major goods-producing industries that identify energy consumption on an industry-by-industry basis. At a more aggregated level, the Energy Information Administration (EIA) constructs energy use information from producers' reports of sales to end users. EIA reports industrial energy use monthly and annually in the Monthly Energy Review (EIA, Monthly); industrial energy use is reported by state in the State Energy Data Report (EIA, 1988c). Some data by industry existed prior to MECS. For 1972 and for the years 1974-1981, either the Annual Survey of Manufactures or the Census of Manufacturers collected energy consumption data for purchased fuel and power (only) by industry. The data, which end in 1981, have been used as a basis for constructing the National Energy Accounts (NEA) (Faucett, 1984). These

(a) These estimates are obtained by adding industrial, commercial and half of transportation energy use, ignoring electricity system losses. The data source is EIA (1988c).

accounts balance energy use in 130 industry sectors of the economy (89 of which fall within the industrial sector) with primary energy estimates that the U.S. Department of Energy develops based on information from major energy producers. The construction of the NEA required the balancing of primary energy use and industry consumption based on incomplete indicators of energy consumption such as transportation mileage estimates and Census surveys. Although these data are constructed, they provide the best estimates of energy use by industry that have been available prior to the appearance of MECS.

The NEA energy data are introduced into the analysis by constructing measures of energy intensity by industry, then mapping these industry data to the same sectoring plan used to describe the economy structure (i.e., the I/O table). To construct these measures, a physical measure of energy consumption from NEA is divided by an inflation-adjusted measure of output (U.S. Department of Labor 1981); specifically, Btu of energy by constant (1972) dollar gross output. Gross output has been selected, rather than an alternative measure such as value added, because output includes the contribution of materials, of which energy is a part. If value added is used, the energy-intensity measures fluctuate widely because of the change in the ratio of value added to output, which is observed as the relative prices of material and other factors change. Exactly how these intensities are used is the topic of the Section 2.2.

Input-Output Tables

The benchmark I/O data are published every five years by the Inter-industry Economic Division of the Bureau of Economic Analysis of the U.S. Department of Commerce. The latest official I/O table is for 1977 (BEA, 1984), although an updated version of the 1977 table for 1982 was published in May of 1988 (BEA, 1988). The official 1982 table is due out at the end of 1990.^(a) The 1982 table used below was obtained from the University of Maryland's INFORUM project.

(a) Telephone conversation with Mark Planting, Interindustry Economics Division, Bureau of Economic Analysis, U.S. Department of Commerce, January 13, 1989.

Merchandise Trade

Exports and imports are components of total final demand that are available with the I/O table. The time series of merchandise trade used in a later section of this chapter were also obtained from INFORUM.

2.2 METHOD

The examination of the effects of structural change on energy use is based on a decomposition of changes in energy use into several components; the components are changes in final demand, changes in interindustry flows, changes in energy-use intensity, and four interaction components.^(a) The decomposition relies on the standard I/O identity. The total value of each industry's output is the sum of output sold to other industries as intermediate purchases and sales to final consumers. If intermediate purchases are represented by the matrix A, where the typical i,jth element represents the sales of the output of industry i to industry j, and output of all industries by X, a vector of industry outputs, the standard I/O representation of an economy is

$$X = AX + F \text{ or } X = (I - A)^{-1} F \quad (2.1)$$

where F is the vector of industry final demands allocated among sales to personal consumption expenditures, business investment, foreign trade, and governments. While these final demands sum to Gross National Product, of special interest for the issue of the competitiveness of U.S. goods in international trade are the vectors for exports and imports.

Energy use by industry was calculated as follows. E represents total energy use for all industries in the economy for a given year. C is a vector

-
- (a) The details about the method of analysis can be found in Roop, J. M. and D. B. Belzer. 1987. Changes in the Structure of the U.S. Economy: An Input-Output Analysis. PNL-SA-35961, Pacific Northwest Laboratory Richland, Washington. Results have been reported in several papers and presentations; see, for example, Roop (1987). Results similar to those reported in Roop (1986) are contained in the section on merchandise trade, below.

of energy intensities (for the same year) by industry. In matrix notation the factor use summation over industries is calculated as

$$E = CX \quad (2.2)$$

To examine the changes over time, Equations (2.1) and (2.2) are first combined, to yield an interindustry representation of energy use in the economy. After simplification, these terms are decomposed into three major elements--the change due to intensity, the change due to interindustry structure, and the change due to changes in final demand. There are also three interaction terms that occur when two of these major changes (e.g., I/O structure and energy intensity) interact, and a final interaction term when all three interact. These are as follows:

$$\begin{aligned} \Delta E &= \Delta(CX) = \Delta[C(I - A)^{-1}F] = \Delta[CLF] \\ &= \Delta C(LF) + C(\Delta L)F + (CL)\Delta F - \Delta C\Delta L(F) \\ &\quad - \Delta C(L)\Delta F - (C)\Delta L\Delta F + \Delta C\Delta L\Delta F \end{aligned} \quad (2.3)$$

where ΔC = change in energy intensity

ΔL = change in interindustry structure $[(I - A)^{-1}]$

ΔF = change in final demands.

The decomposition, along with these interaction terms, can be displayed as a Venn diagram (Figure 2.1). Using 1972 as a base year, Figure 2.1 shows the change in energy use in the United States as the small circle on the left; energy use increased by 3669 trillion Btu (TBtu).

The three circles to the right of the brace represent the first three terms of Equation (2.3). Cross-hatched areas represent the decomposition terms, of which there are four. The uppermost circle represents the change in final demand and indicates that this component would have increased energy use by nearly 9000 TBtu. But this growth was offset by changes represented by the other two circles. Changes in the I/O structure reduced energy by 2790 TBtu while changes in energy intensity further reduced energy by

FIGURE 2.1. Venn Diagram of U.S. Energy Use Changes, 1972-1977

3577 TBtu. Figure 2.1 also partitions the change in final demand into two components--one associated with the change in the level of final demand, the other with compositional changes: the shift in the distribution of final demands among industries. The large outer circle represents the change in final demand resulting from increases in the scale of the economy; i.e., the change in energy if all industries had grown equiproportionately. The difference between the outer and the inscribed circle represents the change in energy use as a result of changes in the composition of final demand.

In Section 2.3, this decomposition is applied to the U.S. economy based on I/O tables for 1972, 1977, and 1982 (see Section 2.1.4). When the official 1982 table is available, these results will be updated.

This decomposition is also applied to exports and imports, reported as part of the official I/O tables. To construct these numbers, Equation (2.3) is modified as follows:

$$\Delta E = \Delta(C L [X M]) \quad (2.4)$$

where the final demand vector, F , is replaced by the trade components, exports (X) and imports (M). The section on merchandise trade (Section 2.4) uses a time series of exports and imports (merchandise trade figures for manufacturing) and fixes the technology at the 1977 I/O representation, which was the most recent when these results were calculated.

2.3 RESULTS: AGGREGATE U.S. ECONOMY

The decomposition represented by Equation (2.3) is shown in Table 2.1 for three periods: 1972-1977, 1977-1982 and 1972-1982. The sum of the two period changes adds to the total change for the period 1972-1982 by construction. Venn diagrams for the later periods are shown as Figures 2.2 and 2.3.

Structural change alters total energy use over the ten-year period (and for each of the subperiods) in three major ways. Changes in the inter-industry structure of the economy [the first term of Equation (2.3) which corresponds to the third row of numbers in Table 2.1] reduced total energy use for the first time period and for the total period. Second, changes in energy intensity [the third term of Equation (2.3) corresponding to the

TABLE 2.1. Changes in Energy Use in the U.S. Economy: Selected Years
(in TBtu)

Row	Economic Factor	1972-1977	1977-1982	1972-1982
1	Change in Energy	3,699	-1,425	2,244
	Due to Changes in:			
2	Final Demand	8,743	2,546	11,289
3	I/O Structure	-2,790	1,710	-1,080
4	Energy Intensity	-3,577	-7,090	-10,667
	Interaction Terms			
5	Final Demand and I/O	-582	855	273
6	Demand and Intensity	-604	-512	-1,116
7	I/O and Intensity	-134	-1,791	-1,925
8	All Three	-27	-39	-66
	Decomposition of Demand			
9	Scale	8,797	8,805	17,602
10	Composition	-54	-6,259	-6,313

FIGURE 2.2. Venn Diagram of U.S. Energy Use Changes, 1977-1982

FIGURE 2.3. Venn Diagram of U.S. Energy Use Changes, 1972-1982

fourth row of numbers] clearly reduced energy use in all periods. Third, net changes in final demand [represented by the second row of numbers in Table 2.1 and the third term in Equation (2.3)] always increase total energy use.

Net changes in final demand can be further decomposed into two terms--the changes that result from increases in the scale of the economy and changes in final demand because of changes in the composition of final demand. Changes in scale are measured by assuming that each industry contributes to GNP in the same proportion as occurred in the earlier year, but scaling each industry's final demand so that the sum of all elements equals the output level that occurred at the later date. The compositional effect, then, is the difference between the scale effect and the net effect. These results are reported on the last two lines (9 and 10) of Table 2.1. In all cases, the scale effect was positive and was larger than the net effect. In the earlier period, this scale effect was only slightly larger than in the early period--a mere 54 TBtu more or 8797 TBtu (shown in line 9 of the table). Over the later subperiod, energy use would have increased by 8805 TBtu--shown on line 9, column 2 of Table 2.1--if consumers and governments had not altered the mix of commodities purchased. That consumers changed the composition of their purchases reduced energy use by 6259 TBtu in the 5-year period 1977-1982. The scale effect alone would have increased energy use 17.6 quad over 10 years ($8.8 + 8.8$). Compositional changes reduced this by 6.3 quad over 10 years, a change that is the result of a small decrease in the early period and a larger reduction in the latter period.

That compositional changes in final demand were always negative can be explained in part by the effect of price changes and in part by the cyclical pattern of economic activity during the years for which I/O tables are available. Price changes in 1973-1974 more than doubled for imported oil, but these price increases occurred at the end of a regime of administered prices and policy responses that attempted to mitigate the effect of these price changes by controlling the normal functioning of the market. In 1979, the oil price increase was transmitted with less interference throughout the economy, so the results appeared much more rapidly. The effect on final goods prices in the earlier subperiod, therefore, would have occurred less

rapidly than in the late subperiod. This partially explains why the composition effect was so small in the 1972-1977 period.

Cyclical patterns provide additional explanation for the changes. In 1972, the U.S. economy was two years into an expansion after the recession of 1969-1970. In 1977 the situation was repeated; the economy was two years into the recovery after the 1974-1975 recession. But 1982 was at a trough of activity, with the economy declining 2.5 percent between 1981 and 1982. The differences are reflected in the five-year growth rates for the subperiods: after adjustment for inflation, the economy grew 13.4 percent between 1972 and 1977. From 1977 to 1982, the economy grew only 5.3 percent. The rapid growth in the economy between 1972 and 1977 and the slower transmission of energy prices to other goods favored the consumption of more energy-intensive commodities and served to offset the price changes that occurred during this period.

The price shocks that occurred in 1973-1974 and 1979 fell two years after the beginning of each of the subperiods, but the more rapid transmission of price effects in the later subperiod led to a larger adjustment in the later subperiod. These price adjustments are clearly reflected in one set of numbers shown in Table 2.1: changes in energy intensity. Intensity changes accounted for a 3577 TBtu reduction in the early period and a 7090 TBtu reduction in the later period. Energy-intensity changes accounted for the bulk of the energy savings for the entire period and for each of the subperiods. Improvements in the efficiency of energy use during the period 1972-1977 were substantial, belying the argument that such efficiency improvements can only occur with substantial changes in capital stock. The even larger reduction in energy use as a result of efficiency improvements in the second subperiod is startling in light of the low growth over this period. These changes reflect adjustments that were made in response to increases in energy prices.

That energy-intensity changes caused such a large share of the energy savings can be explained by the dramatic nature of the price shock that occurred in 1973-1974. Until the first price shock, energy prices in the U.S. economy had followed a fairly stable pattern: continued reductions in

their relative costs. In both a relative and absolute sense, energy costs were not nearly as important as the costs of labor, capital and non-energy materials, except in the most energy-intensive industries. And even in the most energy-intensive industries, energy as a factor was of declining importance. After the first price shock, all of this changed. Industry became acutely aware of energy as a factor of production and moved, quite rapidly it turns out, to reduce or economize on the use of energy. But these adjustments took some time. In 1979 when the second major price shock occurred, history was repeating itself. Under these circumstances, then, it is no surprise that the adjustment was not quite as rapid during the first subperiod as in the second.

Price changes may also account for some of the I/O changes that occurred, although changes in interindustry transactions provide mixed results. Industry transactions accounted for a reduction of 2790 TBtu in the early subperiod and an increase of 1710 TBtu in the later subperiod, for a net reduction of slightly more than a quad over the entire period.

That interindustry changes added to energy use in 1977-1982 can be partially accounted for by the large interaction between I/O changes and energy intensity changes. This interaction, shown in line 7, column 3 of Table 2.1, is larger than the I/O structural change by itself, suggesting that the bulk of the interindustry adjustments occurred in the way energy was used, both directly and indirectly. When this interaction is small, as in the period 1972-1977, then the I/O structural changes reduce energy use.

2.4 RESULTS: TRADE COMPONENTS OF THE I/O TABLE

The decomposition of Equation (2.4), applied to exports and imports as separate components of final demand, provides two Venn diagrams (Figures 2.4 and 2.5, with numbers reported in Table 2.2) which represent the changes in energy use that result from changes in our trade between 1972 and 1977.

The circle on the left of Figure 2.4 represents the total change in energy required to produce exports--an increase of 1067 TBtu over the five-year period 1972-1977. The decomposition of Equation (2.4) suggests that the

FIGURE 2.4. Decomposition of Export Energy Use, 1972-1977

FIGURE 2.5. Decomposition of Import Energy Use, 1972-1977

growth of exports, absent any other change, would have increased energy use by 1242 TBtu and changes in interindustry flows would have increased energy use by another 12 TBtu. Offsetting these increases was a reduction in energy

TABLE 2.2. Changes in Energy Use for Exports and Imports, 1972-1977
(in TBtu)

Row	Economic Impact	Exports	Imports
1	Change in Energy	1067	1527
	Because of Changes in:		
2	Final Demand	1242	657
3	I/O Structure	12	952
4	Energy Intensity	-378	-364
	Interaction Terms		
5	Final Demand and I/O	-76	-180
6	Demand and Intensity	-105	-12
7	I/O and Intensity	-8	-80
8	All Three	2	10
	Decomposition of Demand		
9	Scale	1699	982
10	Composition	-457	-325

intensity (accounting for 378 TBtu). (The difference between these major terms and the change in energy use, 191 TBtu, is accounted for by the interaction terms.) If all industry imports had grown equiproportionately, the level of exports would have required even more energy than the 1242 TBtu actually required--the scale effect alone would have required 1699 TBtu. However, the change in the composition of goods exported reduced energy requirements by 457 TBtu, or 27 percent of the scale effect.

Although we do not know how much energy was required to produce foreign-made goods purchased in the United States, the energy that would have been consumed if those goods had been produced domestically can be estimated. (The strategy described in Chapter 3 explains how a more accurate measure of the energy actually embodied in these imports can be obtained.) Accordingly, the embodied energy content of imports has been valued as if domestic technology had been used.

A decomposition based on this assumption suggests that the change in imports from 1972 to 1977 would have increased energy use by 1527 TBtu if those goods had been produced in the United States. By importing these goods, the economy saved that amount of energy, which is represented by the circle to the left of the brace in Figure 2.5.

The net growth of imports accounted for the 657 TBtu increase in energy, represented by the small circle inscribed within the larger circle to the upper right of the brace. The larger of these circles represents the increase in the amount of energy that would have been used if all imports had grown at the same rate and if these imported goods had been produced domestically. The difference between these two, -325 TBtu, represents the decrease in energy use that occurred as a result of consumers, businesses and governments altering the types of imports purchased. The compositional shift in imports accounts for about one-third of the scale increase in final demand shown in Figure 2.5.

The change in interindustry flows, represented by the circle to the far right, added to the energy required to produce the imported goods by 952 TBtu; however, these two positive increments to energy use were offset by a large reduction in energy requirements as a result of intensity changes. If these imports had been produced domestically, more efficient use of energy would have saved 364 TBtu. Again, the difference between these major components and the actual energy change, 282 TBtu, is accounted for by the interaction terms. Table 2.3 shows the levels of energy use for exports and imports and compares them to the value of trade flows.

It is evident from Table 2.3 that the embodied energy content per dollar of exports declined between 1972 and 1977 and that this decline was about 12 percent. This decline in the energy intensity of exports occurred because the dollar value of exports grew at a faster pace (44 percent) than did the

TABLE 2.3. Energy Content and Value of Exports (X), Imports (M), and Net Foreign Balance (X-M), 1972 and 1977, U.S. Manufacturing

<u>1972</u>	<u>X</u>	<u>M</u>	<u>X-M</u>
Energy TBtu	3934	5055	-1121
\$ 1982 Billion	195.2	244.6	-49.4
1000 Btu/\$	20.2	20.7	
<u>1977</u>			
Energy TBtu	5001	6582	-1581
\$ 1982 Billion	281.6	317.1	-35.5
1000 Btu/\$	17.8	20.8	

increase in energy (27 percent) required to produce those exports. The energy content of imports (again evaluated at domestic energy intensities) increased 30 percent over the five-year period as did the value of imports so that the energy intensity of imports remained virtually unchanged. In five years, the gap between energy intensity of exports and imports widened from 500 Btu/\$ (2.4 percent) to 3000 Btu/\$ (16.9 percent).

2.5 RESULTS: MERCHANDISE TRADE

To examine the energy content and value per dollar of trade further, time series of merchandise exports and imports were applied to Equation (2.4) for the period 1972 to 1984. Table 2.4 reports these calculations using energy intensities for the years 1972 through 1981 (see Section 2.1.4). For 1982 through 1984, the 1981 energy intensity was used. Energy use embodied in exports and imports was calculated using the 1977 I/O table; i.e., the technology of production is assumed to remain unchanged at the 1977 level over the entire period. Further, as in the previous section, imports are assumed to have been manufactured at energy-intensity levels of U.S. industry.

TABLE 2.4. Energy Use Calculated from Equation (2.4) for Exports (X), Imports (M) and Net Foreign Balance (X-M), 1977 Technology

Year	Energy Embodied in Trade (TBtu)		
	X	M	X-M
1972	3125	4656	-1531
1973	3904	4668	-764
1974	4294	4586	-292
1975	4306	4144	162
1976	4375	4937	-562
1977	4205	5413	-1208
1978	4646	5619	-973
1979	5101	5371	-270
1980	5458	4895	563
1981	5152	5360	-208
1982	4681	5288	-607
1983	4463	5810	-1347
1984	4747	8033	-3286

Although the merchandise trade data differ from the I/O data, the levels in 1977, the year to which the technology applies, are similar. The energy embodied in exports calculated from the merchandise trade data is within 800 TBtu (84 percent) of the I/O calculated energy use. The import data match about as well, with the embodied energy from merchandise trade at 82 percent of I/O energy use. Merchandise exports in 1972 account for about 79 percent of the I/O results, while merchandise imports accounted for 92 percent of I/O energy use. Table 2.4 also suggests that the deficit in the merchandise trade energy balance for 1972 is slightly larger than the I/O deficit, while the merchandise trade energy balance in 1977 is somewhat smaller than the I/O energy balance. The embodied energy content of merchandise trade (i.e., Table 2.4) is shown in Figure 2.6.

Overall, Table 2.4 suggests that the United States was a net importer of energy as a result of trade, because imports are more energy intensive. In 1974 and 1979, when our net foreign balance was closest to zero, this country

FIGURE 2.6. Embodied Energy in Foreign Trade

was a net importer of energy, although the amount of imported energy was small. In every other year, when we imported energy, we also ran a trade deficit. In 1983 and 1984 the effects of large trade deficits magnify energy imports.

Table 2.3 shows a sharp reduction in energy per dollar of I/O exports between 1972 and 1977. The pattern of export and import energy intensities over time can be illustrated by converting the results of Figure 2.6 to a Btu/\$ basis. To calculate these intensities, the embodied energy reported in Table 2.4 is divided by the constant dollar value of merchandise exports and imports reported in Table 2.5, yielding the numbers plotted in Figure 2.7.

2.6 DISCUSSION AND CONCLUSIONS

Although a few studies have appeared, not many have analyzed the energy content of trade. The following discussion will focus on two issues related to the topic: how the findings reported here compare with previous studies and what conundrums arise from these results. Conclusions are then drawn.

The major reference to previous studies is Dunkerley and Alterman (1977) who calculate the energy content of nonenergy trade for the United States,

TABLE 2.5. Inflation-Adjusted Value of Merchandise Trade (Billions \$1972)

Year	X	M	X-M
1972	42.61	54.91	-12.30
1973	54.66	56.06	-1.40
1974	62.48	56.80	5.68
1975	62.54	49.79	12.75
1976	65.73	60.65	5.08
1977	67.07	66.72	0.35
1978	75.89	73.18	2.71
1979	84.88	73.33	11.55
1980	92.90	70.92	21.98
1981	94.87	83.72	12.15
1982	86.38	86.46	-0.08
1983	83.03	97.74	-14.71
1984	88.78	135.46	-46.61

FIGURE 2.7. Energy Intensity of Exports and Imports

Canada, Japan and several European countries for 1972. The intensity per dollar of trade is based on U.S. intensities applied to the embodied output calculated from the vectors of exports and imports for each of the countries, using an I/O approach. In the case of the United States and four other countries, the flows were in approximate balance; two others had slight outflows; and Germany, Japan and Sweden had outflows that amounted to between 10 and 13 percent of domestic energy consumption. Both the merchandise trade and I/O results reported in the previous subsections are consistent with these findings. For other examples of trade-related studies that use an I/O framework, see United Nations (1984, Part One).

Industry-specific anecdotes suggest that the United States has substituted imported energy in the form of semifinished and finished commodities. Instead of importing bauxite, for example, the United States currently imports alumina (the oxide of aluminum) primarily from Surinam, Jamaica and

Australia. Some aluminum ingots are imported as well, thus saving both the fossil energy used to convert bauxite to alumina and the electricity used to reduce alumina to aluminum. Other commodity imports that have increased since the early 1970s include finished steel products, paper and allied products, and even cement clinker. Finished goods, although not so energy intensive, are also included in the list of imported manufactured goods that have increased over time: automobiles, consumer electronics and machine tools are examples.

Yet the evidence from this analysis suggests that merchandise trade flows to the United States are less energy intensive now than in the past. Figure 2.7 clearly suggests that the intensity of both imports and exports has declined since 1975. This trend is contrary to the anecdotal evidence suggested by changes in imports of specific industries. The current analysis does not allow the resolution of this puzzle; however, the decline in the energy intensity of imports is partially explained by the dramatic change in the energy intensity of domestic industry. In Chapter 3 we will address how this analysis can be improved to resolve this puzzle. Figure 2.5 provides evidence that U.S. energy use would have increased if materials that were imported (represented by the change in interindustry flows) had been produced domestically. This is consistent with anecdotal industry evidence.

Over the 10-year period 1972-1982, changes in the structure of the U.S. economy substantially altered energy use patterns. As a result of these changes, the U.S. economy's use of energy increased by only 2.2 quad (4.5 percent) even though GNP increased by 21.4 percent. This growth in final demand would have accounted for an increase of about 11.3 quad if offsetting changes had not occurred. This growth in energy was offset by two factors: a reduction in the intensity of energy use in the production of goods and services and a reduction in industries' purchases of energy-intensive material from other industries. The intensity changes alone reduced energy use by 10.6 quad. The changes in material purchases accounted for a reduction of 1.1 quad of energy. The interaction of the final demand, intensity and interindustry flow components accounted for +2.7 quad, so that reductions and additions in energy use sum to the changes over the period.

This is the evidence that structural change has dramatically altered the way that the United States uses energy, although changes in energy use alone do not reflect these changes fully. The decomposition of structural change into component parts shows that additions to energy use that result from the growth of the economy, while very large, were mostly offset by changes in the use of purchased materials and changes in the intensity of energy use. The energy saved directly by economizing and the energy saved by using less energy-intensive materials offset all but about 2.2 quad of the energy increases that resulted from economic growth. This is a good example of the fact that a very small change in energy use disguises the large changes in the structure of the economy: positive changes in growth are offset by improvements in energy intensity.

It is clear from Table 2.4 and Figures 2.5 and 2.6 that some of these reductions in energy use are attributable directly to the energy embodied in trade flows. At this stage of the analysis, this embodied energy is estimated based on U.S. industry energy use. These figures could be substantially different if foreign countries use energy differently than we do. The research design presented in the next chapter explains how this deficiency can be corrected to provide a better estimate of the role of energy in the competitiveness of U.S. goods in international trade.

3.0 THE ROLE OF ENERGY IN COMPETITIVENESS: RESEARCH DESIGN

Assessing the role of energy in the competitiveness of U.S. goods in international trade is a sizeable undertaking. First, information about the important elements that affect the domestic economy--macroeconomic policies and the microeconomic decision making of involved economic agents--must be organized. Since these elements coalesce in structural change, knowledge about how that structural change affects energy use and, in turn, how energy use affects structural change must also be acquired. To this list is added an understanding of international trade flows. All of the domestic elements that apply to the U.S. economy must be understood as they apply to each of the United States' trading partners. Finally, then, the importance of energy's role needs to be determined from the evidence of changing structure and changing multilateral trade flows. This chapter describes how this goal can be accomplished based on the concepts introduced in the previous chapters.

In capsule form, the research design is as follows. First, use the method described in Chapter 2 to analyze structural change in one of the major trading partners of the United States. Second, examine trade flows between that country and the United States from both the domestic and the foreign perspective. Third, compare the trade flow changes with changes in the industry structure of both countries, identifying the industries in which the adjustments have been most severe. Fourth, assess whether the hypotheses developed below are supported or repudiated by the evidence. Repeat steps one through four until the six major trading partners of the United States have been analyzed. Examine multilateral trade flows among the seven countries, as was done bilaterally for the U.S. and each trading partner. Organize the results of these studies into a final report that assesses the role of energy in international trade and focuses on the policy implications.

3.1 HYPOTHESES

This section develops hypotheses that relate to energy's role in the competitiveness of U.S. goods in international trade. As identified in Chapter 1, energy can play both an indirect and a direct role in shaping the

economic environment that brings about structural change in the U.S. economy. Fiscal policy can affect energy use through tax incentives that influence business decisions about capital purchases, research and development; since energy is a major part of U.S. trade, trade policies influence its use directly; new equipment purchases help determine the efficiency of energy use in the economy, so savings and investment decisions also influence energy use. How structural change affects energy use is highlighted in Chapter 2. Both changes in the level and composition of final demand and changes in interindustry transactions influence energy use indirectly, while changes in energy intensity (business adjustments of direct energy use) affect the direct use of energy. The hypotheses listed below draw on these earlier discussions, but one major assumption needs to be clearly stated. The hypotheses are stated as causal relations all others things equal.

3.1.1 Hypothesis 1

The country with the relative cost advantage in energy will export those commodities that are more energy intensive (i.e., chemicals, primary metals, pulp and paper, etc.).

Discussion

Many things can give rise to cost advantages: lower material prices, lower wage rates, lower costs of capital, etc. This points out the importance of the phrase "all other things equal." So, the hypothesis applies only after adjustments have been made for any other cost advantage.

3.1.2 Hypothesis 2

Where embodied energy is only an insignificant element in the costs, the country with the higher energy costs will export relatively more commodities with low levels of embodied energy.

Discussion

This is a corollary to the first hypothesis. A particular country that has a cost disadvantage in energy can either overcome this disadvantage by using other materials, labor and capital more efficiently or it can focus on

commodities that have a small embodied energy content. Indeed, economic incentives suggest that decision makers will move to production of goods for which they have a relative advantage.

3.1.3 Hypothesis 3

Where aggregate adjustments to changes are similar between trading partners, trade flows will not be materially affected.

Discussion

If a common external force (e.g., energy price shocks) impacts two economies in a similar manner, and they both make similar adjustment, the pattern of trade between the two countries is not likely to be materially affected.

When analyzing each bilateral trading partner of the United States, the study will focus on these hypotheses. During the course of these studies, evidence will accumulate that either refutes or supports them. The preponderance of evidence, when all bilateral studies are complete, will determine whether or not energy plays a major role in the competitiveness of U.S. goods in foreign trade.

3.2 APPROACH

The approach to the investigation of structural change in major U.S. trading partners will be similar to the study of domestic structural change reported in Chapter 2. A major dimension of structural change is the efficiency with which industries in different countries use materials and other factors in production: capital, labor, energy and non-energy materials. The work reported in Chapter 2 also provides a methodology for examining changes that occur over time in the structure of the economy, including the efficiency of factor use. When this method is applied to the economic structure of major trading partners, significant changes in the organization of industry can be identified. Having established the patterns of structural change in these trading partners since the early 1970s, the analysis then examines the effect of this structural change on trade flows among the major industrial countries of the world. Changes in trade patterns, which mirror

changes in the structure of the economy, are the basic measure of a country's competitive position vis-a-vis the rest of the world. As Chapter 2 indicates, the trade component of domestic economic activity has had a disproportionate effect on energy use in the United States; further investigation will determine if these results hold for other countries and will serve to put this information into an international context. The final step in the investigation will be to draw policy implications from the findings.

The approach suggested for the bilateral phase of this study, then, can be summarized by the following steps: 1) Examine structural change in the United States' major trading partners, with special emphasis on the role of energy in these changes. 2) Examine trade flows among major developed economies. 3) Correlate the trade flows with structural changes. 4) Assess the hypotheses developed below in light of an examination of major industries that are both major actors in foreign trade and affected by structural change. To add substance to the approach, further detail on each of the steps is provided.

3.2.1 Step 1: Examine Structural Change

The examination of structural change uses a decomposition of changes in energy use into three major components: changes in final demand, changes in interindustry flows, and changes in energy use intensity. The method was previously described in Section 2.2. For each of the three terms, the major effects of changes can be identified for separate industries as well as for the export and import components of final demand. This decomposition provides the basis for the examination of major trading partners and can be accomplished for any country for which input-output data and energy intensity data are available. This approach is currently being implemented for Japan. Similar data are available for the United Kingdom, the Federal Republic of Germany, France and Canada. That the trade components can be identified in final demands is the basis for the second step.

3.2.2 Step 2: Examine Trade Flows

The examination of trade flows that will serve to integrate the United States and major trading partners can be done at different levels of detail.

At a high level of detail, commodity trade flows among nations could be collected, aggregated to an appropriate level of industry definition, then correlated with structural change within each of the developed countries under investigation. A simpler approach reverses this method. First the industries that are instrumental in, or affected most directly by, structural change are identified by disaggregating the final demand components so that imports and exports are treated separately. For those industries that play a major role in trade in the separate examination of the major trading countries, the flows among nations would be identified. This simpler approach would exclude data collection for all those industries that play only a minor role in the structural changes or trade flows. An example of this approach, through Step 2, is provided in Roop (1987), although the major industries affected by trade have not been separately identified. Further winnowing of these data is the focus of Step 3.

3.2.3 Step 3: Compare Trade Flow Changes with Structural Changes

The objective of the third step of the analysis is to determine which industries in which countries should be selected for further study. Industries and trade components that are important to the analysis were identified in Step 2; this step is designed to identify how these components interact through trade. If, for example, in the bilateral study of Japan, steel exports have contributed significantly to trade flows and have contributed to the improved efficiency of energy use, and the U.S. steel industry has shown only moderate efficiency improvements and imports have increased over the same time period, then steel would be a candidate industry against which the hypotheses articulated below would be assessed. It is important at this stage to select industries for which there are adequate data and which demonstrate the force of competition among countries other than just the United States. It is also important to select periods of analysis during and after the dramatic appreciation of the dollar in foreign trade. The richness of energy data and the availability of foreign and domestic input-output tables will allow such a selection. As the evidence accumulates for or against the hypotheses, energy's role in structural change and international trade will become clearer.

3.2.4 Step 4: Assess Hypotheses

The objective of Step 4 is to assess the role of energy in international trade by examining whether the evidence supports or refutes the hypotheses developed in Section 3.1. The hypotheses focus on the role of energy in trade: if they are confirmed, then the evidence would support the conclusion that energy plays a major role; alternatively, if the hypotheses are rejected, then one possible conclusion might be that energy's role in trade is minor.

* * * * *

Steps 1 through 4 are repeated for each of the trading studies for which data will allow the proposed analysis. Current expectation is that the all six of the United States' major trading partners (Japan, Canada, United Kingdom, West Germany, France and Italy) have comparable data that will allow the analysis to be conducted bilaterally. As each of the major trading partners is studied and compared with the United States, a report will be issued on that country's trade. When all the bilateral studies are complete, the final steps of the analysis will be undertaken.

* * * * *

3.2.5 Step 5: Examine Multilateral Trade Flows

In this step multilateral trade flows among all seven countries are examined. Although bilateral studies allow an analysis of changes in trade between any two countries, a multilateral study is needed to determine if the interaction among all countries has an effect that cannot be ascertained by the bilateral studies. An example may clarify the benefits of such a multilateral study. Say that the bilateral studies between the United States and Japan indicate that chemicals and steel are industries of interest because Japan now exports more steel to the United States while the United States exports more chemicals to Japan. In addition, another bilateral study has revealed that U.S. trade with France suggests that machine tools and apparel are industries of interest because the U.S. now exports more machine tools to France and France exports more clothing to the U.S. The multilateral study might further reveal that France imports from Japan textiles that are made with the chemicals imported from the United States, and that France finances this trade by exporting to Japan transportation equipment made with

U.S.-purchased machine tools. This sort of interaction could not be identified without the multilateral phase of the study.

3.2.6 Step 6: Identify Policy Implications and Develop Recommendations

The final step reports on the multilateral study and organizes the policy implications of each of the prior steps into a set of conclusions and recommendations.

•

•

•

•

•

•

•

4.0 REFERENCES

Bureau of the Census. 1986. Statistical Abstract of the United States, Year. U.S. Department of Commerce, Washington, D.C.

Bureau of Economic Analysis. 1984. The Input-Output Structure of the U.S. Economy, 1977. U.S. Department of Commerce, Washington, D.C.

Bureau of Economic Analysis. 1988. "The Input-Output Structure of the U.S. Economy, 1982," Survey of Current Business 64(5):42-84.

Business Week. 1988. "Will the New *Maquiladoras* Build a Better *Manana*?" November 14, pp. 102, 106.

Choate, P. and J. K. Linger. 1986. The High-Flex Society: Shaping America's Economic Future. Alfred A. Knopf, New York.

Darmstadter, J., J. Dunkerley and J. Alterman. 1977. How Industrial Societies Use Energy: A Comparative Analysis. Johns Hopkins University Press for Resources for the Future, Baltimore, Maryland.

Dornbush, R. 1988. "Doubts About the McKinnon Standard," Journal of Economic Perspectives. 2(1):105-112.

Energy Information Administration. Monthly. Monthly Energy Review. DOE/EIA-0035(Year/Month). Washington, D.C.

Energy Information Administration. 1988a. Annual Energy Review, 1987. DOE/EIA-0384(86). Washington, D.C.

Energy Information Administration. 1988b. Manufacturing Energy Consumption Survey: Consumption of Energy, 1985. DOE/EIA-0512(85). Washington, D.C.

Energy Information Administration. 1988c. State Energy Data Report Consumption Estimates, 1960-1986. DOE/EIA-0214(86). Washington, D.C.

Faucett, Jack, Associates. 1984. National Energy Accounts. JACKFAU-84-316, Chevy Chase, Maryland.

Feenstra, R. C. and J. N. Bagwati. 1982. "Tariff Seeking and the Efficient Tariff." Import Competition and Response, ed. J. N. Bagwati. University of Chicago Press for the National Bureau of Economic Research, Chicago, Illinois.

Gramlich, E. M. 1978. "State and Local Budgets the Day After it Rained: Why is the Surplus So High?" Brookings Papers on Economic Activity I. The Brookings Institution, Washington, D.C.

Hatsopoulos, G. N., P. R. Krugman and L. H. Summers. July 15, 1988. "U.S. Competitiveness: Beyond the Trade Deficit." Science 241:299-307.

Klan, M. S., D. B. Belzer, S. J. Marsh, J. M. Roop and R. D. Sands. 1988. Energy Use and Conservation Trends: 1972-1986. PNL-6714, Pacific Northwest Laboratory, Richland, Washington.

Landau, R. 1988. "U.S. Economic Growth," Scientific American 258(6):44-52.

McKinnon, R. I. 1988. "Monetary and Exchange Rate Policies for International Financial Stability: A Proposal," Journal of Economic Perspectives. 2(1):83-103.

Office of the President and Council of Economic Advisors (CEA). Annual. Economic Report of the President Together with the Annual Report of the Council of Economic Advisers. U.S. Government Printing Office, Washington, D.C.

Organisation for Economic Co-operation and Development (OECD). 1984. Competition and Trade Policy: Their Interaction. Paris.

Poyer, D. 1983. Residential Fuel Consumption Patterns for Poor, Black, and Elderly Households: A Comparative Study Volume 2: Analytical Assessment. ANL/EES-TM-236, Argonne National Laboratory, Argonne, Illinois.

President's Commission on Industrial Competitiveness. 1985. Global Competition: The New Reality. Volume 1. U.S. Government Printing Office, Washington, D.C.

Roop, J. M. 1986. "The Trade Effects of Energy Use in the U.S. Economy: An Input-Output Analysis," Proceedings. Eighth Annual Meeting of the International Association of Energy Economists. IAEE, Washington, D.C.

Roop, J. M. 1987. "Energy Implications of Structural Change in the United States Economy," IEA Energy Demand Analysis Symposium: Preceedings, pp. 215-231. Organisation for Economic Co-operation and Development, Paris, France.

United Nations. 1984. Proceedings of the Seventh International Conference on Input-Output Techniques. New York.

U.S. Department of Labor, Bureau of Labor Statistics. 1981. BLS Economic Growth Model: System Used for Projections to 1990. Bulletin 2112, Washington, D.C.

U.S. General Accounting Office. 1988. "Foreign Investment: Growing Japanese Presence in the U.S. Auto Industry." GAO/NSIAD-88-111, U.S. Government Printing Office, Washington, D.C.

Williams, R. H., E. D. Larson, and M. H. Ross. 1987. "Materials, Affluence, and Industrial Energy Use," Annual Review of Energy 12:99-144.

Williamson, J. 1988. "Comment on McKinnon's Monetary Rule," Journal of Economic Perspectives. 2(1):113-119.

Zysman, J. and L. Tyson, eds. 1983. American Industry in International Competition: Government Policies and Corporate Strategies. Cornell University Press, Ithaca, New York.

DISTRIBUTION

No. of
Copies

No. of
Copies

OFFSITE

ONSITE

12 DOE/Office of Scientific and
Technical Information

DOE Richland Operations Office

E. C. Norman

M. Podolak
U.S. Department of Energy
Washington, D.C.

15 Pacific Northwest Laboratory

V. Stagliano
U.S. Department of Energy
Washington, D.C.

D. B. Belzer
J. E. Danko
G. L. Koller
J. M. Roop (5)
D. E. Serot
Publishing Coordination
Technical Report Files (5)