FEDERAL INITIATIVES TO INDUCE INNOVATION IN THE AUTO INDUSTRY

A STATE-OF-THE-ART ASSESSMENT

- JANUARY 1978 -

by

Bruce Rubinger

Contributors:

Herbert Eskowitz

Val Livada

Robert Ricci

TABLE OF CONTENTS

PREFACE

In response to the urgent national need to develop socially beneficial auto technology, the Auto Technology Program is assessing the role of alternative incentives as tools for inducing innovation. This is a complex task, and a multi-year effort is underway to address these questions.

The goal of this report is to examine the innovation process, identify the critical issues and provide a state-of-the-art assessment of the subject. In pursuing this objective the report draws upon six technology contracts completed under the program, and in particular, relies heavily on the forthcoming report "Assessment of Effectiveness of Past Federal Actions Intended to Bring About Changes in Automotive Technology Having Substantial Public Benefit" by William J. Abernathy and Balaji S. Chakravarthy. The studies performed under contract were complemented by in-house activities which examined the spectrum of incentive policies, identified critical issues, analyzed the parameters of the innovation process, and explored past experience with economic incentives. In bringing this information together some editorial changes were made, but responsibility for the technical content rests solely with the respective authors.

Incentives for innovation is a dynamic subject, and this state-of-the-art assessment document will be continually updated to reflect the results of ongoing studies. It is being released in its current, preliminary, form in the hope that it will stimulate a national debate on this crucial issue.

BRUCE RUBINGER
TSC STUDY LEADER

ACKNOWLEDGEMENT

This work was carried out as part of the Auto Technology Program (OS-714) at the Transportation Systems Center, and sponsored by the Office of the Secretary of Transportation. The support and advice provided by the sponsor, Dr. William Devereaux, are gratefully acknowledged.

Incentives for innovation is a very broad subject with an extensive literature. Among this body of work several papers were particularly useful in generating this report and should be singled out; these are identified in the bibliography on innovation.

1. THE AUTO TECHNOLOGY PROGRAM

1.1 INTRODUCTION

In the future, the Nation must seek further reductions in emissions, fuel consumption, and fatalities due to automobile use. To insure that these goals are achieved, it is necessary to understand more thoroughly alternative strategies available to the Federal Government to encourage the development and adoption of innovative automobile technology.

The objective of the Auto Technology Program is to assess federal initiatives for more rapid development and production of cars with improved automotive technology, and to provide technical, economic and other analyses to support formulation of the Secretary's policies for implementation of improved automotive technology by the private sector. Strategies to be addressed include federal R&D, regulatory actions, and economic, informational, and institutional incentives. The impacts of each strategy on the automobile manufacturers' behavior in such areas as R&D, manufacturing, marketing, finance, and the international arena will be analyzed under the program. In addition, institutional incentives and barriers to technology innovation in the automobile industry will be examined, and institutional modifications necessary for successful implementation of federal policies identified. Finally, criteria will be developed for assessing the effectiveness of the spectrum of alternative federal strategies for achieving specific goals in the areas of automotive fuel economy, safety, emissions, and noise.

The objective of the current report is to describe the status of the program and the results to date. This "state-of-the-art" document will be continually updated as the work progresses.

1.2 BACKGROUND

The Auto Technology Program evolved from the Automotive Energy Efficiency Program which was initiated in FY 1974 to evaluate the capability of the automotive industry to improve the fuel economy of their production vehicles and assess the associated aggregate energy, safety, economic, and environmental effects. The importance of these objectives was subsequently recognized by the Interagency Federal Task Force on Motor Vehicle Goals Beyond 1980. In 1976, responsibility for setting fuel economy standards for vehicles up to 10,000 pounds gross vehicle weight (GVW) was delegated to NHTSA, and the current program emerged with its focus on significant issues of technical innovation as influenced by federal policies.

In FY 76T four small contracts were initiated: (1) Decision Process for Innovation in Manufacturing and Marketing; (2) The Role of Suppliers in Automotive Innovation; (3) Industry Response to Federal Regulations on Safety Requirements; and (4) Inducing the Development of Socially Efficient Auto Technology.

In 1977 several studies were initiated and are in various stages of completion (see Task Descriptions for further details). These activities are: (1) Contractual obligation of a study concerning the "Multi-national Aspects of Automotive Innovations"; (2) Contractual obligation of a study to "Assess Past Federal Actions in Automobile Technology"; (3) Commitment of a contract entitled "Analysis of Corporate Strategy in the Automotive Industry"; (4) Obligation of a contract entitled "Workshop on Automotive Issues"; (5) Commitment of a study to examine "Incentives and Acceptance of Electric, Hybrid, and other Alternative Vehicles"; (6) Commitment of a study entitled "An Analysis of Federal Incentives to Stimulate Consumer Acceptance of Electric Vehicles"; (7) Commitment of a study "The Effects of Government Regulatory Policies in the Automobile Industry"; and (8) Commitment of a study entitled "The Effects of Government R&D Policies in the Automobile Industry".

1.3 ACCOMPLISHMENTS

The following studies were carried out under the Program:

1) <u>Analysis Support for Federal Initiatives</u>

<u>Regulatory Actions</u>

- o An Analysis of Industry Responses to Federal Regulations in Safety Requirements for New Automobiles (March 1977)

Economic Incentives

- o Inducing the Development and Adoption of Socially Efficient Automotive Technology (April 77)
- o Incentives and Acceptance of Electric, Hybrid, and other Alternative Vehicles (May 1977)
- o An Analysis of Federal Incentives to Stimulate Consumer Acceptance of Electric Vehicles (Sept 1977)
- o Federal Incentive Programs for Electric and Hybrid Vehicles (July 1977)

Institutional Incentives

- o Institutional Factors in Transportation Systems and their Potential for Bias Toward Vehicles of Particular Characteristics (August 1977)

2) Issues

Two workshops were held under the auspices of Harvard University to discuss the critical issues associated with auto innovation. Participants included high-level representatives of the major automobile producers, auto suppliers, dealer organizations, insurance firms, consumer groups, and government. The focus of these meetings was:

- o The Regulatory Process: Implications for Technical Progress.
- o The Consumer: As a Factor in Future Automotive Technology.

3) Data Assessment

- o Analysis of Federal Stimuli to the Development of New Technology by Suppliers to Auto Manufacturers (March 1977)

- The Decision Process for Innovations in the Automotive Industry as it Relates to Marketing and Manufacturing (Jan 77)

1.4 TECHNICAL APPROACH

The program consists of three task areas: (1) The identification, development and assessment of federal initiatives (i.e. regulatroy action, R&D, economic incentives, institutional incentives, and informational incentives) to promote automotive innovation and examination of the impact of these policies on automotive manufacturers' R&D, marketing, finance, manufacturing, and international behavior; (2) The identification of critical issues associated with innovation; and (3) Data assessment of the automotive industry's function of manufacturing, marketing, supplier inputs, multi-national aspects, and corporate strategy. The technical approach and program flow are illustrated in Figures 1-1 and 1-2 respectively.

For implementation of Task 1, several major contracts are anticipated, covering: (1) R&D incentives; (2) Regulatory actions; (3) Economic Incentives (4) Institutional Incentives; (5) Informational Incentives; and (6) An Integrated Incentive Study. Under Task 2, a contract has been obligated to identify the issues in the auto industry to stimulate innovation via a series of automobile workshops. In Task 3, six small contracts ($10K - 20K) have been obligated to assess the available data in the areas of manufacturing, marketing, finance, and multi-national aspects of the auto industry. This task will rely as much as possible on data available from the NHTSA AFER (Automotive Fuel Economy Regulatory) program.

1.5 TASK DESCRIPTIONS

<u>Task I</u> - Federal Initiatives

Federal initiatives for promoting innovation in the auto industry will be assessed with particular attention focused on whether federal incentives should take the form of output oriented

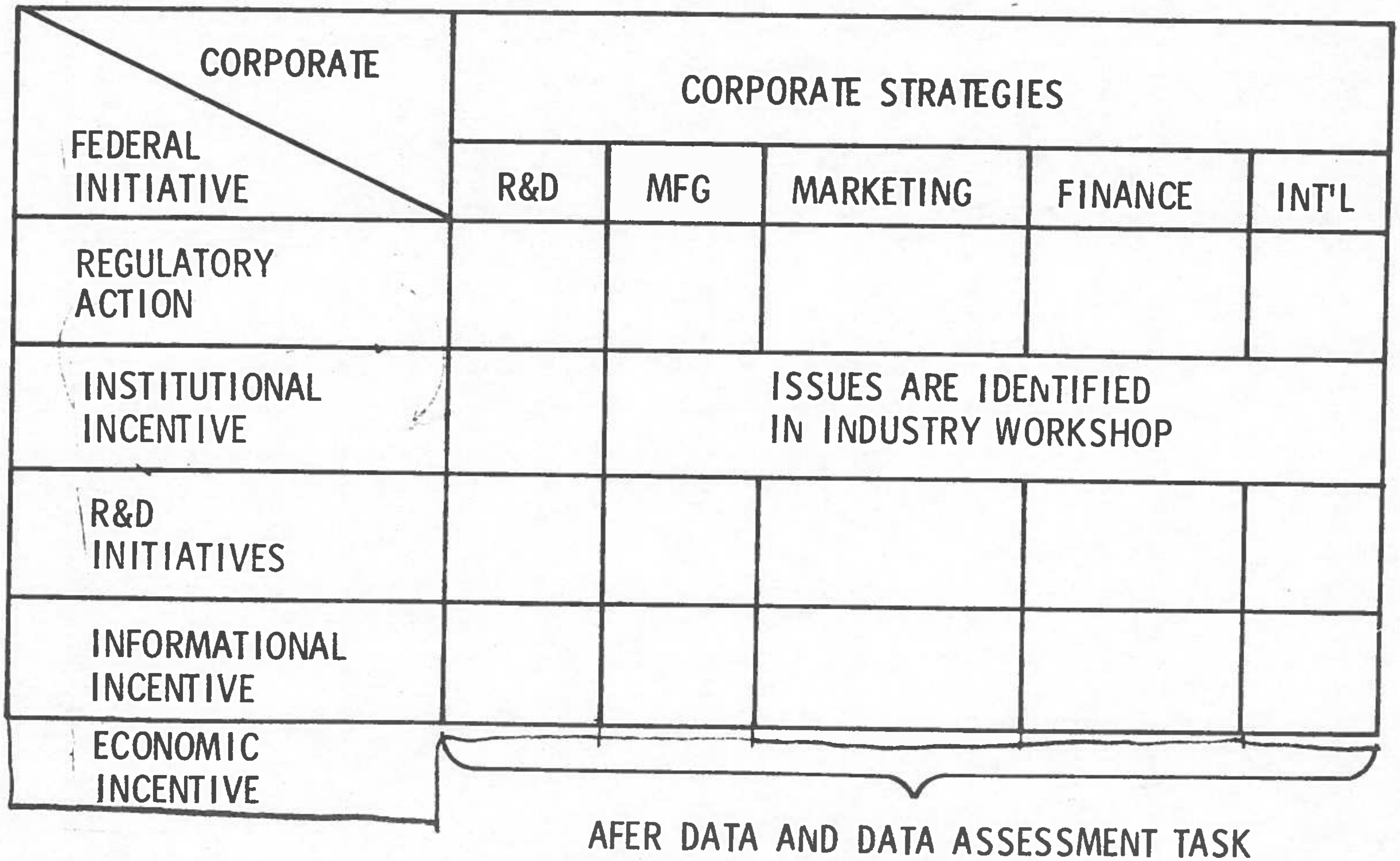


FIGURE 1.1 AUTOMOTIVE TECHNOLOGY PROGRAM TECHNICAL APPROACH

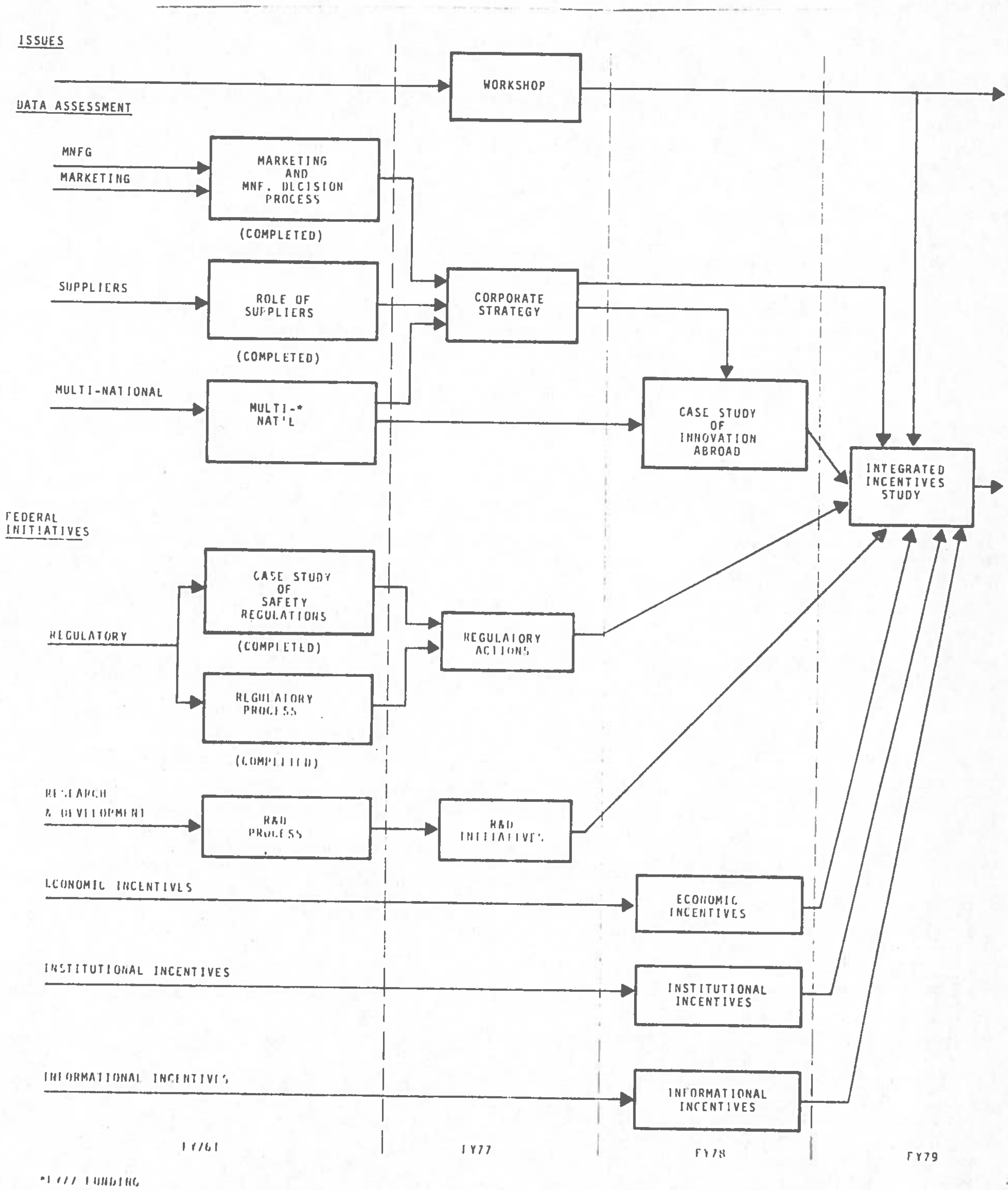


FIGURE 1-2. PROGRAM FLOW

intervention (i.e., R&D, economic, institutional, informational incentives).

Task 1.1:

Output-Oriented Initiatives

a. Regulatory Action

An assessment will be conducted of the motor vehicle industry's recent response to regulatory action aimed at fuel economy improvement. Emphasis will be placed on years 1975 to 1977, which cover the conduct of the Federal Study on Motor Vehicle Goals beyond 1980 as well as development and promulgation of the rules concerning the 1981-1984 Passenger Auto Fuel Economy.

Progress in the simultaneous implementation of motor vehicle changes necessitated by other government regulations, i.e., safety, emissions, and occupational safety and health, will be examined. Evidence to date suggests that output oriented actions, are frequently used in preference to process oriented initiatives.

A methodology will be developed to give predictive insights into the effects of future regulatory actions, and allow the identification of efficient and equitable policies for bringing about these initiatives.

Task 1.2:

Process Oriented Initiatives

a. R&D Initiatives

The assessment initiated in FY 77 of the impact of federal R&D initiatives on the automobile manufacturers' R&D, manufacturing, finance, and organizational behavior regarding decisions to implement innovative technology will be continued. Risk and risk factors for each firm associated with R&D, production and finance will be evaluated. The role of R&D in achieving national automotive goals will be identified, the expected payoff from such federal initiatives assessed and the remaining critical R&D issues addressed.

b. Economic Incentives

A study of the role of federal economic incentives (e.g., subsidies, tax policies, protection against foreign competition, financial penalties, direct government grants) for stimulating innovative technology will be initiated. A methodology will be developed for predicting the effects of future economic incentives and will be used to determine their impacts, effectiveness in achieving desired objectives, and efficiency. Comparisons will be made between innovations stimulated by market forces and those stimulated by federal incentives.

c. Institutional Incentives

The various institutional issues and changes in institutional structure which need to be resolved for the successful implementation of federal R&D policies, regulatory, or economic incentives will be determined through a study of the historical background of institutional, legal and political impediments to automotive innovation. Critical institutional modifications necessary for effective policy making will be identified.

d. Informational Incentives

Informational requirements for federal policies designed to promote socially efficient technology will be identified. These will include data needed by: (1) The lawmakers for setting goals and evaluating compliance, (ii) By the consumer in choosing between competing designs (e.g., vehicle fuel economy, safety, damageability, repairability, life-cycle cost), and (iii) By manufacturers for key decision points (e.g., cost and reliability of alternative designs, future regulatory environment). Current and alternative federal policies will be evaluated in terms of the amount of data they require, the cost and availability of this information, and the complexity of the decision process. Improved policies will be identified which incorporate incentives for information generation, reduce the informational uncertainties, and achieve the desired social results at a minimum cost.

Task 2 - Issues

A series of automotive workshops will be held under the auspices of Harvard University to provide a forum for the discussion of critical issues in the area of technology in the auto industry. Individual workshops will focus on (a) The Regulatory Process, (b) the Consumer as a Factor in Future Automotive Technology, (c) International Competition and Technology Transfer, (d) The Innovation Potential of Suppliers, and (e) The Changing incentives for Research, Development and Innovation. The participants in these meetings will be drawn from organizations with direct interests in the outcome of these changes, and include the major U.S. and foreign automobile producers, major suppliers, dealer organizations, consumer groups, insurance firms, government agencies, etc. The results of these workshops will be collected and published as a book.

Task 3 - Data Assessment

This task addresses the assessment of existing data in the areas of R&D, marketing, finance, multi-national, role of suppliers, and corporate strategy for the automotive industry. See Table 1-1 for a summary of four recently completed and two presently active contracts. Two subtasks remain to be completed in this area: (1) An analysis of corporate strategies, and (2) Multi-national aspects of automotive innovation.

Task 3.1 - Analysis of Corporate Strategies

In order to assess the impact of federal incentives in the auto industry an analysis of corporate strategies is needed. Therefore, under this task the formal organizational decision process for each of the four major U.S. domestic automobile manufacturers will be identified, along with the internal information flows and analysis support activities. Each firm's methods for evaluating and responding to risk and uncertainty will be determined. Corporate goals, objectives, and values, both short-term and long-run will be identified. The effects of non-automotive and foreign operations on the overall decision making process will be defined. Finally, potential future manufacturer strategies will

TABLE 1-1. AUTOMOTIVE TECHNOLOGY PROGRAM - DATA ASSIGNMENT CONTRACTS

TITLE	COMPLETION DATE
Decision Process for Innovation in the Automotive Industry as it Relates to Marketing and Manufacturing.	Completed
Analysis of Federal Stimuli to Development of New Technology by Suppliers.	Completed
Industry Responses to Federal Regulations on Safety Requirements.	Completed
Multi-national Aspects of Automotive Innovation.	March 1978
Assessment of Past Federal Actions on Auto Technology.	February 1978
Analysis of Corporate Strategy.	April 1978

be identified in such areas as: (1) Relationship with Federal and State Governments; (2) Relationship with suppliers; (3) Product development; (4) New market development; (5) Dealer relations; and (6) Corporate expansion.

Task 3.2 - Multi-national Aspects of Automotive Innovation

a. Technology Transfer by the Major Domestic Automotive Manufacturers

Work will continue that was initiated in FY 77 to determine the number, location and characteristics of R&D facilities located abroad that are owned by the four major domestic manufacturers. The type and extent of technology transfer that takes place among these foreign facilities, and between foreign and domestic organizations of each manufacturer will be evaluated.

2. INCENTIVES FOR INNOVATION - THE ISSUES AND OPTIONS

2.1 INTRODUCTION

During the 35-year period prior to 1970, the only major technical innovations in the auto industry were the widespread adoption of the V-8 engine and the automatic transmission. As befits a mature product, the focus within the industry was on manufacturing productivity and, measured by this yardstick, the industry was enormously successful; vehicle price per pound declined by a factor of four and consumers were provided with cars ideally suited to an energy-rich society. One attendant result of the productivity emphasis was the introduction of additional design constraints and a decline in innovation. Change became an evolutionary process inexorably tied to refinements in an integrated production unit. This, at a time when the ability of the industry to implement change is diminished, the need for innovation has never been greater. In response to economic, strategic, social and environmental forces, dramatic improvements are needed in the fuel economy, damageability, crashworthiness, and emissions levels of the new car fleet over the next decade. Meeting these needs will pose the greatest challenge the industry has ever faced.

While the task of achieving the fuel economy, safety, and emissions goals is formidable, the national benefits are equally great. Table 2-1 illustrates some aspects of the societal cost of the motor vehicle. In the early 1970's the automobile was involved in 37 million accidents annually, resulting in 3.5 million injuries and 55,000 fatalities. Implementation of enhanced crashworthiness requirements (Level II Safety) is expected to reduce this annual carnage by 17,000 fatalities, yielding a cumulative twenty-five year saving of 165,000 lives. (See Table 2-2).

Focusing next on energy requirements, the passenger automobile fleet consumed 5.1 million barrels of petroleum per day in 1975, and this usage rate was projected to increase with VMT growth to 8.3 MM Barrels/Day by the year 2000. It is estimated that

TABLE 2-1. SOCIETAL COST OF THE AUTOMOBILE

SAFETY	ENERGY	EMISSIONS
37 million annual accidents 60 million damaged automobiles 3.5 million injuries, and 55,000 deaths (35,000 were auto occupants)[1]	5.1 million barrels per day consumption (1975). Cumulative 25-year fuel consumption of 60.1 billion barrels if fuel economy were unchanged	1100 excess person days of aggravation of asthma
Aggregate property damage $11.40 billion, total annual society cost due to auto accidents of $38.9 billion[2]		16,000 excess person days of coughs
		1,000,000 excess attacks of lower respiratory disease in children
		10,000 excess person days of heart and lung disease in elderly patients

Source: (1) The Federal Task Force on Motor Vehicle Goals Beyond 1980, Vol., 2, Sept. 1976.

(2) "1975 Societal Costs of Motor Vehicle Accidents", U.S. Department of Transportation, NHTSA, Planning and Evaluation, Dec. 1976.

TABLE 2-2. SELECTED SOCIETAL BENEFITS FROM ADOPTION OF INNOVATIVE AUTO TECHNOLOGY

SAFETY	ENERGY
17,000 fewer annual fatalities by 2000. Cumulative 25-year reduction of 165,000 fatalities due to adoption of Level II Standards in 1985.	1.5 million barrels per day savings by 1985. 25-year cumulative savings of 18.9 billion barrels resulting from EPCA.[a]

Source: a) The Federal Task Force on Motor Vehicle Goals Beyond 1980, Vol. 2, Sept. 1976.

b) Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards, Feb. 1977.

technological improvements in the post 1975 period can reduce daily fuel consumption in the year 2000 by 3.8 MM Barrels/Day without sacrificing vehicle performance or interior roominess. The associated cumulative twenty-five year fuel savings is 18.9 billion barrels.

Thus, the adoption of socially beneficial automotive technology involves not only unprecedent market risk and large investment requirements, but also represents a unique national opportunity. The future that we inherit will be shaped by our actions today. Incisive, creative federal policy at this time can insure adequate energy supplies and relatively low fuel prices, along with cleaner air and a reduction in traffic fatalities.

2.2 INCENTIVES FOR INNOVATION - THE OPTIONS

The federal government has at is disposal a broad range of strategies for inducing innovation in the auto industry. For the purpose of analysis it is useful to group these under five generic headings: these are Regulatory actions, R&D Initiatives, Economic Incentives, and Information Incentives (Table 2-3). Within each category, a spectrum of options exists as illustrated in Table 2.4.

TABLE 2-3. FEDERAL STRATEGIES FOR PROMOTING INNOVATION

Output Oriented Initiatives	Process Oriented Initiatives
o Regulatory Actions	o R&D
	o Economic Incentives
	o Institutional Incentives
	o Information Incentives

Regulatory actions are consistered. These include techno-ogical standards, product standards, and voluntary programs. Regulatory actions are classified in terms of the extent of market constraint imposed, and range from weak market modification to product intervention. It is interesting to note that over the last fourteen years regulatory action, with increasingly greater product intervention, has emerged as the favorite policy tool of the law makers; this development is examined in detail in Chapter 6.

Focusing next on R&D initiatives, the federal options include stimulating R&D, in-house R&D, Government/Industry cofunding, and information exchanges. When R&D is employed the particular strategy selected should be in harmony with the life-cycle development process of an innovation. Five distinct types of research have been identified; these are survey research, basic research, applied research, developmental research, and rulemaking support. This leads to the two dimensional R&D decision matrix illustrated in Table 2-5.

Federal technology creation efforts have played an important role in the development of such products as the computer, jet engine, and advanced semi-conductor devices. In contrast, Federal R&D activities in the automotive sphere have been largely limited to rulemaking support, and survey research. The implications of a continuation of the current R&D focus is discussed in Chapter 6, while the relationship between innovative input and output is analyzed in Chapter 3.

TABLE 2-4. SPECTRUM OF FEDERAL STRATEGIES FOR PROMOTING INNOVATION

REGULATORY ACTIONS	R&D INITIATIVES	ECONOMIC INCENTIVES	INSTITUTIONAL STRATEGIES	INFORMATION INCENTIVES
o Technological Standards	o Stimulatory R&D	o Tax incentives	o Constant examination & Revision of Regulatory Policies to Reflect New Data	o Fuel Economy Labels
o Product Performance Standards	o In-house R&D	o Protection against foreign competition	o Federal Planning Horizons compatible with Industry Load Time Requirements	o Mandatory Crash-worthiness and Pre-parability Ratings
o Voluntary Program	o Gov't/Industry Co-Funding	o Subsidies	o Better understanding of the Innovation Process	o Life-Cycle Cost
o Market forces alone	o Information Exchange	o Investment tax credits	o Anti-trust Philosophy	
	o No Government R&D	o Loan guarantees	o Procedure for establishing Insurance Liability.	
		o Capital depreciation allowances	o Industry Structure	
			o Identification of Sources of Innovation	

TABLE 2-5. R&D DECISION MATRIX FOR INNOVATION

FEDERAL STRATEGY	SURVEY RESEARCH	BASIC RESEARCH	APPLIED RESEARCH	DEVELOPMENTAL RESEARCH	RULEMAKING SUPPORT
Stimulatory R&D		X	X	X	
In-house R&D	X		X	X	X
Government/ Industry Co-funding			X	X	
Information Exchanges			X	X	

Types of Research and Development

*Denotes the Federal strategy is suitable for achieving the Type or R&D indicated.

Of the various alternative policies, economic incentives have received the most attention in the academic literature. Most of these papers are concerned with the efficiency of taxes and subsidies as tools for reducing externalities, such as those associated with air and water pollution. The spectrum of economic incentives can be classified in terms of orientation as follows: (1) supply side incentives and (2) demand side incentives. Examples of the former include capital depreciation allowances, investment tax credits, loan guarantees and protection against foreign competition. The latter group includes income tax credits, rebates and various disincentives to consumption (e.g., gasoline taxes, auto excise taxes).

The identification and elimination of institutional barriers to innovation is one high payoff area which has received scant attention. Examples of such institutional issues include: a) anti-trust philosophy, b) political barriers (e.g., Federal and state Government relationship, c) Federal planning horizons, d) industry structure, e) financial practices which focus almost exclusively on acquisition cost and ignores operating cost, f) insurance liability procedures which do not encourage vehicle safety improvements, and g) an incomplete understanding of the innovation process and its key parameters.

The importance of information incentives has been recognized by several recent publications [Ref. 42]. These policy instruments differ in their orientation, and can be used to generate data for either law makers, auto manufacturers, or consumers. Examples of informational issues include; a) to what extent do information uncertainties surrounding such factors as vehicle technical performation, cost, and the future regulatory environment, retard the introduction of innovative technology, b) what information is needed to optimize policy, is this data obtainable and at what cost and c) which vehicle attributes (i.e. fuel economy, emissions, safety, noise, damageability) can be promoted with product information.

2.3 CRITICAL ISSUES IN INNOVATION

As a prelude to assessing the role of alternative incentive policies in a program to promote the development of socially efficient auto technology, it is invaluable to identify the critical issues. Such an exercise provides a focus for subsequent discussions and analysis. In addition, it serves to identify the relative importance of the various issues among diverse constituencies.

Table 2-6 contains a list of critical issues in innovation grouped under the broad categories of: a) regulatory actions, b) economic incentives, c) R&D initiatives, d) institutional issues, e) informational incentives and, f) integrated incentive policies. This list is not intended to be exhaustive, but representative of the key concerns of this complex subject. It should be emphasized that the choice of critical issues is not static, but will evolve over time to reflect new information.

Several critical issues were selected for further discussion, and these are highlighted in the next section.

2.3.1 Critical Issue -- What Role Should Market and Regulatory Forces Play in Inducing Innovation

There is an ongoing debate concerning the efficiency of market forces vs. regulatory actions in inducing desired change. On the one hand, according to traditional economic gospel (modern welfare economics) consumers act in their own self interest, and that the choices they make in the market among competing private and social utilities reveals their values. Thus it is argued, change is most efficiently brought about through the use of competitive market institutions complemented by a taxation approach whereby externalities (e.g. pollution, safety, energy) reflect their true social cost. In support of this view knowledgable sources[1,2] such as

---

[1] Schultze, Charles L., "The Public Use of Private Interest," Brookings Institute, May 1977;

[2] Haden Boyd, "Inducing the Development and Adoption of Socially Efficient Automotive Technology", Charles River Associates, Report #322, April 1977.

TABLE 2-6. CRITICAL ISSUES IN INDUCING AUTO INDUSTRY INNOVATION

A) REGULATORY ACTIONS

- DO REGULATORY ACTIONS LEAD TO INCREMENTAL INNOVATION AT THE EXPENSE OF RADICAL INNOVATION?
- HOW EFFECTIVE HAVE PAST REGULATORY ACTIONS BEEN IN ACHIEVING THEIR GOALS?
- WOULD REGULATORY POLICIES BE MORE EFFECTIVE IF THEY WERE FORMULATED SO AS TO BE CONTINUALLY UPDATED TO REFLECT NEW INFORMATION?
- ARE REGULATORY INITIATIVES BETTER SUITED TO CERTAIN CLASSES OF PROBLEMS (E.G. AIR QUALITY, SAFETY, FUEL ECONOMY) THAN OTHERS?
- WHEN ARE TECHNOLOGICAL STANDARDS PREFERABLE TO PRODUCT PERFORMANCE STANDARDS?
- UNDER WHAT CIRCUMSTANCES ARE REGULATORY INCENTIVES MOST EFFICIENT?
- WHO SHOULD REGULATE; THE STATES, FEDERAL GOVERNMENT OR INDUSTRIES?
- RELATIONSHIP TO COLLECTIVE BARGAINING?
- TIMING OF IMPLEMENTATION?

B) R&D INITIATIVES

- IF FEDERAL AUTOMOTIVE R&D IS UNDERTAKEN, WHAT AREAS SHOULD IT FOCUS ON, I.E., APPLIED RESEARCH, SURVEY RESEARCH, RULE-MAKING SUPPORT, BASIC RESEARCH?
- DO TECHNOLOGY CREATION PROGRAMS PLAY AN IMPORTANT ROLE IN STIMULATING INNOVATION?
- WHAT IS THE EXPECTED PAYOFF FROM R&D INITIATIVES?
- WHAT ROLE CAN INTERNATIONAL R&D TRANSFER PLAY IN INNOVATION?

TABLE 2-6. CRITICAL ISSUES IN INDUCING AUTO INDUSTRY INNOVATION (CONTINUED)

B) <u>R&D INITIATIVES (CONTINUED)</u>

- SHOULD FEDERAL R&D GO TO A RICH COMPETITIVE INDUSTRY WHILE OTHER INDUSTRIES (E.G., STEEL) FLOUNDER IN OBSOLESCENCE?
- FOR MAXIMUM PAYOFF WHICH ORGANIZATIONS SHOULD BE SELECTED TO PERFORM FEDERALLY SPONSORED R&D; GOVERNMENT LABS, UNIVERSITIES, RESEARCH ORGANIZATIONS, AUTO MANUFACTURERS, OR SUPPLIERS?
- WHAT AUTO TECHNOLOGIES SHOULD FEDERAL R&D PROGRAMS FOCUS ON?
- WHAT SHOULD BE THE TIME HORIZON OF FEDERAL R&D INITIATIVES; SHORT TERM OR LONG RUN?
- HOW SHOULD ANY RESULTS OF FEDERAL R&D BE SHARED, OR EVEN MEASURED?
- TIMING.

C) <u>ECONOMIC INCENTIVES</u>

- CAN ECONOMIC INCENTIVES WORK, OR ARE THEY "JUST A LICENSE TO POLLUTE"?
- IS IT FEASIBLE TO MEASURE THE COST OF "EXTERNALITIES" AND DERIVE SHADOW PRICES?
- HOW EFFECTIVE HAVE ECONOMIC INCENTIVES BEEN IN THOSE INSTANCES WHERE THEY'VE BEEN USED?
- DO EQUITY CONSIDERATIONS RULE OUT THE USE OF ECONOMIC INCENTIVES?
- HOW EFFICIENT ARE POLICIES WHICH RELY ON ECONOMIC INCENTIVES?
- WILL THE MARKET PROVIDE STRONGER FORCES ON INNOVATION THAN OTHER OPTIONS?

TABLE 2-6. CRITICAL ISSUES IN INDUCING AUTO INDUSTRY INNOVATION (CONTINUED)

C) <u>ECONOMIC INCENTIVES (CONTINUED)</u>

- o HOW MUCH SHOULD THE FEDERAL GOVERNMENT BE WILLING TO PAY, THROUGH VARIOUS ECONOMIC INCENTIVES POLICIES (E.G., SUBSIDIES, CAPITAL CONSUMPTION ALLOWANCE, FOREIGN PROTECTION, ETC.) TO SAVE A BARREL OF PETROLEUM?
- o WILL THE REDUCTION IN COMPETITION RESULTING FROM A POLICY OF IMPORT QUOTAS RETARD OR ASSIST INNOVATION?
- o TIMING OF IMPLEMENTATION.

D) <u>INSITUTIONAL ISSUES</u>

- o IS SOME MONOPOLY POWER NECESSARY FOR INNOVATION?
- o DO CORPORATE ATTITUDES TOWARDS RISK RULE OUT RADICAL BREAKTHROUGHS, AND IF SO CAN THIS PROCESS BE MODIFIED?
- o HOW DO FOREIGN GOVERNMENTS INTERVENE ON BEHALF OF THEIR NATIONAL AUTO PRODUCERS, AND WHAT ARE THE IMPLICATIONS FOR THE UNITED STATES?
- o ARE THE LEAD TIME REQUIREMENTS FOR MODIFYING COMPLEX SYSTEMS INCOMPATIBLE WITH THE TIME HORIZONS OF POLICY MAKERS?
- o ARE PUBLIC PERCEPTIONS OF THE ENERGY CRISIS, AUTO PASSENGER SAFETY, AND THE AIR QUALITY PROBLEM, CONSISTENT WITH THE SEVERITY REFLECTED IN CURRENT AND PENDING LEGISLATION?
- o POLITICAL
- o STATE, LOCAL GOV'T, AND FEDERAL GOV'T RELATIONSHIP
- O COLLECTIVE BARGAINING
- o CURRENT AND PROJECTED BUSINESS PHILOSOPHY
- o PROJECTED CHANGES IN AUTOMOBILE INDUSTRY AND ITS STRUCTURE

TABLE 2-6. CRITICAL ISSUES IN INDUCING AUTO INDUSTRY INNOVATION (CONTINUED)

D) INSTITUTIONAL ISSUES (CONTINUED)

- INTERNATIONAL RELATIONSHIP - INDUSTRY AND POLITICAL.
- WHAT ARE THE SOURCES OF FUTURE INNOVATIONS IN THE AUTO INDUSTRY (E.G., SUPPLIERS, INTERNATIONAL R&D TRANSFERS, FEDERAL R&D PROGRAMS, AUTO MANUFACTURERS, INDIVIDUAL INVENTORS)?
- WHAT ARE THE MOST SIGNIFICANT PARAMETERS OF THE INNOVATION PROCESS?
- TIMING OF IMPLEMENTATION.

E) INFORMATION INCENTIVES

- DO INFORMATION COSTS RETARD THE INTRODUCTION OF INNOVATIVE TECHNOLOGY?
- WHAT ARE EFFECTIVE FEDERAL POLICIES FOR LOWERING INFORMATION COSTS AND REDUCING INFORMATION UNCERTAINTIES?
- WHICH VEHICLE ATTRIBUTES (I.E., FUEL ECONOMY, SAFETY, EMISSIONS, DAMAGEABILITY) CAN BE PROMOTED WITH INFORMATION INCENTIVES?
- WHAT INFORMATION IS REQUIRED BY CONGRESS, THE MANUFACTURERS, AND CONSUMERS TO OPTIMIZE POLICY, AND IS SUCH INFORMATION AVAILABLE?
- CAN INFORMATION INCENTIVES ACHIEVE POLICY GOALS WHERE EXTERNAL DISECONOMIES EXIST?

TABLE 2-6. CRITICAL ISSUES IN INDUCING AUTO INDUSTRY INNOVATION (CONTINUED)

E) <u>INFORMATION INCENTIVES (CONTINUED)</u>

- WHAT HAS BEEN THE EXPERIENCE WITH PAST CONSUMER INFORMATION PROGRAMS?
- TIMING?

F) <u>INTEGRATED INCENTIVES POLICIES</u>

- HOW SHOULD REGULATORY, R&D ECONOMIC AND INFORMATIONAL INITIATIVES BE COMBINED FOR MAXIMUM EFFECT?
- ARE TECHNOLOGY CREATION OR MARKET PULL ACTIONS MORE IMPORTANT FOR INDUCING INNOVATION?
- SHOULD WE CONTINUE TO ESTABLISH INDEPENDENT GOALS FOR VEHICLE FUEL ECONOMY, SAFETY AND EMISSIONS? WOULD IT BE MORE EFFECTIVE IF A COMBINED PERFORMANCE MEASURE WERE USED, WHICH SPECIFIED MINIMUM PERFORMANCE REQUIREMENTS AND ALLOWED TRADEOFFS (E.G., SUPERIOR FUEL ECONOMY WITH SOME EMISSIONS DEGRADATIONS) AMONG THE ATTRIBUTES OF INTEREST?
- SHOULD ANTI-TRUST PRESSURES AGAINST JOINT AUTO INDUSTRY RESEARCH UNDERTAKINGS BE RELAXED?
- TIMING?

Charles Schultze argue:

- Determination of regulatory standards is too complex, resulting in erroneous decisions.
- The process of monitoring compliance overtaxes the capabilities of a central administrative agency.
- There is a growing body of evidence that regulatory actions are not achieving their objectives, and are frequently counter-productive.
- The rash of regulatory mechanisms established in recent years - for pollution control, energy conservation, industrial health and safety, consumer product quality and safety - have generated a backlash of resentment against excessive red tape and bureaucratic control (100,000 Federal employees are currently engaged in regulatory activities).
- Federal regulatory activities, and their compliance requirements, drain vital human and capital resources which could otherwise be employed to improve productivity.
- Standards are often based on political and social factors, which ignore economic parameters and place both the consumer and producer in a difficult position.
- Standards create strong incentives for the regulated entities to delay progress via the legal system.
- Standards do not generate adequate incentives for innovation since there are great penalties for failure to meet the standards, even by a small amount, and no incentives to exceed the standards.

In contrast with the above drawbacks, proponents of economic incentives argue:

- The prospect of profit is the major force which drives innovation.

- Reliance on market forces eliminates the need for a cumbersome, and expensive, regulatory mechanism.

- The burden for making tradeoffs between competing private and social utilities is shifted onto those with the best information on costs and utilities, manufacturers and their customers.

In contrast with the rosy picture painted above on behalf of market forces, advocates of regulatory action emphasize instances where the market system does not perform effectively.[3]

Flaws in the economic incentive approach include:

- The difficulty in real world situations of deriving the "shadow" prices associated with externalities

- Uncertainty over implementation rates and ultimate progress

- Impact on income distribution; the required taxes on externalities are often regressive and hence not politically feasible. Attempts at circumventing this problem by establishing income distribution mechanisms lead to the same bureaucratic problems associated with traditional regulatory support mechanisms.

- The legal background of a majority of Congressmen makes them more comfortable with regulatory actions than with tax strategies.

2.3.2 Critical Issue -- What Role Should Federal R&D Play in Bringing about the Development of Socially Efficient Technology?

The literature on the proper role of the Federal Government in the area of R&D is extensive and diverse. It is best summarized by the classic comment of Hamilton Hermann while testifying before Congress:

---

[3] Lerman, F., "Standards Versus Taxes: The Political Choice", in Heywood, J.B., Jacoby, H.D., and Linden L.G., Regulating the Automobile, M.P.T. Energy Laboratory Report 77-007.

"In the R&D game, everybody can have his own opinion" [Ref. 1, pg. 96].

Although general agreement about the proper role of Federal R&D is easy to come by, the specifics of each major Federal R&D effort raise a host of technical, economic and political questions. Consider for example the question of "appropriateness of Federal involvement." Under the Federal Non-nuclear Energy Research and Development Act of 1974[2] the following criteria are proposed:

A) *"The urgency of public need for the potential results of research, development or demonstration effort is high, and it is unlikely that similar results would be achieved in a timely manner in the absence of Federal assistance.*

B) *"The potential opportunities for non-Federal interests to recapture the investment in the undertaking through the normal commercial utilization of proprietary knowledge appear inadequate to encourage timely results.*

C) *"The extent of the problems treated and the objectives sought by the undertaking are national or widespread in their significance.*

D) *"There are limited opportunities to induce non-Federal support of the undertaking through regulatory actions, end-use controls, tax and price incentives, public education, or other alternatives to direct Federal financial assistance.*

E) *"The degree of risk of loss of investment inherent in the research is high, and the availability of risk capital to tne non-Federal entities which might otherwise engage in the field of the research is inadequate for the timely development of the technology.*

F) *"The magnitude of the investment appears to exceed the financial capabilities of potential non-Federal participants in the research to support effective efforts."*[3]

In practice, application of the above criteria involves considerable research, and because of its inherently subjective nature raises additional concerns. While the criteria can guide assessment of proposed Federal R&D oriented toward advancing the state-of-the-art, much Government funded research has a more immediate objective, e.g., regulatory support, information dissemination, etc.[4] Other Federal R&D objectives range from general promotion of national economic prosperity or international competitiveness to demonstration programs aimed soley at meeting "high policy" goals (e.g. the Nuclear Ship Savannah, Supersonic Transport).[5,6,7]

The feasibility and desirability of proposed Federal R&D in the automotive sector hinges on a number of major concerns about which there is no consensus at present. These include:

- Should Federal R&D go beyond the basic research phase to prototype or even 'production prototype' development? The "big-4, and others, say "no".[8,9,10,11 and 12]
- Is it true that the auto industry is a leader when it comes to private R&D expenditures?[13] If so, why should Federal R&D go to a rich competitive industry while other industries (e.g. steel) flounder in obsolesence?
- Must Federal R&D rely essentially on the big three or can it successfully incorporate the efforts of suppliers, foreign auto firms, or non-automotive laboratories and firms?[15,16]
- Is there sufficient automotive R&D talent to productively absorb a substantial Federal R&D effort?
- How should any fruits of Federal R&D be shared? Should the government own the patents or will mandatory licensing agreements with government contractors suffice?[18]
- Will Federal R&D help small automotive firms or allow new entrants to the automotive industry?[19]

- Can the U.S. auto industry really compete with foreign state owned auto firms (e.g., Volkswagen, British Leyland, Renault) without substantial Federal R&D in basic research?
- Should Federal R&D in the auto industry be accompanied by a relaxation of anti-trust pressures against joint auto industry research undertakings?[21]
- What leverage can Federal R&D have on private auto industry R&D?[22]
- Should Federal R&D be focused on component development or on integrated vehicle development?[23]
- What type of Federal R&D is most appropriate to meeting regulatory requirements? Are the MIT Energy Lab conclusions valid (see Table 2-7) or do they reflect an industry rather than a 'public interest' perspective?

The contentious questions raised above are suggestive of the complexity and breadth of this subject. However, in addressing the topic some guidance is provided by three generally agreed upon axioms: 1) The absence of a private R&D effort in a particular area does not <u>by itself</u> indicate that Federal R&D is appropriate, 2) The reasons for the difference between private R&D and needed "socially efficient" technology should be studied closely, 3) Federal R&D should support rather than supplant, a Federal effort to remove institutional barriers, and provide incentives that will maximize private R&D directed at achieving "socially efficient" automotive technology.

TALBE 2-7. APPROPRIATE DIRECTIONS FOR FEDERAL R&D EFFORTS*

	OBJECTIVES			
Types of Research	Advance State-of-Art	Support Procurement	Data for Policy Regulation and Public Info.	"Leverage" on Private Efforts
Basic Research	Appropriate		Not usually relevant	Not relevant
Technology Development	May be appropriate when problems or options are not being explored.		Appropriate when information not available or credibility questioned.	
Advanced Development		All these types of research are appropriate to support procurement		Limited impact on industry R&D programs
Engineering Development	High cost, questionable		Unlikely to be appropriate	
Product Improvement	Not Appropriate		Not Appropriate	
Assessments and Impact Studies	Not usually relevant		Appropriate	
Performance and Emission Testing	Supports technology development		Appropriate	

*SOURCE: Heywood, J., et al., The Role for Federal R&D On Alternative Automotive Power Systems, (MIT Energy Laboratory, 1974), Report No. MIT-EL-74-013), p. 57.

REFERENCES

1. U.S. Congress, House. Subcommittee On Domestic and International Scientific Planning and Analysis of the Committee on Science Technology, Selected Readings On Research and Development Expenditures and the National Economy, 94th Cong., 2nd session, 1976, Serial 2.

2. Public Law 93-577, Section 7, as quoted in ERDA, A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices For The Future, Volume 1: The Plan, p. 17.

3. Ibid.

4. Heywood, John, et al., The Role for Federal R&D On Alternative Automotive Power Systems, (Massachusetts Institute of Technology Report No. MIT-EL-74-013), p. 42-48.

5. "The Silent Crisis In R&D", Business Week, March 8, 1976, p. 90.

6. Haggerty, Patrick E., "Science and National Policy," Science, June 28, 1974, Vol. 184, p. 1348.

7. Pavitt, Keith "Technology, International Competition, and Economic Growth: Some Lessons and Perspectives," World Politics, January 1973.

8. U.S. Congress, op. cit., Chrysler Corporation response, p. 139.

9. U.S. Congress, op. cit., Ford Motor Company response, p. 150.

10. U.S. Congress, op. cit., General Motors Corporation statement, p. 163.

11. U.S. Congress, op. cit., American Motors Corporation response, p. 137.

12. U.S. Congress, op. cit., Assistant Secretary of Transportation, Hamilton Hermann, written response, p. 99.

REFERENCES (CONTINUED)

13. U.S. Congress, op. cit., Rep. Goldwater quoting "The National Science Foundation Study," p. 60.
14. U.S. Congress, op. cit., Ford Motor Co. response, p. 50.
15. U.S. Congress, op. cit.,
16. U.S. Congress, op. cit., p. 56.
17. "Why Science Can't Save Us - A Conversation with Dr. William O. Baker, President Bell Telephone Laboratories", Forbes, February 16, 1974, (Vol. 13), p. 68.
18. U.S. Congress, op. cit., Ford Motor Co. response, p. 158
19. U.S. Congress, op. cit., p. 89.
20. U.S. Congress, op. cit., p. 56.
21. U.S. Congress, op. cit., p. 98.
22. Heywood, John, op. cit., p. 59.
23. U.S. Congress, op. cit., p. 23.
24. Heywood, John, op. cit., p. 34-60.

3. THE INNOVATION PROCESS WITHIN THE AMERICAN AUTOMOBILE INDUSTRY

3.1 INTRODUCTION

In July 1977 Joan Claybrook, new head of NHTSA, speaking at the Automotive News World Conference criticized the automobile industry for what she called "its snail pace of innovation".[1] One of the noteworthy aspects of this remark was not its occurrence, for government and industry sources often do not see eye to eye, but the fact that it represents the views of a large segment of the American population. In these days of increased awareness of fuel economy, safety and emissions issues, the American automobile industry is often pictured as unable or unwilling to manufacture a "more socially desirable" vehicle. The gamut of opinions range from those of some private consumers, who insist that Detroit limits their options by emphasizing style at the expense of technological innovation, to those of consumer advocate Ralph Nader who believes that:

> "There is no technological reason why new cars cannot get 25 miles per gallon. There are only political and anti-competitive reasons...When you see a four door 1974 GM model getting 9, 11, 12 miles per gallon, the explanation basically is that fuel efficiency as far as the automobile manufacturers in this country are concerned, it is at the lowest run of priority, apart from safety, and that basically they are not interested in fuel efficiency. They are interested in using the internal combustion engine as a multiple power source for trivial, phony, expensive adjuncts and options and power units to their already overly chrome-bedecked automobiles".[2]

Knowledgeable academicians that have analyzed the automobile industry, including Lawrence J. White and William Abernathy, also argue that the industry has changed its character from its early

---

[1] Automotive News, July 18, 1977.

[2] Automotive Fuel Economy and Research and Development, Hearings before the Committee on Commerce, U.S. Senate, 94th Congress, First Session, March 12-13, 1975, p. 85-86.

days of high technological development to the present era where "innovation has given way to standardization as a competitive tool, product diversity has given way to the economies of scale, and external pressure on the industry has replaced entreprenurial action as the major stimulant of technological change".[3]

Some sources attribute this situation to the lack of competition between firms. Walter Adams, economic professor and past president of Michigan State University summed up this viewpoint, stating:

> "In the automobile industry, at least since World War II, the public interest has not been protected by effective competition among the domestic producers. The industry is an oligopoly which is not competitive in structure, nor competitive in practice, nor competitive in performance. Price competition is non-existent, and such rivalry as does exist turns on trivial forms of product differentiation centering around style and model changes, accompanied by a cacophony of advertising.
>
> On the technology front, since World War II, American automobile manufacturers, particularly the Big Three, have a record of innovative lethargy and unprogressive sluggishness. They have lagged not led, in the battle to develop cleaner, safer, and more fuel-efficient cars. They have chosen to react to change, rather than to initiate it-- to adapt reluctantly to the two exogenous pressures over which they had only limited control, namely the government's insistence on minimum safety standards and emission control requirements, on the one hand, and foreign competition on the other hand.[4]

---

[3] William J. Abernathy, The Productivity Dilemma; A Roadblock to Innovation in the Automobile Industry, Harvard University Graduate School of Business, Boston, 1976, p. 2-2.; Similar views are expressed by Lawrence J. White in The Automobile Industry Since 1945, Harvard University Press, Cambridge, 1975.

[4] Public Hearings on Automotive Fuel Economy Standards 1981-1984, Transcripts of Proceedings, U.S. Department of Transportation, NHTSA, March 22, 1977, p. 66.

Others, such as the U.S. Department of Commerce, argue the low innovation rate is due to the "lack of management ability".

> "We find the major barrier is one of attitude and environment. It is a problem of education- not of antitrust, taxation or capital availability".[5]

Finally, some sources argue that the industry does not spend enough money on research and development, and what is spent is misdirected in terms of technolgoical needs. Quoting Joan Claybrook again:

> "If the auto industry even raised its research and development funding to 5 percent, the difference could be dramatic for safer and more economical cars. Instead it chooses to pour billions of dollars into redesigning and retooling for cosmetic changes in fenders, hood ornaments, fancy wheel covers, new headlight and tail-light treatments and sporty paint jobs."

Ms. Claybrook went on to criticize Detroit for spending only 3.6 percent of sales in the 1970-1974 period for research and development, compared with about 6 percent for IBM.[6]

While all of the above statements suggest that the automobile industry has consistently failed to pursue a highly innovative course of action, a definitive conclusion can not be reached since supporters of the auto industry can respond with an equally impressive array contradictory evidence.

For example, they can argue that R&D expenditures of the auto manufacturers are more than adequate. For the period 1976-1981, GM alone is reported to have budgeted some $6.5 billions for R&D. This sum exceeds the expenditures of any other U.S. firm and the R&D budgets of the entire oil or telephone industry.[7] On a

---

[5] U.S. Department of Commerce, Technological Innovation Environment and Management, Washington D.C., U.S. Government Printing Office, 1968, p. 16.

[6] Automotive News, July 18, 1977.

[7] Business Week, "How GM Manages its BIllion Dollar R&D Program, June 28, 1976, p. 54-8.

strict numercial comparison, the auto industry's R&D expenditures measure quite favorably with those of the chemical industry, an industry which is considered by many to be a very progressive entity.

Furthermore, any analysis of the industry's rate of innovation should take into account the fact that Detroit has managed through the years, to produce a dependable, comfortable, and affordable product. In doing so it has continuously improved the product while normally managing to keep annual price increases below the rate of inflation. As an example, in October 1977 the price index for new cars for 4.7% higher than a year earlier, while the overall consumer price index rose by 6.4%. (The actual dollar price increase was 5.3%, with 11.8% of the price change attributed by the Bureau of Labor Statistics to "product improvement".[8]). The historic pattern of new automobile consumer price indexes and other price comparisons (See Figs. 3-1 and 3-2) appear to indicate that the automobile manufacturers have an enviable record of innovation, a record seemingly skewed toward process innovation but nevertheless a worthy accomplishment.

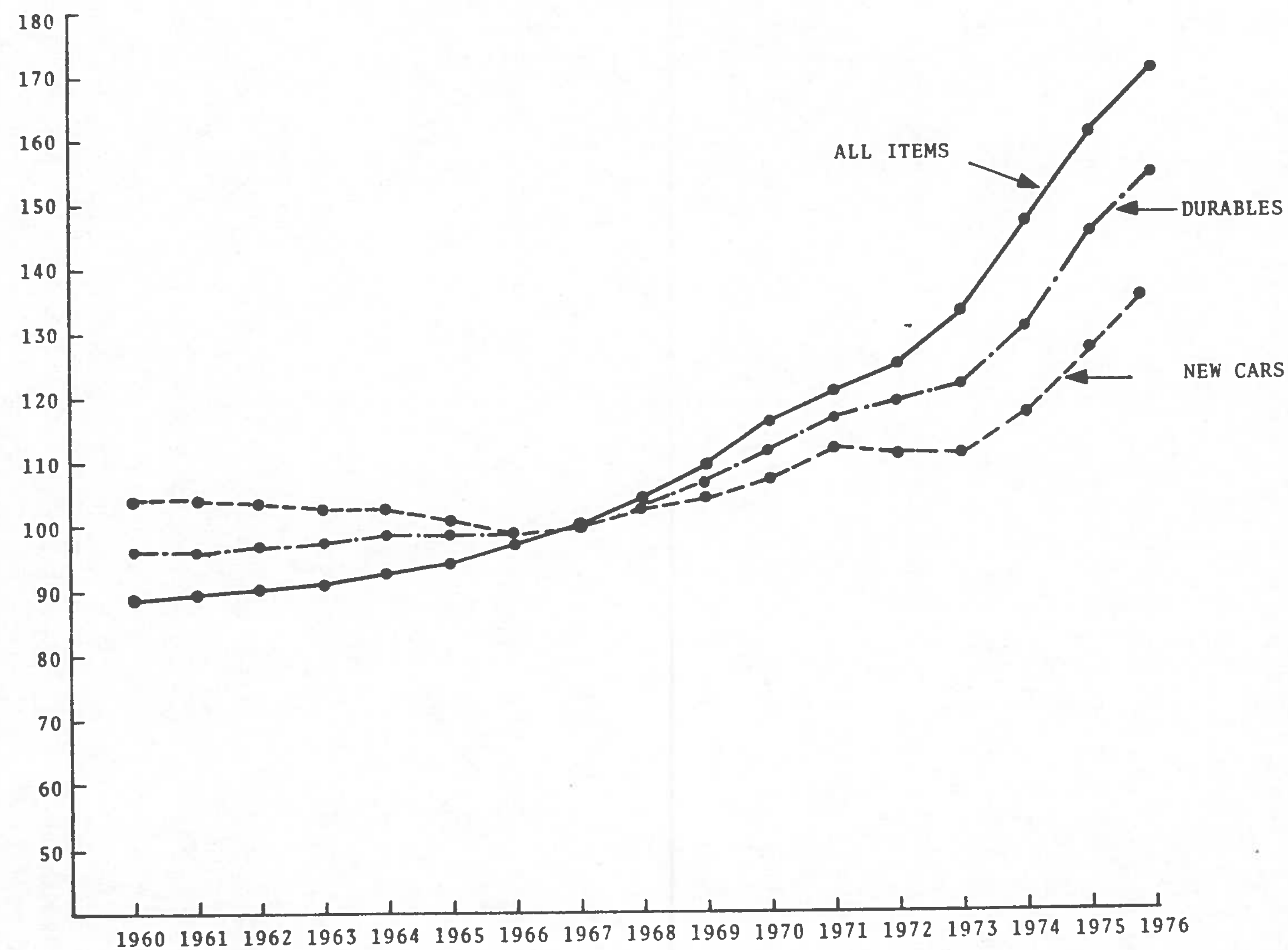
Finally, it could be argued that the complaints of some consumers represent the opinions of isolated interest groups and that, on an overall basis, the automobile manufacturers have produced vehicles according to the demands and needs of the majority of customers and that some of the governmental regulations imposed on them were not representative of market characteristics.

The controversy highlighted above suggests the critical need for more information on the innovation process within the domestic auto industry. Related issues include: How is innovation measured? what are the sources of new innovations? and Which are the key parameters of the innovation process? These questions are addressed in the following sections which are organized into two

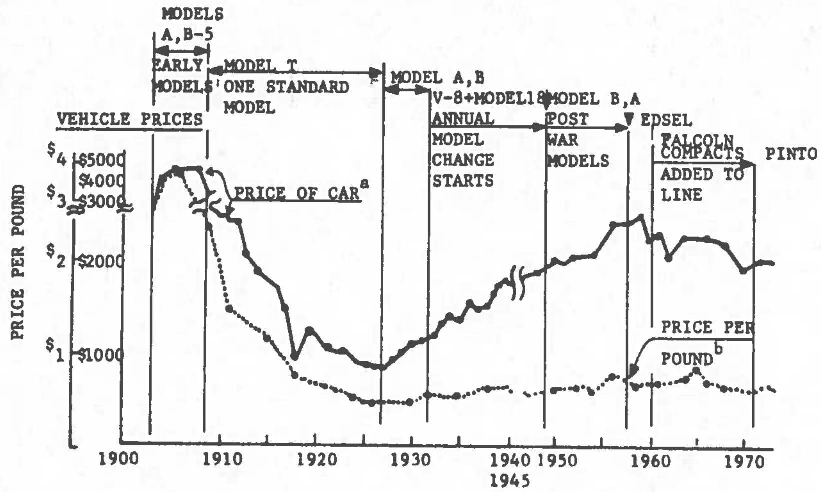
---

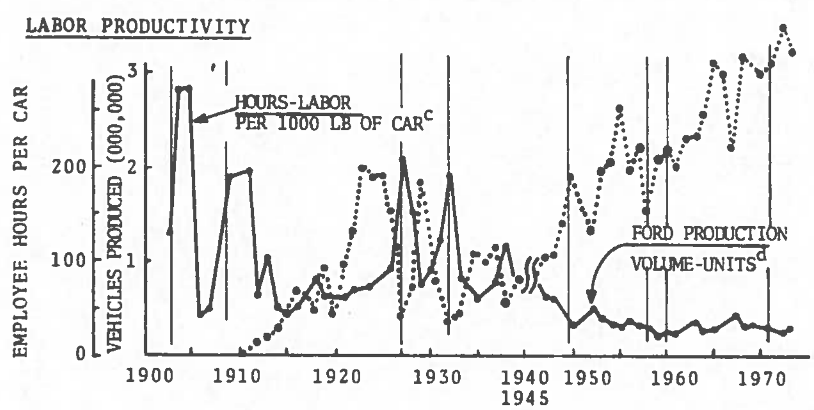
8 Bureau of Labor Statistics, Report on Quality Changes for 1987 Model Passenger Cars, U.S. Department of Labor, Washington, November 3, 1977.

CONSUMER PRICE INDEX (1967 = 100)



Operating Trends, Ford Motor Company
North American Operations





NOTES:
a - RETAIL PRICE FOR MEDIAN PRICED CAR IN 1958 DOLLARS
b - PRICE PER POUND OF CAR FOR CURVE (a)
c - FORD EMPLOYEE HOURS (Non salaried) PER 1000 LB OF VEHICLES PRODUCED
d - UNIT PRODUCTION VOLUMN FOR NORTH AMERICAN OPERATIONS-FORD

SOURCES: CORPORATE REPORTS; FORD ARCHIVES; AUTOMOTIVE INDUSTRIES STATISTICAL ISSUE, VARIOUS YEARS: AND U.S. BUREAU OF LABOR STATISTICS parts: (1) a description of the general factors affecting industrial innovation, and (2) the particulars of innovation in the automobile industry.

3.2 THE INNOVATION PROCESS

3.2.1 Introduction and Overview

The development of human civilization is often correlated to milestones of technological progress. Thus, the ages of man: stone, bronze, iron etc. Similarly, socio-political events are also attributed to the introduction of new technologies, i.e. the Fall of the Roman Empire is traced to the introduction by the invading "Barbarians" of the stirrup.

Later, the end of the middle ages is traced to the emergence of the "Renaissance Man", that individual who combined an appreciation of the softer sciences with a passion for scientific and technological progress. For centuries, his drive to learn and produce was synonymous with innovation. The lone inventor was responsible for Mankind's technological maturation.

Recently however, the role of the lone inventor appears to have been eclipsed by the activities of large industrial complexes backed by extensive research facilities.[9] One of the significant factors behind this change has been the increased complexity of the innovation process. According to some sources, the majority of current and projected innovations are beyond the technological and economic capabilities of isolated individuals and small entities.

In the words of John Kenneth Galbraith:

> A benign Providence..has made the modern industry of a few large firms an almost perfect instrument for inducing technical change... There is no more pleasant fiction than that technical change is the product of the matchless ingenuity of the small man forced by competition to employ his wits to better his neighbour. Unhappily, it is

---

9 Jewkes, J., Sawers, D., and Stillerman, R., The Sources of Invention, MacMillian & Co. Ltd. New York, (1960, pp. 29-31)

fiction. Technical development has long since become the preserve of the engineer. Most of the cheap and simple inventions have, to put it bluntly, been made.[10]

John Jewkes summarizes this modern view by stating that until the twentieth century

> ...most invention came from the individual inventor who had little or no scientific training, and who worked largely with simple equipment and by empirical methods and unsystematic hunches. The link between science and technology was slight. Manufacturing businesses did not concern themselves with research. In the twentieth century the characteristic features of the nineteenth are rapidly passing away. The individual inventor is becoming rare; men with the power of originating are largely absorbed into research institutions of one kind or another, where they must have expensive equipment for their work. Useful invention is to an ever-increasing degree issuing from the research laboratories of large firms which alone can afford to operate on an appropriate scale. There is increasingly close contact now between science and technology, both through the closer association of the workers in the two fields and because the border-line between the two formerly separate functions is becoming obliterated. The consequence is that invention has become more automatic, less the result of intuition or flashes of genius and more a matter of deliberate design. The growing power to invent, combined with the increased resources devoted to it, has produced a spurt of technical progress to which no obvious limit is to be seen.[11]

While this conclusion needs some qualifications, such as the following one by Dr. Vannewar Bush:

> In addition, there is the independent inventor, whose day is not past by any means, and who has a much wider scope of ideas and who often does produce out of thin air a striking new device or combination which is useful and which might be lost were it not for his keenness... New ideas are coming forward with as great

---

[10] Galbraith, J.K., American Capitalism: The Concept of Countervailing Power, Houghton Mifflin Co. Boston (1952), p. 91.

[11] Jewkes, Sources of Invention, p. 31-32.

> frequency today as they ever have, and while a great research laboratory is a very important factor in this country in advancing science and producing new industrial combinations, it cannot by any means fulfill the entire need. The independent, the small group, the individual who grasps a situation, by reason of his detachment is oftentimes an exceedingly important factor in bringing to a head things that might otherwise not appear for a long time.[12]

Any analysis of industrial innovative activity appears to require the placement of overriding emphasis on the attributes of large R&D entities.

Some of the factors that shape the industrial innovative process include

- o Size of Firm
- o Monopoly Power
- o Market Concentration
- o Ease of Entry
- o Character of the Industry
- o General Stock of Knowledge

These factors, in turn, are affected by additional parameters, some of which are not yet fully understood. For example, attempts have been made to correlate the size of the firm with innovative input (principally R&D employment) and output. Studies of firm size also attempt to analyze other innovation process characteristics such as the ambiance of research, and bureaucratic process, and the character of research. In the case of market characteristics knowledgeable sources point out that the type of market (i.e., oligopoly, monopoly, etc.), the competitive nature, general state of knowledge and transfer level of technology all combine to influence the rate of innovation. The parameters of innovation and their relative significance are examined in the next section.

[12] Ibid, p. 92.

3.2.2 Parameters of Innovation

3.2.2.1 Forces Inducing Innovation - A quick survey of the available literature on innovation indicates that despite the overwhelming number of interdependent, and sometimes redundant, factors judged to affect the process, the intrinsic force having the greatest impact on innovation is the potential for reward, be it economic returns, professional recognition, or psychological well-being.

In the case of industrial innovation, the overriding force is the potential for economic profit. As a consequence the rate of this process is in a sense determined by two major factors:

- Demand; either as an increase in demand for the product to which the advance was applicable, or a growing shortage of a commodity (due to rising costs or growing difficulty of procurement) which gives rise to an effort to minimize the effect of the shortage.
- Capability; proportional to the number of people possessing the knowledge needed to invent, the materials with which they work and the stock of knowledge they can apply.[13]

Paralleling these factors are a number of facets which determine the production function (defined as the type and amount of R&D needed to make a design idea operational). These facets include:

- Magnitude of the advances sought; as the magnitude of the projected advancement increases the required inputs increase disproportionately. The number of specialized components mount sharply and initial uncertainties about potential problems and their solution will also mount.
- Size and complexity of the unit; innovation within large and complex systems (products with numerous and interrelated components) creates additional difficulties

[13] Nelson, Richard R. Peck, Merton J., and Kalachek, Edward, D. Technology, Economic Growth and Public Policy, The Brookings Institution, Washington, 1967, p. 29-35.

because a change in one section will cause a chain reaction throughout the system.

- Stock of knowledge and components; the amount of required input effort depends on the background knowledge of the researcher and the tools at his disposal.[14]

Some of the barriers to innovation in the private sector include:

- Short-term interests vs. long-term potential; since the primary function of a firm is to make money, in periods of stress the firms must switch their resources from long-term possibilities to near-future interests.
- Effects of cost-accounting; the efficiency of firms has recently been improved through the system of close comparison between costs and returns for short periods of time and for smaller parts of the whole of the firms' activities. This cost-consciousness can have detrimental results for "long-term, inefficient operations."
- Ambiance of research; regardless of their faith in long-term returns, firms have a difficult time creating an atmosphere conducive to "pure" research, an atmosphere often found in university research laboratories.[15]

3.2.3 Particulars of the Industrial Innovative Process

3.2.3.1 Firm Size, Monopoly Power and Innovation - One of the most discussed aspects of industrial innovation is the relationship between firm size, monopoly power and innovative effort. The debate over size and monopoly power is extremely pertinent because it touches on some very sensitive issues which not only encompass the realm of innovation but extend well beyond it. In the United

[14] Ibid, p. 23-28.
[15] Jewkes, Sources of Invention, p. 140-1.

States, for example, considerable wide-spread (and powerful) sentiment exists against monopoly power, accompanied by a mistrust of large firms. This opinion is exemplified by Stigler when he argues that:

> There are two fundamental criticisms to be made of big business: they act monopolistically, and they encourage and justify bigness in labor and government.
>
> First, as to monopoly. When a small number of firms control most or all of the output of an industry, they can individually and collectively profit more by cooperation than by competition. This is fairly evident, since cooperatively they can do everything they can do individually, and other things (such as the charging of non-competitive prices) besides. These few companies, therefore, will usually cooperate.
>
> ...they do compete - but not enough, and not in all the socially desirable ways.
>
> Second, as to bigness in labor and government. Big companies have a large - I would say an utterly disproportionate - effect on public thinking. The great expansion of our labor unions has been due largely to favoring legislation and administration by the federal government. This policy of favoring unions rests fundamentally upon the popular belief that workers individually competing for jobs will be exploited by big-business employers - that U.S. Steel can in separate negotiation (a pretty picture!) overwhelm each of its hundreds of employees.
>
> Big business has also made substantial contributions to the growth of big government. The whole agricultural program has been justified as necessary to equalize agriculture's bargaining power with "industry", meaning big business. The federally sponsored milkshed cartels are defended as necessary to deal with the giant dairy companies.[16]

It is interesting to note that such sentiments are less apparent, or non-existent, in other countries (i.e., Japan and Western Europe) which have employed measures designed to consolidate and limit the number of competing firms within the industry.

---

[16] George J. Stigler, "The Case Against Big Business", in Mansfield, Edwin, Monopoly Power and Economic Performance, W. N. Norton and Co., Inc., N.Y., 1968, p. 5-7.

Studies dealing with the subject of size, monopoly power, and innovation tend to support and contradict the above conclusions. Galbraith, one of the stronger supporters of corporate size presents a number of contentions:

> Because development is costly, it follows that it can be carried on only by a firm that has the resources associated with considerable size. Moreover, unless a firm has a substantial share of the market it has no strong incentive to undertake a large expenditure on development. There are, in practice, very few innovations which cannot be imitated - where secrecy or patent protection accords a considerable advantage to the pioneer. Accordingly the competitor of the competitive model must expect that his innovation will be promptly copied or imitated. Whether it be a new product or a new way of reducing the costs of producing an old one, the change will be dispersed over a market in which he has only an infinitely small share. The imitators, who haven't stood the cost of development, profit along with the pioneer. And presently prices will adjust themselves to remove entirely the advantage of the innovator. He is thus restored to a plane of equality with his imitators. Thus the very mechanism which assures the quick spread of any known technology in the purely competitive market - and which was a strong recommendation of that market - eliminates the incentive to technical development itself. It leaves to the pioneer, apart from the rare case of effective patent protection, only the fleeting rewards of a head start. Where the costs of development are considerable, there is no reason to suppose that the returns to the pioneer will be sufficient to compensate for the cost. On the contrary, as the costs of development increase - and with time and progress toward more sophisticated innovation they must increase - there is a diminishing likelihood that they will be recovered. The higher the level of science and technology required for change, the more nearly static an industry which conforms to the competitive model will become.
>
> In the industry that is shared by a relatively small number of large firms, the convention that excludes price competition does not restrain technical innovation. This remains one of the important weapons of market rivalry. The firms, typically, are large. Hence resources are available on a scale appropriate to the modern requirements of technical development. Some of them in fact are the fruits of market power - of monopoly gains. And, while imitation must be assumed and expected, the convention which limits price competition also insures that the reutrns, whether to a new product or from

cost-reducing innovation, will accrue to the innovator as well as to its rivals for a period of time. The presence of market power makes the latter time period subject to some measure of control.

Thus, in the modern industry shared by a few large firms, size, and the rewards accruing to market power combine to insure that resources for research and technical development will be available. The power that enables the firm to have some influence on prices insures that the resulting gains will not be passed on to the public imitators (who have stood none of the costs of development) before the outlay for development can be recouped. In this way market power protects the incentive to technical development.

The net of all this is that there must be some element of monopoly in an industry if it is to be progressive.

Galbraith acknowledges the possible existence of aberrations but limits their importance:

> To be sure, some room must be left for exceptions. One can imagine that the convention against price competition could be extended, in the industries of small numbers, to innovation. And, as in the well-publicized instances of patent suppression, that has undoubtedly happened. But to maintain a convention against innovation requires a remarkably comprehensive form of collusion. This is difficult as well as legally dangerous. While it would be going too far to say that oligopoly insures progress, technical development is all but certain to be one of the instruments of commercial rivalry when the number of firms is small.[17]

Additional arguments on the positive attributes of size are advanced by Schumpeter, the actual originator of these ideas, who envisioned the capitalist system as a "process of creative destruction" where regeneration and growth are achieved through replacement of existing products, processes and organizations by improved ones. The propelling force of this process is innovation. A force that requires considerable commitment of resources and this demands considerable returns, i.e., temporary monopoly power in order to be desirable.[18]

---

[17] John Kenneth Galbraith, "The Economics of Technical Development", in Mansfield Monopoly Power, p. 38-40.

[18] Schumpeter, J. A., Capitalism, Socialism and Democracy, 3rd editions, Harper and Row, New York, 1950.

G. W. Nutter states that "just as the prospect of monopolistic position raises the odds in favor of the most risky innovation, so bigness makes possible the most expensive".[19]

Finally, large firms can insure against the uncertainties associated with innovation by undertaking a broad range of projects and by having the possibility of a broad range of applications.[20]

The arguments in favor of monopoly and size have drawn a certain amount of criticism from several studies which contend that size is not always directly proportional to the rate of innovation. These studies, based on comparisons between size and innovative output and input, attempt to disprove any direct correlation of these factors, especially beyond a certain size.

Size and Innovative input; in an attempt to calibrate the relationship between a firm's size and its innovation effort several studies have focused on the employment of R&D personnel. Scherer found out that the relationship between firm size and R&D employment has an inflection point, with R&D employment rising faster than firm size among smaller firms but more slowly among larger firms. Scherer also implied that the largest firms have proportionately fewer R&D employees than small firms (see Fig. 3-3). It must be noted however, that the chemical indusry and the leaders of the auto and steel industry might be exceptions to this rule.[21]

A study by Philips arrived at similar conclusions, i.e., pointing out that the total number of research employees in Belgian firms grows faster than total employment up to about 7,000 employees, and at a decreasing rate thereafter, achieving a peak intensity at 10,000 employees.[22] Mansfield has observed that in general the

---

19 Nutter, G. W., "Monopoly, Bigness and Progress", Journal of Political Economy, Vol. 64, 1956, p. 524.

20 Nelson, R. R., "The Simple Economics of Basic Scientific Research", Journal of Political Economy, June 1959, vol. 67 no. 3

21 Scherer, F. M., "Market Structure and the Employment of Scientists and Engineers", American Economic Review, vol. 57 no. 3, June 1967, pp. 524-31.

22 Philips, L., "Research", in Effects in Industrial Concentration: A Cross Section Analysis of the Common Market, North-Holland Publishing Co., Amsterdam, 1971-72.

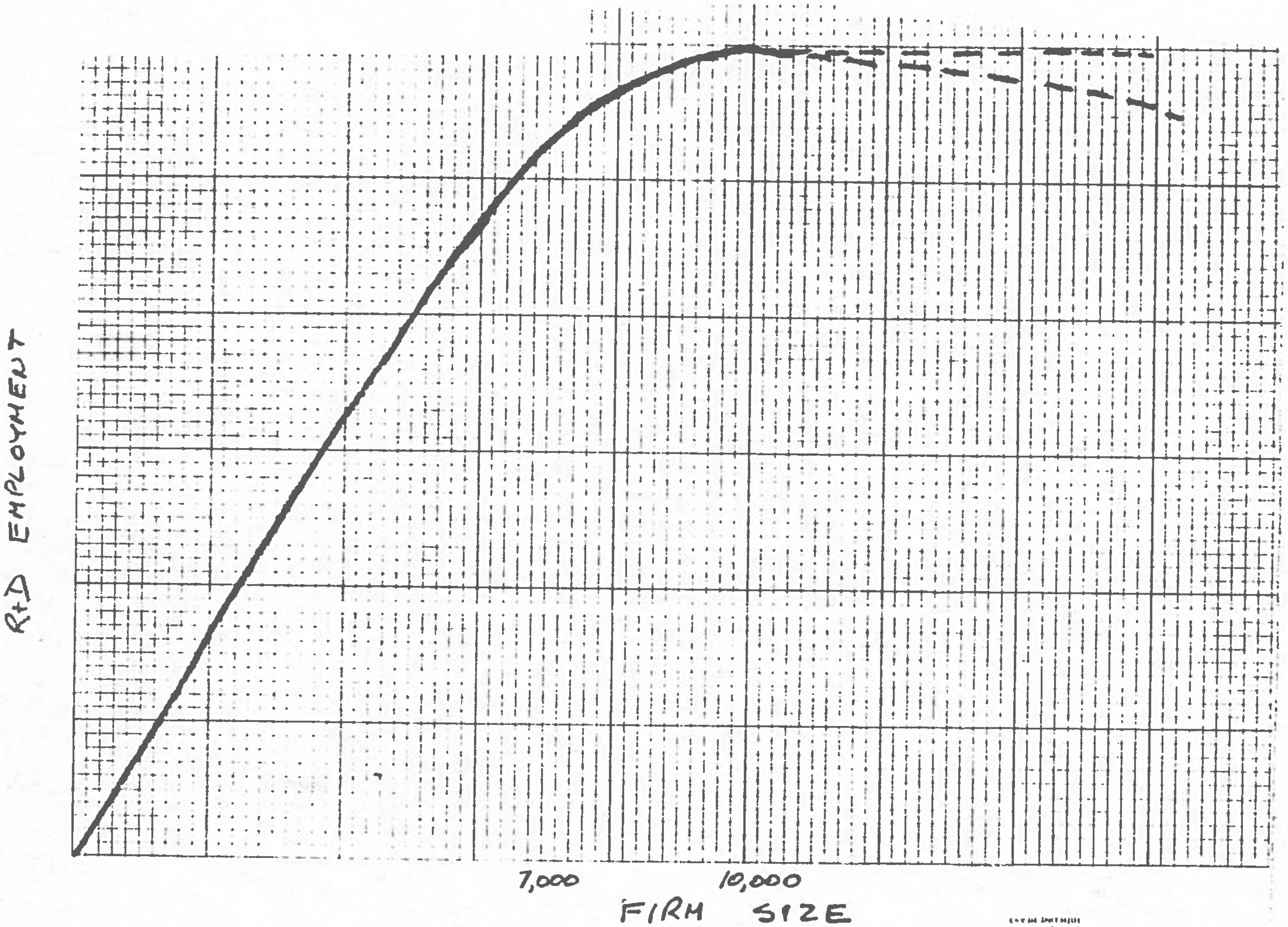


FIGURE 3-3. THEORETICAL CURVE; R&D EMPLOYMENT VS. FIRM SIZE

largest firms spend no more on R&D relative to sales than the somewhat smaller ones.[23] Basing their opinions on the findings of these and other studies, Kamien and Schwartz conclude that:

> "Thus, it seems that with the possible exception of the chemical industry, there is hardly any support for the hypothesis that the intensity of the innovational effort increases with firm size...innovational effort tends to increase more than proportionately with firm size up to some point that varies from industry to industry. For still larger firms, innovational intensity appears to be constant or decreasing with size."[24]

Along with their conclusions, Kamien and Schwartz point out three significant contributing factors worth noting. First, different industries have different innovation patterns. Second, factors other than R&D employment affect the innovation effort. Third, the literature mainly reflects sustained R&D efforts, typical of that undertaken by the majority of large firms, so that small firms with sporadic research programs are under-represented.

Size and Innovative Output; comparisons based on innovative output are somewhat trickier than R&D employment analyses due to the problems of identifying "output". Studies based on patent incidence have not yet provided definitive answers. As summarized by Kamien and Schwartz, different industries and different countries have had diverging experiences. In the U.S. studies done by Mansfield show that

> The largest four firms in the coal and petroleum industries were found to be responsible for a larger share of their respective industry's innovations than of its productive capacity, but the largest four steel producers were responsible for fewer. In a later

---

[23] Mansfield, E., The Economics of Technological Change, Norton, N.Y., 1971.

[24] Kamien, Morton I., and Schwartz, Nancy, L., "Market Structure and Innovation: A Survey", Journal of Economic Literature, March 1975.

study, he found the market share of the four largest pharmaceutical firms exceeded their share of the industry's innovations [55, 1971].

Mansfield used these data to estimate the firm size at which innovational intensity is greatest. While the regressions fit the data only moderately well, the results varied considerably among industries. Maximum innovational output intensity occurred at about the size of the sixth largest firm in the petroleum and coal industries. In the steel industry, however, very small firms exhibited maximum intensity. For pharmaceutical advances over 1935-1949, the maximum corresponded to the size of the tenth largest firm. Peak intensity of weighted pharmaceutical innovations over 1950-1962 was found at about the twelfth largest firm; for unweighted innovations, it occurred at the size of very small firms.[25]

A British study of the chemical, electronics and machine tool industry indicates that:

> The number of patents awarded increased more than proportionately with the chemical industry and, for all but the largest firms, within the electrical engineering and electronics industry. In contrast, patenting decreased with firm size in the machine tool industry.

Another British study argues that:

> ...small firms (under 200 employees) acounted for about 10 percent of industrial innovations since 1945, compared with about 25 percent of employment and 21 percent of net output. The rank ordering of industries by the share of small firms in industry innovations corresponded fairly well with the ordering by share of small firms in net output. Small firms contributed more than their proportionate share of innovations in industries characterized by low entry costs and low capital intensity and development costs for many products; they contributed little, either absolutely or relatively, to innovations in industries of high capital intensity.

Finally a Swedish survey shows that

> Excepting the four largest firms, large firms' share of total patent applications in 1965-66 (inventive output) was consistently less than their share of employees in 1966 (firm size). Patent applications

increased faster than firm size among members of the chemical industry, but less than proportionately with firm size in engineering and metal manufacturers.[25]

The comparisons between innovational input/output and firm size are quite important, but several factors must be re-emphasized. First, there is a definite advantage to size; the threshold of innovation vs. size occurs at levels representative of comparatively large firms. Furthermore, as Mansfield et al. point out, the comparison between the size of the firm and the percentage of R&D ignores the fact that the larger firms might be engaged in a different kind of research than the small firms; i.e., basic, risky, and long term.[26] Another difference between the type of research undertaken by large and small firms is that large firms have tended to contribute most to innovation in areas requiring large scale R&D, production, or marketing. In contrast, smaller firms tend to concentrate on specialized but sophisticated components and equipment.[27]

Finally, the innovative performance of large organizations reflects such factors as internal characteristics and the firm's position in regard to the other components of the industry. Cooper argues that although larger firms are better suited, in terms of resources, to conduct R&D research their interests are not necessarily oriented towards innovation. In many oligopolies the emphasis is placed on increased productivity, based in improvements of the existing system, rather than on radical product innovation. Larger firms often become enmeshed in bureaucratic red tape, resulting in a less hospitable atmosphere for creative

---

[25] Kamien and Schwartz, "Market Structure", p. 18-19.

[26] Mansfield, E., Rapoport, J., Schnee, J., Wagner S., Hamburger, M., Research and Innovation in the Modern Corporation W.W. Norton and Company, Inc., New York, 1972.

[27] Pavitt K., and Wald, S., "The Conditions for Success in Technological Innovation", OECD Report, Paris, 1971.

development. The larger the firm the further removed the decision makers are from the problems needing solutions. Furthermore, the smaller the firm the greater the cost consciousness.[28] Blair attributes the reluctance of some large firms to innovate to 1) a desire to protect an investment in current technology, 2) satisfaction with the status quo, 3) underestimation of potential demand for a new item, 4) neglect of the inventor and 5) misdirection of research plus an incompatibility of bureaucracy and creativity.[29]

Jewkes contends that "Larger, well established firms might understandably hold back and allow others to take the risks ('pioneering don't pay' as a great industrialist once put it); they are strategically well placed in the sense that their size and strength enable them to acquire inventions and develop them rapidly when their potentiality has been thoroughly established.[30]

Maclaurin suggests that while some degree of monopoly and firm size is necessary for innovation, it is not sufficient. Ease of entry, entrepreneurial leadership, "a competitive spirit", and the state of underlying art of scientific base are just as vital.[31]

3.2.3.2 Market Structure

Market Type; A factor closely related to the size of individual firms is the nature of the industrial organization, i.e., monopoly, oligopoly etc. As we have pointed out earlier, a very strong sentiment exists against entities composed of one or a few large firms. Dealing exclusively with the innovative practices of

---

[28] Cooper, A.C., "R&D is More Efficient in Small Companies", Harvard Business Review, May/June 1964.

[29] Balir, J.M., Economic Concentration: Structure, Behavior, and Public Policy, Harcourt, Brace, Jovanovich, New York, 1972.

[30] Jewkes, The Sources of Innovation, p. 131.

[31] Maclaurin, W.R., "Technological Progress in Some American Industries", American Economic Review, May 1954, vol. 44, no. 2, pp. 178-89.

such markets, critics argue that competition, one of the driving forces of innovation, is greatly restricted through a variety of circumstances.

Galbraith challenges these contentions by arguing that:

> Thus there can be little doubt that oligopoly, both in theory and in fact, is strongly oriented toward challenge. There can be no serious doubt at all that the setting for innovation, which is so favorable in this market structure, disappears almost entirely as one approaches the competition of the competitive model.[32]

Taking a somewhat middle of the road approach, Nelson suggests that the optimal answer is a combination of sizes:

> These considerations and evidence suggest quite a different conclusion than the one equating large firms and and technological advances. No single size firm is an optimum for conceiving and introducing all inventions of an industry. Rather, the optimum is a size distribution composed of small, medium, and large firms varying from industry to industry and from time to time. The optimum must further include a rate of turnover among firms sufficient to accommodate enough new firms to prevent excessive tradionalism.[33]

A survey of the literature on this subject reveals a gamut of highly opinionated position and, considering the importance and sensitivity of the issue, precludes the analyst from reaching a categorical conclusion. For the time being, the ideal course of action is to refrain from generalization and analyze individual cases on their own merit.

Ease of Entry; Ease of entry is often singled out as one of the more important factors of the innovation process and, according to Comanor, when entry barriers are either too low or too high the incentives for innovation are substantially less than at some

---

[32] Galbraith, "Economics of Technological Development", p. 40-41.

[33] Nelson, Richard; Peck, Norton; and Kalachek, Edward, "The Concentration of Research and Development in Large Firms", in Mansfield's Monopoly Power, p. 50.

intermediate level. Innovative effort appears strongest in industries with some entry barriers which provide barriers to rapid imitation, and is also enhanced when entry has not been effectively foreclosed.[34]

3.2.3.3 Other Factors

o Overall technological progress: One of the factors that has a marked effect on the rate of innovation of a particular firm is the performance of related industries, changes in other industrial sectors, and the general state of scientific progress. Thus, innovation in one industry can benefit considerably from the flow of new materials, components and machinery from supplier industries. A firm whose suppliers experience rapid innovation can achieve a high level of development of its own products and processes with a limited investment. Similarly, the performance of products in one industry is influenced both by the R&D efforts of other industries and by the general development of the scientific process (e.g., as results from Federal R&D expenditures). Finally, high innovation rates and extensive R&D programs occur when there is related but exogenous scientific progress. If scientific achievement slows or moves in directions leading to fewer opportunities, technical progress in the market is reduced.[35]

o Character of the industry: According to Nelson et al, several intrinsic characteristics of an industry affect the emphasis put on technological growth. Two factors in particular are identified:

a. "Some industries are technically more advanced than others. "Science is their business". Such industries may be contrasted with others, perhaps in the

---

[34] Comanor, W.S., "Market Structure, Product Differentiation, and Industrial Research", Quarterly Journal of Economics, vol. 81, Nov. 1967, pp. 639-57.

[35] Phillips, A., "Patents, Potential Competition and Technical Progress", American Economic Review, Part II, Supplement, May 1966.

majority, where empirical methods are widely used and constitute the only path to success. Firms in technically advanced industries even if concerned with knowledge and not extending it, will employ considerable numbers of scientists and technicians and will possess laboratory facilities simply to operate their plants. Therefore, additional costs of expanded innovation might not be considerable."

b. "Some industries are advancing technically faster than others. Such industries have access to a stock of scientific knowledge still largely under-utilized and with fairly direct technical potential. They can be contrasted with other industries where, because the scientific knowledge available has already been thoroughly absorbed into practice, there appears to be very little chance of outstanding technical innovation."[36]

o History of the industry: In cases where the firm, or the entire industry has been established on the basis of technological innovation, it is more likely that the emphasis on innovation will be retained.

o Personnel element: The attitude of some firms regarding R&D often is directly related to the capabilities and interests of key personnel.

In summary it appears that the rate of technological growth in a particular firm or industry is subject to the effects of a large number of forces, many of which have been identified. These forces, independently or jointly, have a direct influence on the innovation function. However, their impact cannot be generalized, but must be evaluated individually for the particular industry of interest.

3.3 PARTICULARS OF THE INNOVATION FUNCTION WITHIN THE AUTO INDUSTRY

This section will examine in detail some of the auto industry characteristics previously identified as having a direct influence on the innovation function. Such an analysis is not intended to be exhaustive, but to set the stage for future work which would delve deeply into each industry characteristic.

---

[36] Nelson et al. Technology, Economic Growth, and Public Policy.

3.3.1 Historical Perspective

The early period of the automotive industry was characterized by intense competition among a large number of comparatively small firms with each dedicated to winning over the public to the idea of purchasing an automobile. Because of the infancy of the product, the major obstacle to its development was customer reticence to purchase a product which radically altered existing values. Thus, the main thrust of the manufacturer was production of merchandise which was clearly practical. The pioneer automobile manufacturers sought to influence the buyer by placing great emphasis on the rate of technological innovation. This effort was greatly facilitated by the state of the art which required comparatively little in the way of research. The innovative process consisted entirely of getting the idea, trying it out and then producing it. Typical innovations were the lightweight chassis, the electric starter, and the automatic transmission. Capital and technological requirements for such inventions were not prohibitive. What must be remembered however, is the fact that despite the ease of invention and product introduction the process of technological development was a very risky proposition. Firms based their existence on the capability to manufacture a technically advanced product and judging from the attrition rate of the early firms, things did not always work according to plan. Granted that one of the major reasons for the failure of many firms was the ease of duplication of the original innovation, the demise of so many manufacturers serves as a grim reminder that innovation does not automatically imply marketing success.[37]

The lessons of the past and the increasing complexity of technological innovation have combined to alter the pattern of the automobile industry. Some sources argue that the emphasis has shifted from the technologic to a more stylistic oriented approach whose premise is gradual innovation, improved productivity, and

---

[37] For an excellent account of the early days of the automobile industry see Chandler, A.D., Giant Enterprise: Ford, G.M. and the Automobile Industry, Harcourt, Brace & World Inc., N.Y., 1964.

the selling of the product on the basis of "attractiveness". According to Abernathy the automobile industry has changed from "...a pattern of radical product innovation to one of the evolutionary product innovation. This shift is related to the development of a dominant product design and is accompanied by heightened price competition and an increase in process innovation".[38]

At this point, it is important to realize that the diminishing rate of product innovation and the added emphasis on process innovation is not necessarily a criticism of the auto industry's innovation record. First of all, process innovation is an integral part of technological innovation, and second of all the experience of the auto industry mirrors the typical pattern of historical product development. (See Figure 3-4.)

The major effect of the drive for increased productivity (increase in process innovation) has been highlighted by the cost of increased specialization of tools. Such a system is not only costly but also technically difficult to change, resulting in an emphasis on gradual innovation. The cost of change is also influenced by the high degree of integration, i.e., an alteration in one feature has ramifications in many others. Thus, "... innovation is incremental and has cumulative effects on cost and productivity".[39]

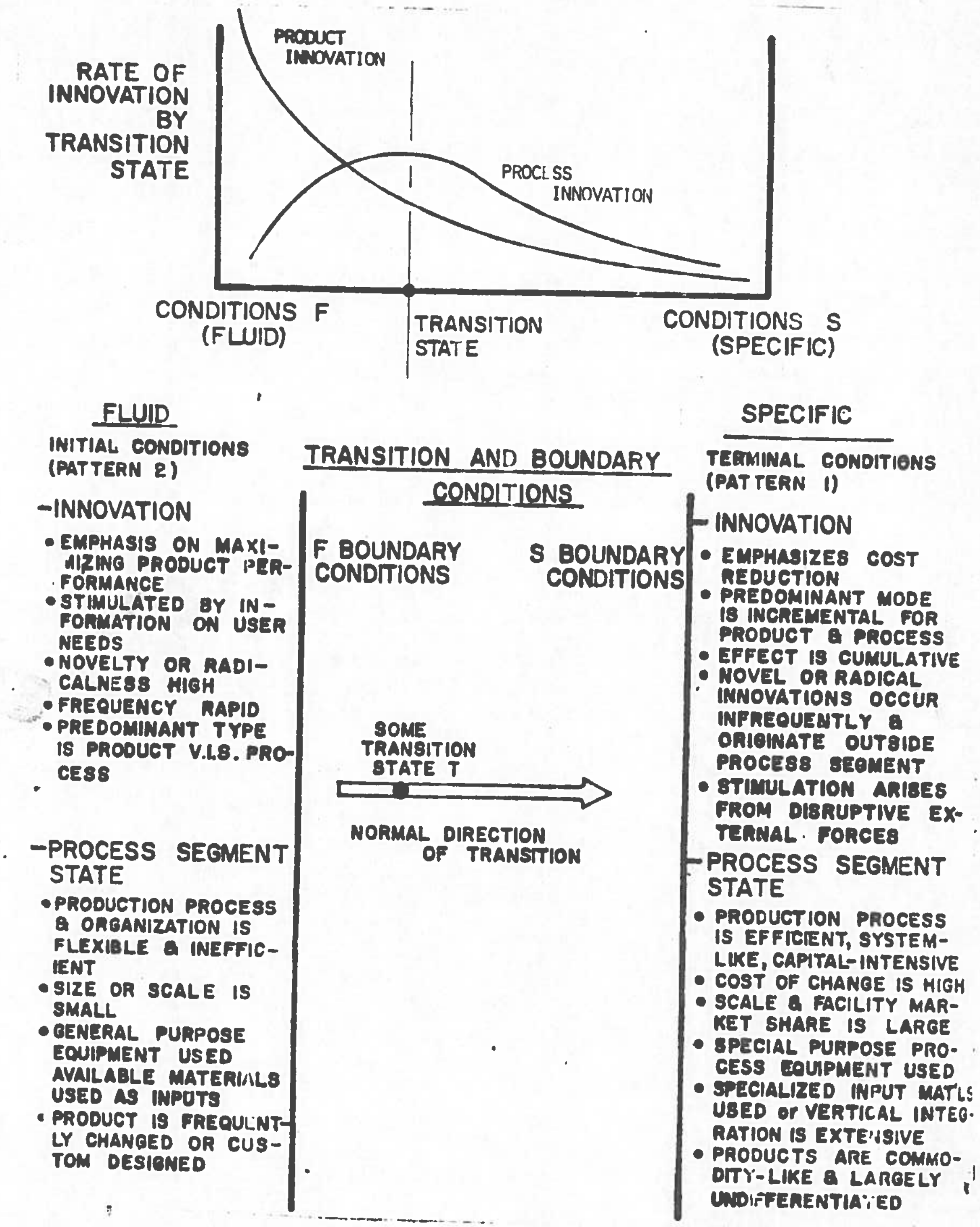
> Since the Model T, no one firm has achieved major production process advantage over others, for they all have evolved in a very similar way. In practice this means that no firm sustains a competitive advantage through product innovation. When all firms have the same process capabilities, than any one firm can replicate the product innovations of any other. Under these circumstances the incentive for significant product innovation is weakened.[40]

---

[38]Abernathy, W.J., <u>The Productivity Dilemma</u>, Harvard Univ. Graduate School of Business Administration, April 1976, p. 4-10.

[39]Ibid., p. 4-3.

[40]Ibid., p. 3-20.



Source: Ashford, Nicholas A., National Support for Science and Technology, CPA 75-12/S, Aug. 18, 1975, p. 1-18.

FIGURE 3-4. THEORETICAL INNOVATION CURVE

3.3.2 Key Elements of Industry Structure

3.3.2.1 Economies of Scale

The principal reason for extreme concentration in the automobile industry is the significant reduction of unit cost with high production volumes. Economies of scale have reduced the number of manufacturers from 12 in the early 1900's to four at the present time. Some sources estimate that full economies of scale could be reached at annual production rates of 250,000-400,000 vehicles.[37] Besides encouraging industry concentration, these economies of scale stimulate manufacturers to limit market segmentation since the emphasis is on producing a large number of components that can be used in a variety of models. This, in turn, creates a bias in favor of technological developments that can be integrated with conventional production facilities and utilize existing components.

3.3.2.2 Capital Requirements

The manufacturing facilities necessary for mass production impose enormous capital requirements on the automobile firms. The Big Four invest 3-4 billion dollars annually in new plants and facilities, with a majority of these expenditures financed internally.[41] In the 1960's it was estimated that a new entrant into the industry would need one billion dollars of venture capital to approximate the economies of scale of the existing firms. In today's market this figure would most likely be closer to two billion dollars. These substantial requirements not only effectively discourage the potential new entrant but also reduces the ability and willingness of existing firms to fund innovative new technology which substantially alters existing processes.

3.3.2.3 Demand Variations

Demand for new automobiles has exhibited marked variations over time. New car sales have averaged 8 to 10 million vehicles per year in recent years but, at the same time the fleet has grown

---

[41] Ibid.

by 2 to 3 million cars annually. This implies that the balance of the sales represents replacements for used vehicles. Therefore, most potential car buyers can postpone the purchase of a new vehicle in times of recession, rising prices, or perceived quality dissatisfaction. Variations on demand affect not only the potential new entrant, who must obtain additional working capital and allow for extra risk premiums, but also the established manufacturer who would obviously forego drastic product changes and opt for stylistic changes to attract replacement sales.

3.3.3 KEY INDUSTRY PRACTICES

3.3.3.1 The Role of Suppliers in the Automotive Innovation Process

In assessing the rate of innovation within the automobile industry knowledgeable sources often argue that one of the vital determinants of this process is the supplier industry. One such source, Lawrence J. White,[42] contends that the auto manufacturers rely heavily on their suppliers for innovative products. In doing so, the automobile companies are viewed, by some, as purposefully shifting onto the suppliers all the accompanying risks and the initial costs of development. In support of this theory White presents a list of recent technological developments attributed to various suppliers. (See Table 3-1.) The nature and extent of the innovations appears to argue favorably for the innovative force of the supplier industry.

Assuming that the available data supports the hypothesis that the manufacturers rely heavily on their suppliers for innovation, an analysis of the rate of innovation of the automobile industry must also consider the rate of innovation by the suppliers and the adoption rate of the manufacturers. These last two factors were the subject of a recent study, initiated by the Auto Technology Program, performed by A.H. Rubenstein and Associates and entitled

---

[42] Lawrence White, The Automobile Industry Since 1945, Harvard University Press, 1971.

TABLE 3-1. INNOVATIONS AND INNOVATORS

	PRODUCT	INNOVATOR
1.	Aluminum components, especially engines	Doehler-Jarvis Division, National Lead Co.
2.	Fiberglass bodies	Fiberglass plastics Manufacturers
3.	Acrylic laquers, enamels	Paint Manufacturers
4.	Tinted glass, laminated safety glass	Glass Manufacturers
5.	Power steering	Gemmer Manufacturing Co., Bendix
6.	Power brakes	Kelsey-Hayes, Bendix
7.	Disc brakes	Budd, Bendix
8.	Non-slip differentials	Dana Corporation
9.	Silicon rectifiers	Motorola
10.	Ball joint front suspension	Thompson Products
11.	Automatic speed control	Perfect Circle Co.
12.	Fuel injection system	American Bosch, Bendix
13.	Teflon products for front suspension joints	duPont, American Metal Products Co.
14.	Transistorized ignition	Motorola, Electric Auto-Lite[1].

Source: Lawrence J. White, The Automobile Industry Since 1945, Harvard University Press, Cambridge, 1971, p. 211-216.

Analysis of Federal Stimuli to Development of New Technology by Suppliers to Automobile Manufacturers: An Exploratory Study of Barriers and Facilitators. The study reached a number of significant conclusions:

a. Impetus and avenues for innovation --- The commitment of resources (time, money, energy, management attention, scarce skills) to the innovation process can be dictated by any of the two or more levels of supplier/customer relationships involved in a particular product or equipment line. In many instances innovation is forced upon suppliers by the manufacturers and second tier suppliers (i.e. the suppliers that interface with the manufacturers, purchasing equipment from other suppliers.) In other cases suppliers themselves press for innovation. Most often, the new product is marketed through the supplier-manufacturer-consumer chain, but in some cases the supplier might introduce the product through the after-market or replacement market. This is done for a number of reasons including: resistance or perceived lack of interest on the part of the manufacturer, chances of higher margin, protection of property interests, and maintenance of independence from the manufacturers.

b. Barriers to Innovation --- By conducting detailed interviews with a number of suppliers the study compiled a list of factors considered, by these suppliers, as the principal barriers to innovation. These are:

   1. Federal laws or regulations --- This factor, which was mentioned in over 1/2 of the responses, operated on several levels including: frequent changes in a regulation or procedure requirement, uncertainty of the future regulatory climate, vacillation of government's activity, establishment of very high (in some cases unatainable) standards, and inability to maintain the integrity of the vehicle. The last issue was considered quite important and deals with the

adoption of regulations which ignore the overall effects on a vehicle by failing to consider the interactions of various parts, and the adoption of contradictory standards.

2. Costs --- In addition to the readily apparent barriers created by development costs, suppliers singled out the costs of a continual product revisions in response to the interaction between suppliers manufacturers aimed at generating the most acceptable solution. This interplay includes making design changes., incorporating new materials, automating or otherwise improving the manufacturing process. In many cases the minimization of development costs can be achieved by introducing the new product as standard equipment or option in the premium line of cars and then, after large manufacturing efforts have been established and the learning curve has been improved the product can be introduced in all the lines.

3. Capability of achieving technical reliability --- The barrier in this instance is a combination of two factors: the technical requirements of developing a product, and impact of cost constraints on the resultant product. It was noted that in some cases the technical feasability of improvement was acknowledged but the associated costs were prohibitive.

4. Market considerations --- Closely related to the problem of costs, this factor consists of three categories: lack of marketing interest, problems encountered in entering a new market, and problems associated with consumer acceptance and demand.

5. Maintenance of vehicle integrity --- This factor was mentioned before under item 1 (federal laws and regulations) but its importance was considered such as to merit its inclusion as a separate factor.

6. Lack of consistent test procedures --- This factor, which in some cases contributes to the long development time, includes the need for non-destructive test procedures, consistent standards, and government awareness of the testing problems facing the industry.

7. Lack of top management support --- This is a common factor encountered in the innovation process.

8. Changes in the maufacturing process --- The development of new products often involves complete changes in the manufacturing process, changes which involve high costs and some technological problems. Even when complete alteration is not necessary, significant process changes must be enacted to minimize costs and alter capabilities.

9. Lack of federal interest or competence --- in many cases the suppliers felt that government regulators fail to recognize the role they played, and are somewhat ignorant of the characteristics of the supplier industry. As a result, the regulatory activity of the government is too often directed at the manufacturers, and is sometimes inappropriate for the suppliers.

The perceived impact of the barriers to innovation is shown in Table 3-2. The most frequently cited barriers are federal laws and regulations, costs, and technical reliability.

c. Facilitators of Innovation

1. Federal laws or regulations --- For obvious reasons, the adoption of new requirements produces a stimulus for change. It is interesting to note however, that suppliers expressed the opinion that very specific regulations, i.e., second tier suppliers, specifications, retard innovation by focussing development efforts on a particular component at the expense of alternative, and perhaps better, solutions to the problem.

TABLE 3-2. BARRIERS TO INNOVATION BY SUPPLIERS RANKED BY FREQUENCY OF CITATION

BARRIER	NUMBER OF CASELETTES (INNOVATIONS) IN WHICH BARRIER ACTED	PERCENT OF CASES IN WHICH BARRIER WAS CITED
1. Federal law or Regulation	15	46.875%
2. Cost	14	43.75%
3. Technical Reliability	14	43.75%
4. Market Considerations	8	25. %
5. Maintain Integrity of Vehicle	8	25. %
6. Lack of Adequate Testing Procedure	7	21.875%
7. Lack of Top Management Support	4	12.5 %
8. Changes in Manufacturing Process Required	3	9.375%
9. Lack of Federal Interest or Competence	3	9.375%

Source: A.H. Rubenstein and Associates, Analysis of Federal Stimuli to Development of New Technology by Suppliers to Automobil Manufacturers, TS-13215, March 1977, p. 33.

2. Challenge and incentive of solving a persistent problem --- Having to deal with a particular product line, the suppliers are acutely aware of existing problems and are determined, for a variety of reasons, to solve them.

3. Recognition of market potential --- This factor is otherwise known as market pull and it can involve several market levels, i.e., second tier suppliers, manufacturers, and consumers.

4. Direct government R&D or grant --- On the surface this factor is relatively straightforward, but the implications of Federal R&D are quite complicated (as seen in other sections of this document) and can produce both positive and negative re-inforcements.

5. Technological capability --- Interestingly enough this factor was mentioned in only 16% of the responses.

6. Other governmental factors --- Mentioned in this category were Federal procurement policy, availability of Federal information, and Federal financial incentives.

The facilitators of innovation are given in Table 3-3 with Federal laws and regulations, challenge and incentives for solving of a problem, and market potential being the principal facilitators.

From the results presented in the preceding pages, it appears that the two areas where the innovation process of the suppliers differs from that of the manufacturers' stems directly from the relationship between suppliers and manufacturers or second level suppliers, and the relationship between suppliers and government. In the case of the former factor, the market success of an innovation is dependent on one additional step. The supplier has to first sell his invention to the second level supplier or to the manufacturer. This excludes instances where the supplier

TABLE 3-3. FACILITATORS OF INNOVATION BY SUPPLIERS RANKED BY FREQUENCY OF CITATION

FACILITATOR	NUMBER OF CASELETTES (INNOVATIONS) IN WHICH FACILITATOR ACTED	% (n = 32)
1. Federal Law or Regulation	14	43.75 %
2. Challenge and Incentive of Solving a Persistent Problem	13	40.625 %
3. Recognition of Market Potential	10	31.125 %
4. Direct Government R&D or grant	6	18.75 %
5. Technological Capability of Supplier	5	15.625 %
6. Federal Procurement Policy	4[@]	12.5 %
7. Availability of Federal Information	4[#]	12.5 %
8. Government Financial Incentives	3[#]	9.375 %

[@] only 2 firms reporting this facilitator.
[#] only 1 firm reporting this facilitator.

Source: A.H. Rubenstein and Associates, p. 34.

markets the product on his own. Thus, the eventual acceptance of the innovation does depend, to a certain extent on the adoption rate of the second level suppliers and manufacturers. In the case of the latter factor, the supplier is often faced with a difficult problem caused by the fact that government regulations are often directed toward the manufacturers, and reach him indirectly, creating additional obstacles. Furthermore, in the opinion of many suppliers, the government is not cognizant of their needs and their role in the automotive innovation process. Both of these areas are explored in the following paragraphs.

d. The attitude of the manufacturers as perceived by the suppliers

1. Cost --- In the opinion of many suppliers, the matter of cost is of paramount importance to the manufacturers. They argue that despite considerable benefits, especially in the areas of safety and environmental concerns, the manufacturers will reject an innovation if it adds significantly to the cost of the car. In their opinion, only Federal regulations will force the manufacturer to accept such innovation. Others perceive the cost issue only as a first cost problem, a problem which is tempered, through the passage of time, by two factors: the reduction of uncertainty and cost as the design features are perfected, and the increasing impact of Federal regulatory efforts

2. Decision making on innovation --- The response of the suppliers indicates a wide range of practices on the part of the manufacturers. One of the Big Three was recognized as a prime motivator and adopter of innovation, another, due to its vertical integration, fails to innovate as fast, and the third, which tries hard and is less cautious, fosters competitiveness within the supplier group.

3. Failure of suppliers --- One of the problems of the supplier-manufacturer relationship was perceived to be the tendency of some suppliers to "blow their horn too loudly" to the manufacturers, or to "steal their thunder".

4. Sensitivity to innovation --- Interestingly enough, there appears to be a consensus that manufacturers are willing to hear new ideas and do not supress them. One of the real problems is attributed to suppliers that pull back from innovation out of fear that the ideas are too costly.

5. Regulations --- The impact of the regulatory process upon the manufacturers is subject to great debate, but agreement exists that performance specifications are more conducive to innovation than product or design specifications since they provide more flex- ability.

e. Government activities to support innovation -- The sug- gestions of the suppliers in regard to the direction of governmental activity to support innovation relates to their preceived barriers, and comprise three categories:

1. The government could facilitate the innovation process if it reduced the uncertainties surrounding regulatory action, and tied Federal goals closer to project timing and capabilities of the suppliers.

2. The government should improve its understanding of vehicle integrity constraints. This involves an understanding of the technological interdependence of vehicle production and operation as well as the "broadening" of regulations to include trade-offs between energy, safety, and the environment.

3. The government should improve test standards by defin- ing a consistent methodology. Such a development would improve the uniformity of data in vital areas.

f. <u>Conclusions</u> --- The contention that manufacturers rely heavily on the suppliers for innovative products is often viewed as casting a negative shadow over the activities of manufacturers. The available data indicates that suppliers indeed do provide the automotive industry with a considerable fraction of its innovation. This situation, does not necessarily imply the manufacturers are avoiding their share of the burden, for in many cases the supplier is the entity most ideally suited to introduce the innovation. After all, the suppliers have reached a high degree of specialization with one, or maybe a few, products or processes, and as a result are real experts in the field. The manufacturers on the other hand have to deal with a multitude of products and processes, as well as the task of component integration. Rather than criticize the manufacturers for relying on the suppliers, one should examine the types of innovations performed by the different entities, and analyze the adoption practices of the manufacturers.

The vital role of the supplier in the automotive innovation process should be recognized and thought given to the establishment of an atmosphere conducive to innovation by the suppliers. In its regulatory activity, the government must be sensitive to the needs and capabilities of the suppliers, and to the supplier-manufacturer relationships. Such awareness should have a significant impact on the innovation rate of the supplier industry and thus benefit the automobile industry as a whole.

3.3.3.2 R&D Practices

The issue of both corporate and Federal R&D activities has been drawing a lot of attention of late. Spurred by arguments to the effect that annual R&D expenditures are not keeping up with inflation and that America's technological position is rapidly deteriorating, efforts have been initiated to bolster, re-define, and re-direct national R&D funds.

Exemplifying these developments, President Carter - prior to announcing the new Federal budget - issued a strong public statement in support of research and development. Aware of the decline in the availability of funds for new scientific instruments, the shortage of jobs for young researchers, and the diminishing number of top-ranked research centers, President Carter stated that "we have a problem on our hands, unless we take strong action to correct these trends". The action which he referred to consists of an expanded Federal R&D budget and a directive to all Federal agencies instructing them to accord R&D a higher priority.

The President's remarks were qualified by an earlier statement by Presidential Science Adviser Frank Press who criticized industry's response to efforts to boost R&D and industrial innovation by stating that:

> "I have met with a number of industry officials to listen to their problems, and while I am sympathetic with much of what they have to say, I am left with the feeling that they are overly negative and defensive. I would hope that while we are at work figuring out what Government can do to improve the situation, industry will do some hard thinking on the matter and come up with some positive new ideas and programs also."

In addition, the President emphatically added that increased Federal R&D expenditures do not indicate that "we are trying to establish or maintain a college aid program" R&D, he said, is supported by the public on the basis of its contributions to national well being and security.[43]

---

[43] The above information was gathered from IEEE Spectrum, Special Issue, January 1978, p. 17.

The first step, albeit a cursory step, is a look at the readily available data. The figures presented on the next few pages are based on data from the McGraw-Hill Annual Survey of Business Plans for Research and Development Expenditures. A quick appraisal of the data in these surveys indicates that some of the information (i.e., actual R&D expenditures up to 1974), was derived from work done by the Industries Studies Department of the National Science Foundation, and the rest was gathered by McGraw-Hill through questionnaires sent to individual firms.

In deciding upon the accuracy and value of the data, a number of factors must be recognized:

- a thorough breakdown of the transportation industry is not available, but the figures presented are useful since the transportation industry is defined as: motor vehicles and other transportation equipment and since the "other transportation equipment" figures are small by comparison.
- after 1974 the actual and estimated expenditures are used interchangeably by McGraw-Hill, casting a degree of uncertainty over the real values of the numbers.
- a breakdown of R&D budgets is not available, except for certain areas. As a result, a straight comparison between industries is difficult, and might lead to inaccurate conclusions.

Despite these drawbacks, certain conclusions can be drawn which can serve as points of departure for future analyses of the R&D practices of firms. Figures 3-5 and 3-6 indicate a close relationship between the actual expenditures and the projected expenditures. This speaks well for the forecasting capabilities of the automobile industry, or is indicative of their intransigence in changing expenditures in accordance with changing economic, social and, political situations. The fluctuations of the actual expenditures tends to relate closely to the historic pattern of sales for the industry. The anomalously erratic three-year plans of 1971 and

TABLE 3.6 R&D EXPENDITURES - TRANSPORTATION INDUSTRY

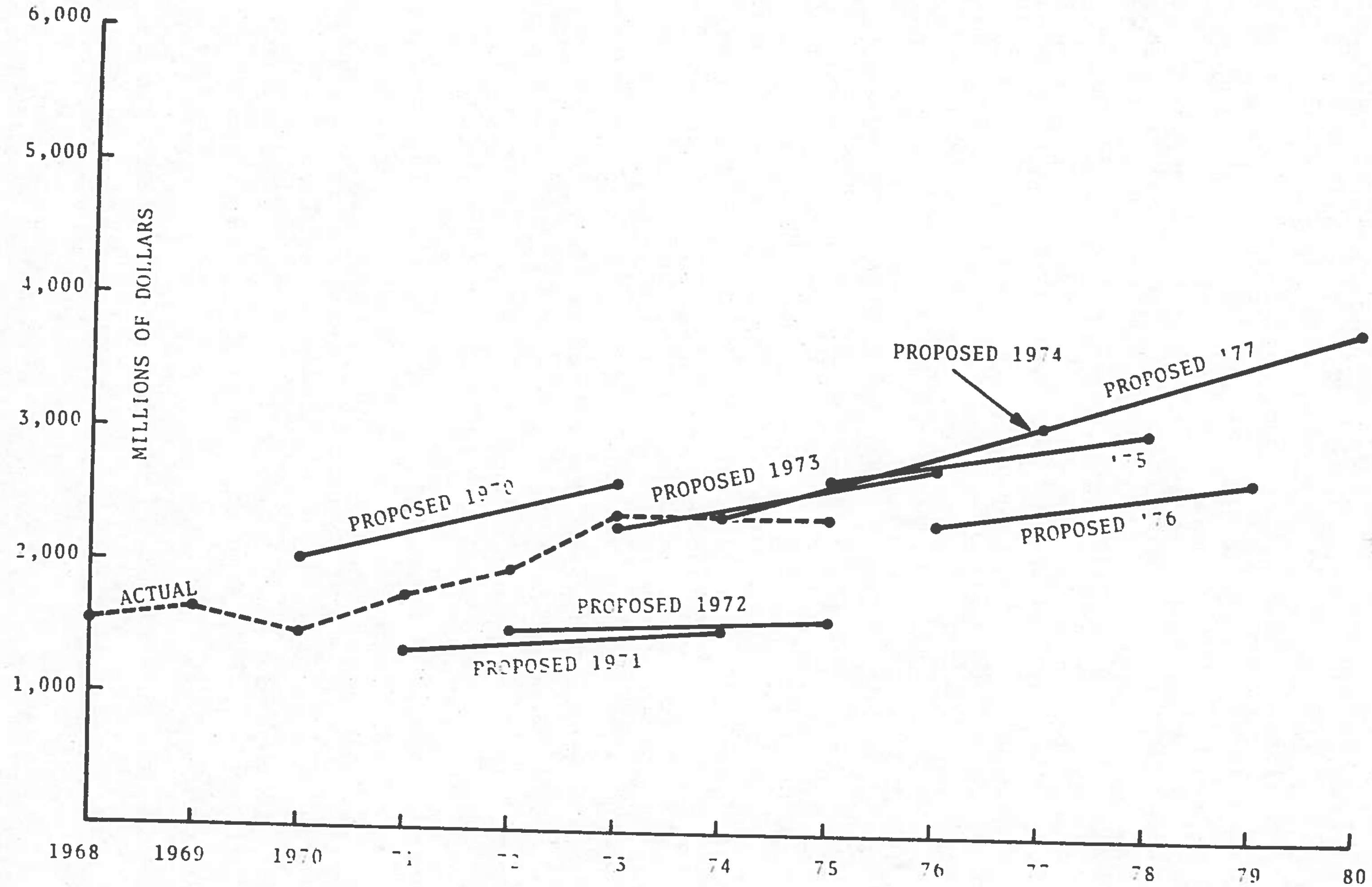


TABLE 3.5 R&D EXPENDITURES - TRANSPORTATION INDUSTRY

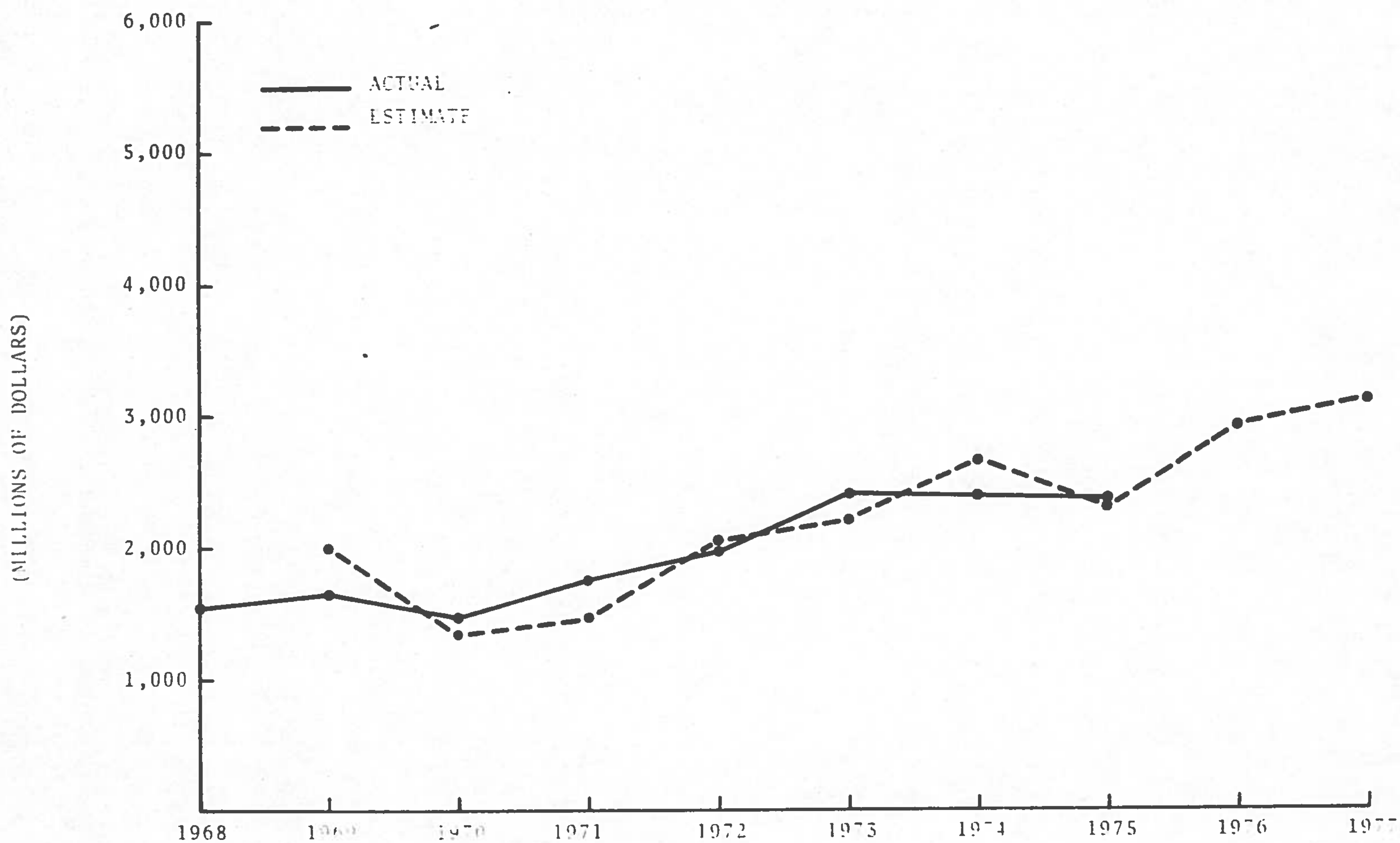


TABLE 3.7 R&D EXPENDITURES - TRANSPORTATION INDUSTRY

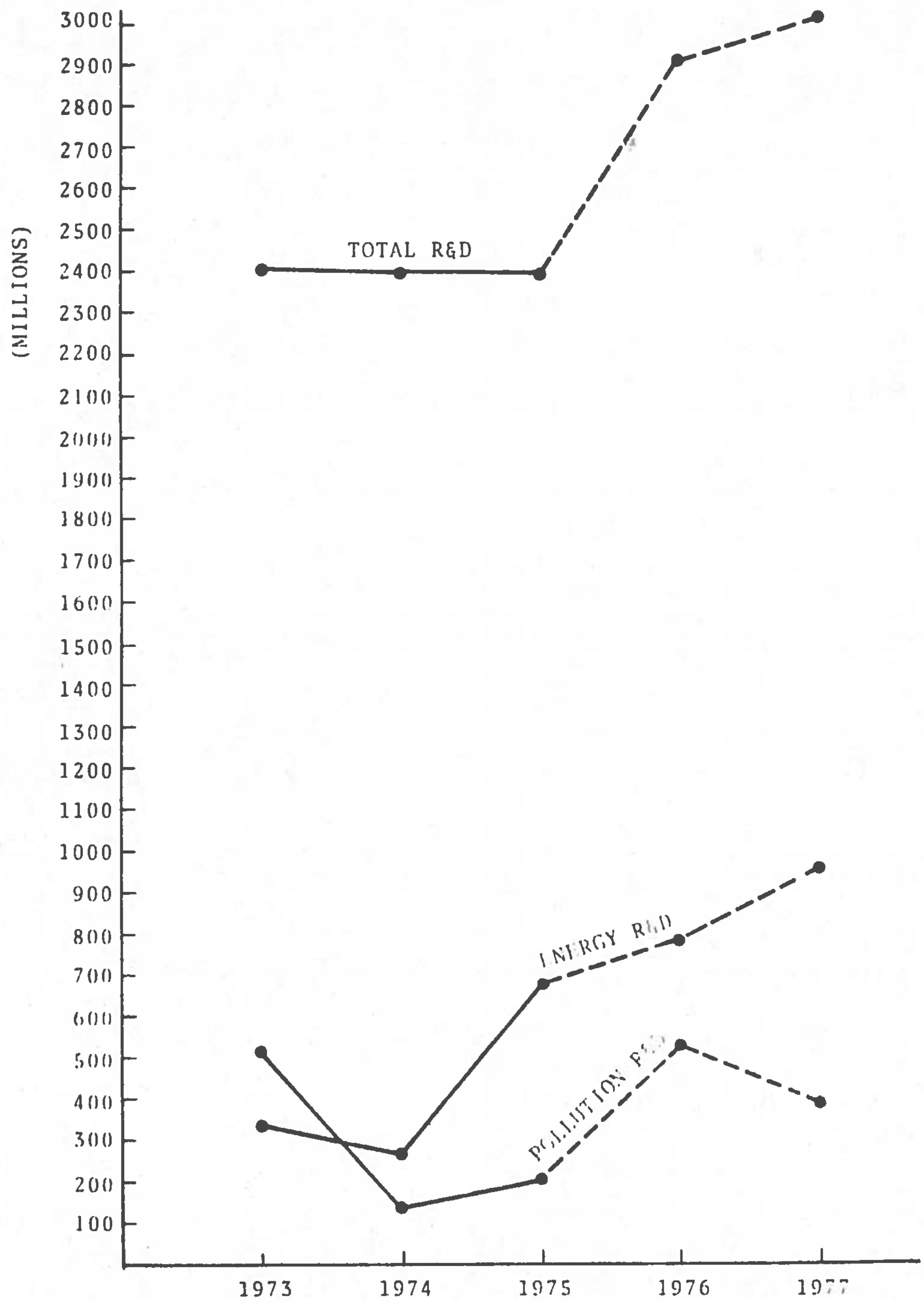


TABLE 3.8 EXPENDITURES - ACTUAL

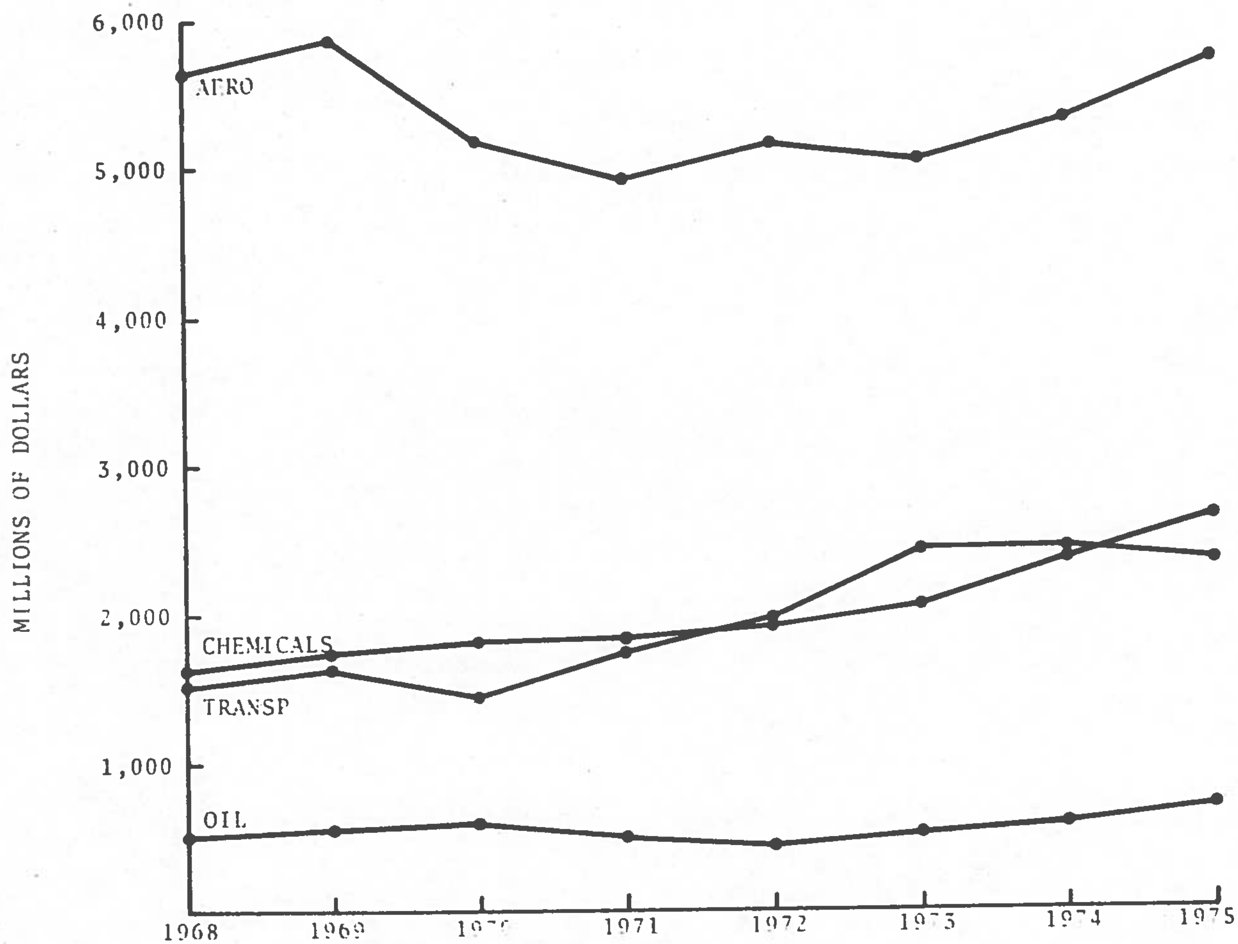


TABLE 3.9 R&D AS PERCENT OF SALES

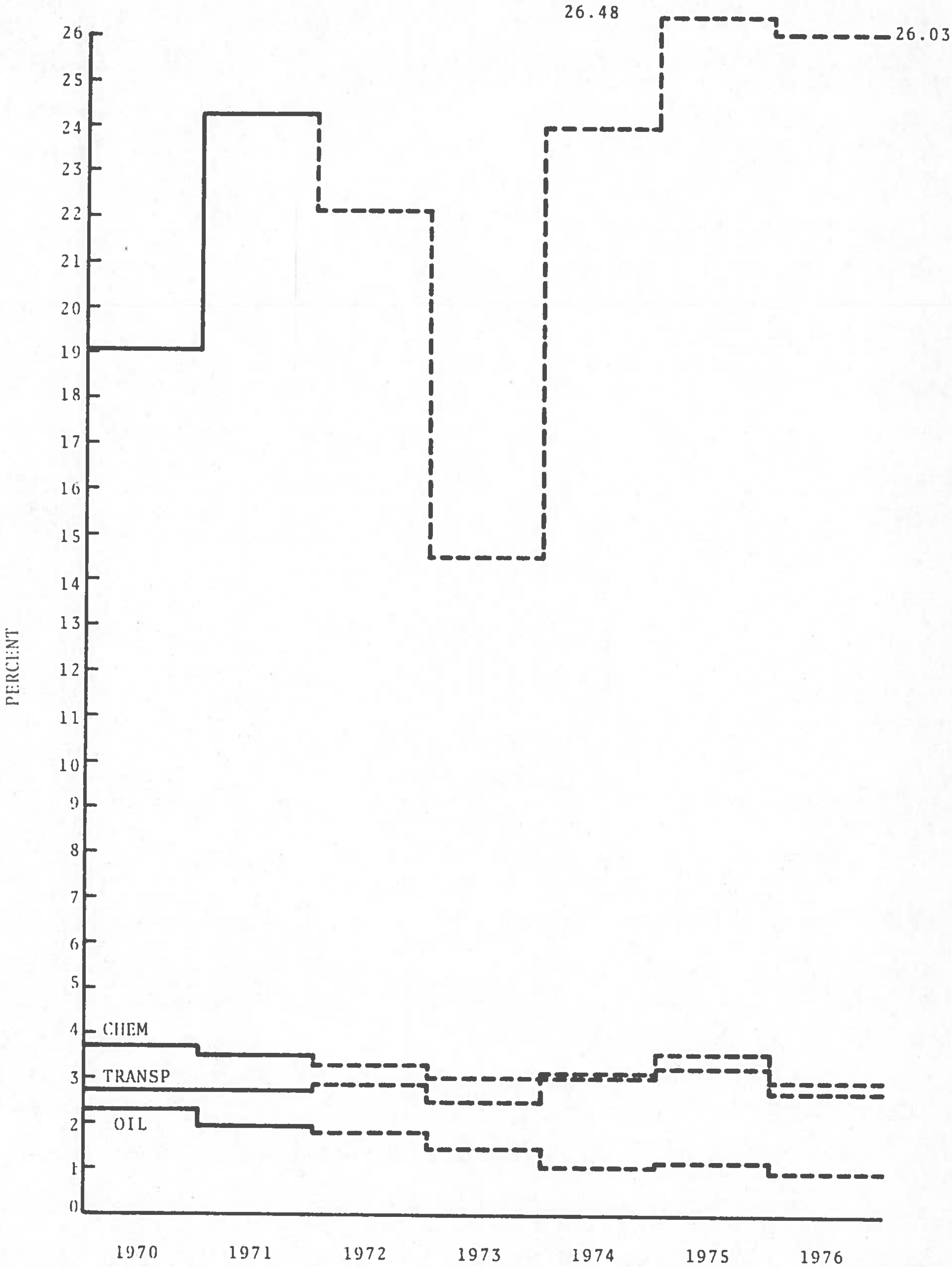


TABLE 3.10 R&D AS PERCENT OF CAPITAL SPENDING

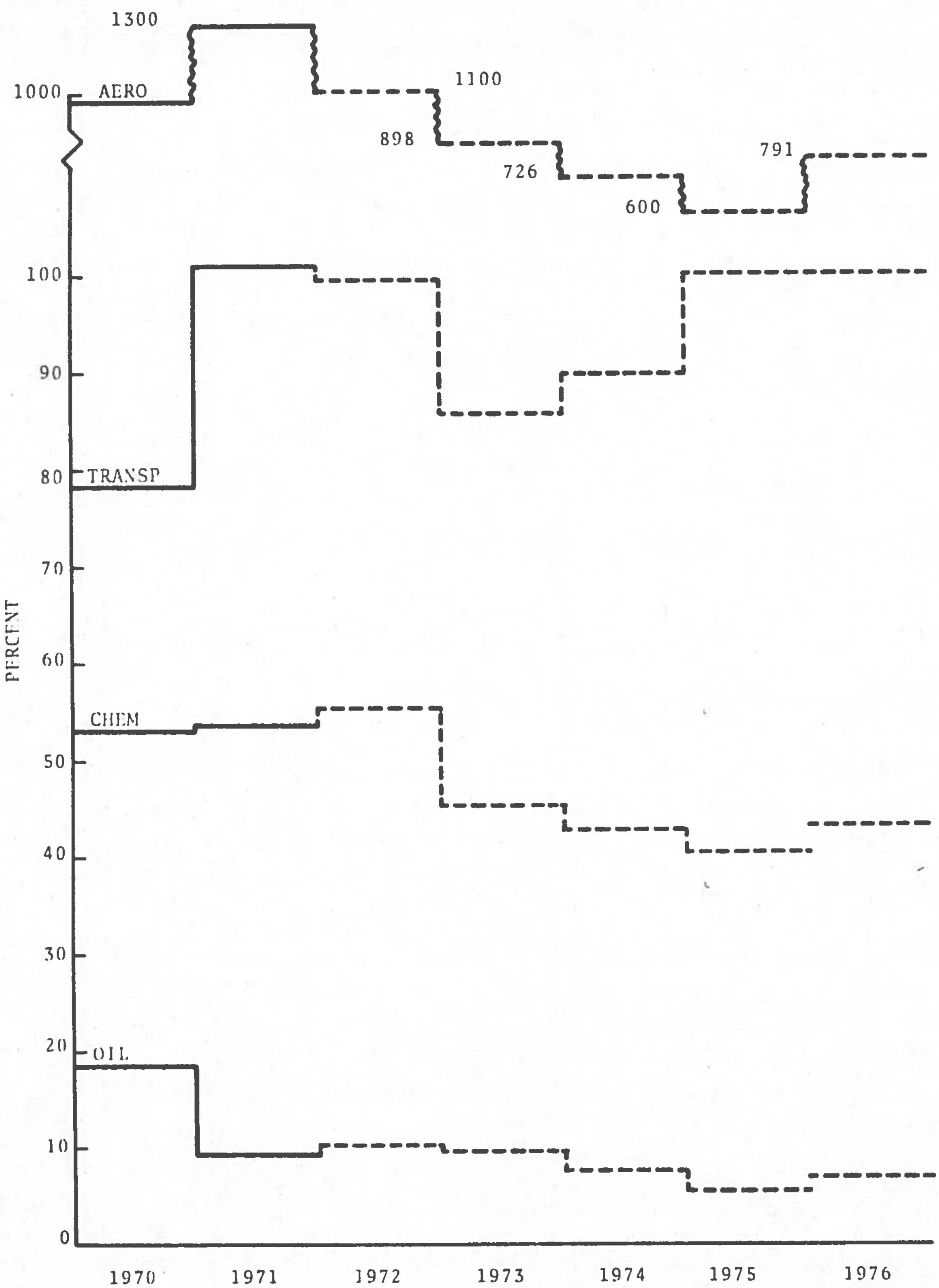
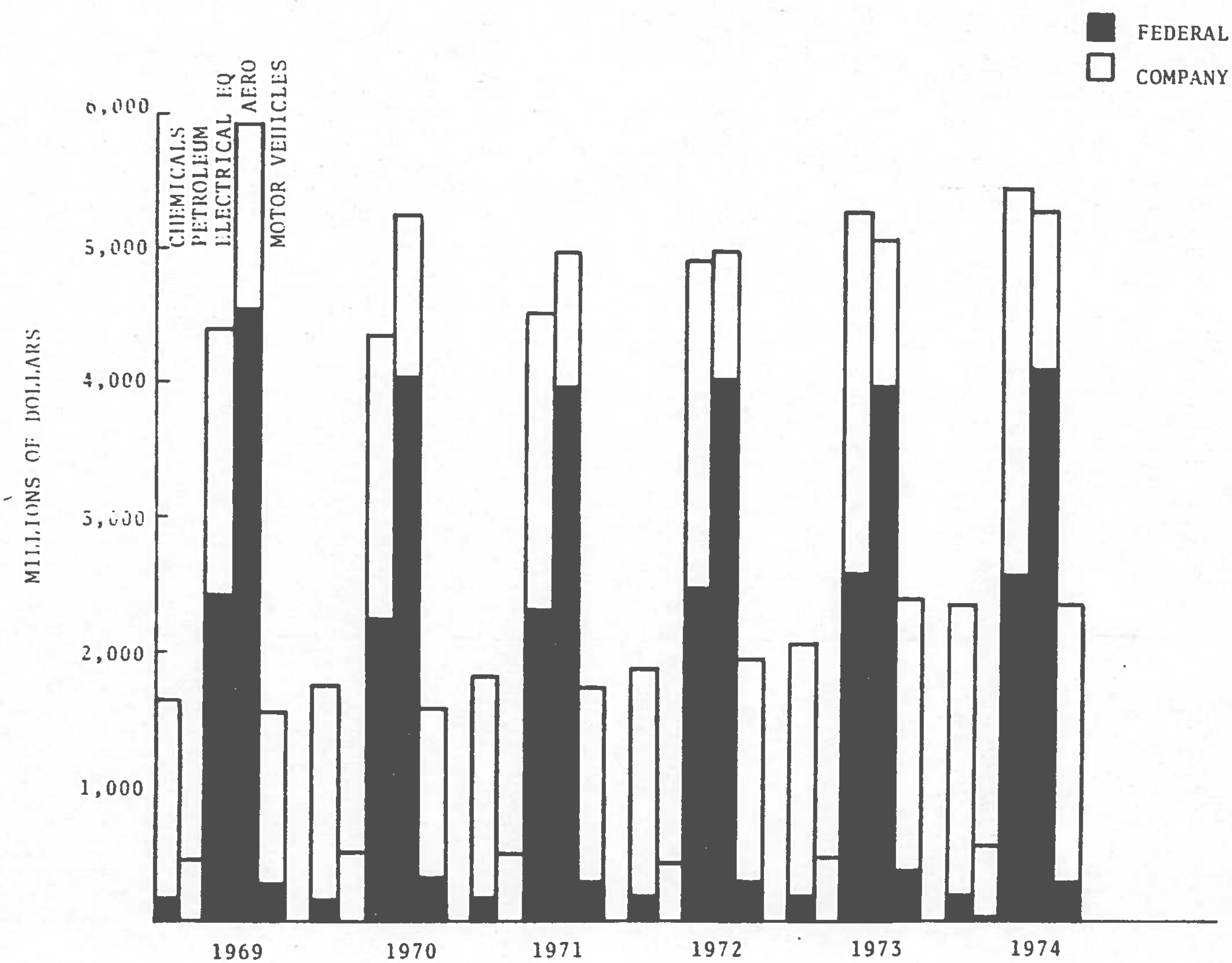


TABLE 3.11 PERCENT R&D EXPENDITURES FEDERALLY FINANCED



1972 might be reflective of the economic problems of 1970. The sharpest upturn in expenditures is recognizable in the proposed expenditures for 1976. The chronology of events between 1973-76 is of particular importance and must be carefully analyzed since the industry's response to the energy conservation standards have been a point of contention among various sources.

Figure 3-7 shows an interesting comparison between pollution and energy expenditures with the latter showing a stronger growth rate. Of particular importance are the projected figures for 1977 which indicate a sharp decline in pollution expenditures accompanied by a sharper increase in energy expenditures. At this stage, such a development is not readily understood, but two possible explanations are that pollution issues are being regulated to a secondary role, or that the technological problems related to energy issues greatly overshadow those related to pollution. Another interesting aspect of Figure 3-7 is the fact that in 1977 the combined pollution and energy budgets amount to less than half of the total R&D budget. These figures are by no means full proof, and a study done for the Automobile Technology Program at TSC preports to show that in 1977 G.M. alone spent $2,000 millions on R&D with $1,750 millions going to fuel economy, pollution and safety issues.

For the purpose of future analyses it is imperative that a detailed breakdown of the R&D budgets, including a breakdown of the energy budget, is obtained. Figures 3-8 - 3-10 represent several comparisons between the R&D expenditures of several industries. On a straight numerical appraisal, the transportation industry measures favorably with the rest, and in particular with the chemical industry whose reputation as a capable innovator is recognized. A straight numerical analysis does not provide a complete picture however. For that, a comparison must be made between innovative outputs as well. The reason being, that if both industries spend the same amount on R&D and one has a greater innovative output, then serious questions can be raised regarding the innovation process of the other.

Figure 3-11 emphasizes the overwhelming Federal support for the aerospace and electrical equipment industries. It also shows that the motor vehicle industry spends more, of its own money, than the aerospace industry.

3.3.3.3 The Decision Process for Innovation

This section outlines the major elements influencing product innovation in the automobile industry. The conclusions are based on data provided by Edgar A. Pessemier in The Decision Process for Innovation in the Automotive Industry as it Relates to Marketing and Manufacturing. The forces affecting the industry's capacity to innovate and the incentives to innovate are viewed from a managerial perspective.

1. Economic Characteristics of Innovation and Sources of Uncertainty

   a. Potential market acceptance --- Due to the difficult nature of assessing product acceptance, careful market analysis is needed in order to properly assess the barriers to adoption. Program and product design should be developed to exploit market needs and insure that useful innovation will be accepted. The problem of rapid adoption of technology is particularly acute if the product is highly critical to the adopter's social and economic welfare, significant uncertainty exists about the product's technological, social and economic performance, and the product's consumption is highly visible. These factors are often encountered when one speaks of automotive innovation.

   b. Overall diffusion process --- The success of an innovation is directly attributable to its diffusion from the manufacturer through the distributor to the producer. This sequence represents a vital process and requires careful planning. Product innovations that provide visible net benefits can often be efficiently introduced by concentrating on the early adopter segments of the market. By progressively introducing new models and redirecting promotion programs, the adoption process can be effectively transferred to less venturesome segments. The process is more complicated for product innovations that show diffuse social benefits, particularly if large economic costs or personal inconveniences are added to them. In this case, the entire gamut of possible market reactions to the product must be understood before the innovation program can be implemented.

c. Displacement of sales --- In addition to the standard evaluations of the likely financial success and amount of risks related to the product's market acceptance, the manager must also make allowances for changes in the sales and profit contribution of the current product line(s) which will occur if the innovative product is introduced.

d. Displacement costs --- Product innovation can result in serious side effects attributable to the displacement of current product sales. In addition, facilities, stocks of raw materials, finished parts and supplies may be rendered obsolete, reducing or destroying their normal economic value. This is true for both manufacturers and suppliers. Careful thought must be given to the overall effect before the process can be implemented.

e. Changes in marketing and distribution costs --- The success of an innovation is often based on a considerable marketing effort. The benefits of change and the acquisition and maintenance process must be explained to the consumer. Gaining the support of marketing and distribution facilities is a difficult but vital task.

f. Initial levels and cost reduction rate --- The initial unit costs of manufacturing and distribution of a new product are typically high. The initial level of unit cost declines with accumulated production and marketing experience. The downward path of costs will be determined in large measure by the characteristics of the innovation, the achieved design stability, and the cumulative amount of applicable experience.

g. Capital investment --- Innovations that require large amounts of new capital, that are not easily adapted to alternative uses, and that involve substantial technological risk will obviously be viewed by managers as less desirable opportunities.

h. Tax effects and formal incentives --- The financial attractiveness of an innovation can be directly affected by various tax programs such as investment tax credits, and accelerated depreciation schedules for investment in product innovation. Similarly, non-tax subsidies, loss-protection schemes and the like can be used to reduce risk or increase returns.

i. Overall financial risk-reward structure --- The general worth of a project is best summarized by the expected annual cash flow over the product's economic life. In addition, the time period needed to recover investment dollars provides an index for the period of greatest exposure to technical and market risks.

2. Structural features of the industry

a. Sales concentration --- Given the structure of the industry, effective product innovation must be adopted initially be one or more of the Big Three. To the extent that a new product influences the firm's market success, manufacturing efficiency and financial strength, important changes in the industry's competitive structure may be induced by an innovation.

Furthermore, the relative effects may be greatest among the less important participants, both foreign and domestic.

b. Sales distribution by model --- The capacity to handle innovation is directly related to the firms model mix.

For example, the extensive range of models produced by GM have, in turn, produced a profit effect which enables the company to "experiment" in certain areas without endangering its overall position. Similarly, participation in innovation can effect a firm's model mix. These factors can be an important incentive to innovate and have an apparent influence on the industry's competitive structure.

c. Cost structure - fixed and variable --- The competitive structure of the industry and its willingness to innovate is related to the cost structure of the major firms. Different policies with respect to the use of outside suppliers, and the related differences in the capital invested in labor saving devices lead to uneven mixes of fixed and variable costs among the manufacturers, in turn resulting in different approaches to innovation.

d. Sources of firm's profit --- In assessing the profitability of a firm such factors as size of markets, mix of models, degree of integration and efficiency achieved in manufacturing, must be examined. The realizable price per unit, the investment in plant, equipment, and tooling, and other economic factors of a new product must be examined to estimate the innovation's profit potential and the firm's competitive position.

e. Firm's financial strength --- Historic development, and data on return on assets and equity shows considerable differences, in respect to financial performance, among the automotive firms. Such differences have an important effect on the financial structure of each firm and, as a result, have a significant influence on the firms capacity to raise capital on favorable terms.

f. Product characteristics --- Recent changes in the market demand, i.e., concerns about safety, environmental and fuel economy issues, have created a climate favorable to innovation in respect to certain product characteristics. However, some sources argue that feasibility and marketability of the most interesting potential product innovations remain hard to assess.

g. Market and distribution structure --- Aside from some potential innovations that might result in the development of new distribution systems, most automotive innovations must flow through existing channels, competing for the support of current distributors. Therefore the extent, quality, and response of the distribution system is a vital factor.

h. Foreign competition --- Despite the fact that one out of every five automobiles sold in the U.S. in 1977 was produced overseas, the extent of the effect of foreign competition on the innovation rate of the U.S. firms is not easily ascertained. In more recent times, the domestic manufacturers have reversed, to a certain extent, their initial response pattern, i.e., a slow process typical of a mature industry with a heavy commitment to an established, historically proven product strategy, by adopting a more aggressive approach. The outcome of this development, is still to be determined.

i. Manufacturing process --- The drive for increased productivity has resulted in an increased investment in specialized machines and tools. The facilities which emerged can not be easily adapted to new products. To take advantage of the achieved high level of productivity, the new product must, ideally, consist of modest, incremental changes, for it appears unlikely that consumers (and by implication manufacturers) will accept large cost increases without serious resistance.

j. Sales and profit effects of model changes --- One of the more interesting aspects of product innovation is the extent to which an important model change can increase the firm's sales. Given the past experiences of manufacturers, it is safe to argue that maturity of the product class reduces the advantages inherent in the introduction of a major model change. In cases where a model change represents important additions to the product's utility a new product introduction can make a major contribution to the firm's competitive strength.

3.3.3.4 Market, Technological, and Other Influences on Innovation

a. Market needs and product maturity --- According to some sources, the past activity of auto manufacturers indicates that they have generally responded in a reasonable fashion to market demands. Given the uncertain state of market analysis, long manufacturing lead times, and high sunk costs for relatively inflexible plants, producers manufactured more efficient, environmentally safe cars about as rapidly as they could without incurring unreasonable cost increases. As the demand for product improvements, dictated by changes in the market demand, increases so will the innovation rate.

b. Technological influences --- Given the need for design and process changes demanded by the market, the automobile industry is beginning to encounter the pharmaceutical industry's major R&D problem "The need for fundamantal knowledge to solve well understood user needs." Increasingly scientific as compared to engineering solutions are needed. This type of problem solving is difficult to program and is never assured.

c. Government intervention --- The role of the government in the innovation process is quite important. In cases such as the environmental impact of automobiles, the responsibility of the government is clear-cut and market forces are unlikely to yield totally satisfactory results. In the case of fuel economy, government action is needed to a certain extent, but care should be paid to market forces. In establishing a Federal program, emphasis should be given to modification of existing systems as well as the introduction of new ones. Primary and secondary effects of each program must be reviewed in terms of market and technological and competitive features of the industry. It must be remembered that the least risky programs are the ones that set broad, workable goals and provide ample freedom for the development of imaginative solutions. The riskiest programs use rigid mandates for actions that are not demonstratively practical.

3.4 CONCLUSIONS

From all of the above it appears that technological progress in the auto industry is not only a gradual undertaking but also a risky proposition as well. The process of technological change which is comprosed of basic research, applied research, exploratory development, final product development, and introduction is a lengthy process involving numerous decision processes heavily skewed toward the final stages. The entire process often takes many years from initial conception to widespread use, e.g., the automatic transmission and power steering became popular some 10-20 years after the basic concepts had been worked out.[40]

The rate of technological development appears to be an intrinsic outgrowth of the automobile industry's structure which is not affected by any conscious effort to resist development. New technology usually carries a high price tag, particularly in substantial front-end investments, and carries a high risk.

> The decision to introduce major innovations is, therefore, one the industry makes with great caution, after long study, and, if possible, in conjunction with the phasing out of fully depreciated facilities. The process is gradual because of risks involved, and the risks are there largely because the industry has sought cost minimization through automation.[40]

Expressing a similar thought Abernathy writes:

> The development of highly efficient technologies for mass production has increased costs and raised design constraints to the point of slowing product change. Technological progress is no longer introduced by radical product innovation, but comes about as a cumulative result of incremental change. Forces outside the industry, like government regulations, political action, and fuel prices, now provide

---

[40] Rosenberg, N., et al., Institutional Factors in Transportation Systems and their Potential for Bias Toward Vehicles of Particular Characteristics, Transportation Systems Center, Cambridge, 1977, p. 8-11.

the primary stimulant for change rather than entreprenurial competition within the industry.[41]

This situation however, might be on the verge of a drastic change outside forces. Again as Abernathy points out:

> In the late 1970's, the market conditions seem to have changed more completely than any time since before World War II. Encroaching petroleum supply restrictions, rising gasoline prices and the erosion of consumer purchasing power have completely changed the environment for innovation. Tangible objectives for innovation, which relate to consumer new needs are apparent and new technologies on which such innovations might be based, such as electronics and new propulsion systems that will consume less or new forms of energy, are in the wings, so to speak. It also seems that industry may be responding to the market's demand for change. Opportunities for technological innovation can once again be important to the competitive behavior of the major producers. The type of innovation that results will very likely require a reversion to an earlier stage of development. The success of these merging trends will depend upon the major firm's leadership through their programs for innovation and research and development.[42]

While the preceding discussion has clarified a number of issues affecting the innovative process of the automobile industry, one question still remains and will have to be answered before the final conclusions are drawn. This question concerns the actual definition of innovation. Up to this point, the analysis has relied on a broad and somewhat amorphous terminology which is used exclusively throughout the existing literature. This terminology is appropriate for the present stage of the analysis, but if a final appraisal of the automobile industry's innovative capabilities is to be made, then a precise clarification of the definition of innovation must be made. Of primary importance, particularly as far as the auto industry is concerned, is the separation and individual analysis of product and process innovations. In this respect, data might show that the auto industry

---

[41] Abernathy, The Productivity Dilemma, p. 2-52

[42] Ibid, p. 3-27.

is one of the most innovative as far as process innovation is concerned while lagging, to some degree, in product innovation. In addition, the implications of process innovation, usually associated with a less innovative but dependable and affordable product, as compared to product innovation, possibly associated with a more expensive product, must be defined in terms of national goals. Finally, an assessment of the implications of gradual versus radical innovation is required.

4. INNOVATION CREATION FORCES*

4.1 TECHNOLOGY PUSH VS. MARKET PULL

In order to assess the potential role of the various Federal policies identified in Section 2.2, it is necessary to relate these initiatives to the forces which drive the innovation process. Innovation and technological change can be viewed as governed by three types of forces which the government influences either directly or indirectly:

- Technology Push Actions:

  1. Technology Creation Actions which involve the Government directly in supporting the development of new technology or the modification of existing technology.

- Market Pull Actions:

  2. Product Characteristic Interventions that influence product innovation either directly or indirectly through a variety of sections ranging from persuasion (jaw boning) to regulatory product standards.

  3. Market Modification Actions that induce innovation through changes in the market brought about through changes in price, the indirect effects of regulation in related industries, direct government purchases and other economic incentives.

The third category relies on incentives to producers to create new products (e.g., tax credits, subsidies, protection from foreign competition) and incentives to consumers to purchase socially beneficial technology. This force, together with the second

*Based on the forthcoming report, "Technological Change in the U.S. Automobile Industry - Assessing Past Federal Initiatives" by William J. Abernathy, and Balaji S. Chakravarthy. This work was sponsored by the Auto Technology Program.

category, represents "market pull". The first category, with its emphasis on technology initiatives, seeks to induce innovation through "technology push".

Together with corporate variations reflecting each auto manufacturer's attitudes, the industry's response to any policy should be predictable from the equilibrium of the above forces. An examination of the literature was undertaken to determine the existence of an appropriate predictive model, and revealed no adequate tool is currently available. For example, the stimulus-response model of Goodson, [Ref. 1], even with the refinements proposed by Bunch for the stimulus side, only captures one aspect of the above considerations. Therefore, one objective was to develop and apply a framework, incorporating the technology push and market pull forces, for predicting industrys' response to various Federal initiatives. The resultant methodology examines Federal action and technological response from a perspective which highlights joint consequences. This framework was tested using data from a series of projects whose outcome was known and documented--for this purpose a diverse collection of Federal demonstration programs was selected. Included were examples of Federal initiatives and outcomes within the transportation sector and other areas (see Chapter 5 for a description of these projects). In a later section, Chapter 6, the framework is used to examine current actions pertaining to the U.S. automobile industry.

4.2 TECHNOLOGY CREATION ACTIONS

The costs, timing of payoff and implications of the outcome are distinctly unique for different types of technology creation actions. At one extreme there is basic research which is undertaken to support the creation of new knowledge. As Kenneth Arrow [Ref. 2] and Richard Nelson [Ref. 3] have concluded, the ultimate payoff to society from such work is very high relative to cost. On the other hand the payoff is uncertain and long in coming. A recent National Science Foundation study of ten highly beneficial innovations [Ref. 4] including products like the Heart Pacemaker, Hybrid corn and Magnetic Ferrites, successfully traced the essential underlying research events. The results show the vital contribution of such work but they also highlight the long gestation period. Of the 533 significant events (or breakthroughs) underlying the ten innovations, 72% were the fruits of research (consisting of 34% for non-mission related work and 38% for mission related work) while only 26% arose from development. At the same time the period for innovation alone, from first production conception to commercial application, averaged over 19 years, while half of the essential non-mission research events dated back 30 years prior to commercialization. These and other related studies show the enormous importance of basic research but they also graphically point out the uncertainty, as well as the difficulty, in analytically justifying such investments and in relating the ultimate contribution of any given basic research project to a previously identified product objective.

The other extreme includes programs which involve direct Government expenditures for the production or control of a product that will be placed into immediate use. The best example of this is in equipment or ordnance production for the Department of Defense or for NASA. Even for products destined to serve the private sector, (e.g., nuclear fuels or communication satellites, there are instances of direct "technology push" investment in such "close to market" technology creation activities.

The majority of Federal expenditures in the technology creation category however, fall between these two extremes. Demonstration programs, mission oriented R&D programs leading to prototypes, etc. are other types of actions frequently encountered in practice.

Figure 4-1 lists several different types of technology creation actions arranged in order that highlights two of their important characteristics. Six different types of actions, from criteria and needs research to government controlled production, are described along the left hand side of the figure. The rank order of each initiative is intended to roughly suggest the increasing extent to which it determines the characteristics of the final product. Stated in another way, the order concerns how near the action takes the product concept toward "reduction to practice".

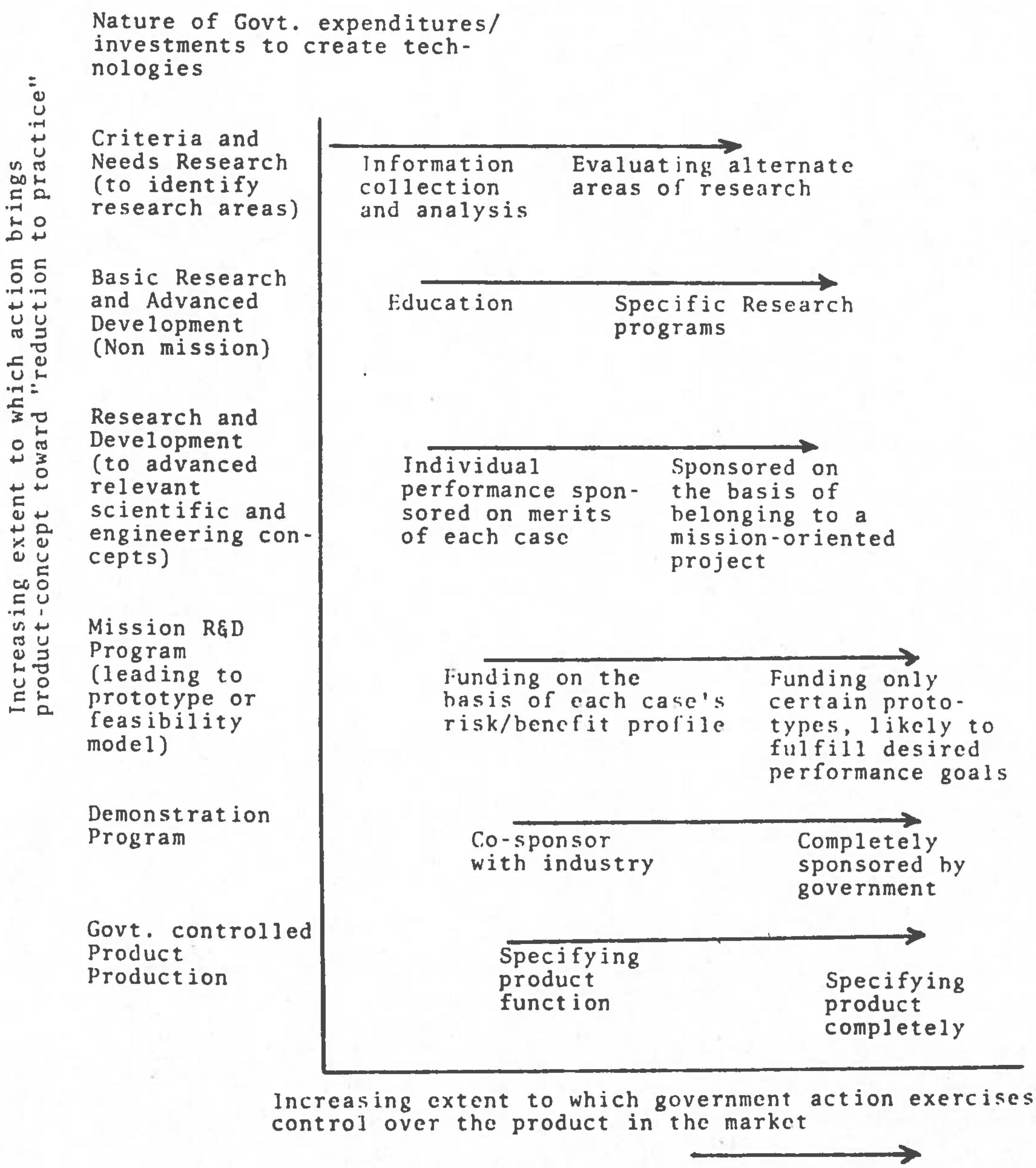


FIGURE 4-1. TECHNOLOGY CREATION ACTIONS

Basic research is shown as furthest removed from product application, while production or control over production quite obviously takes the concept closest to practice. The scale going across the page, on the other hand, shows the increasing extent to which Government control over the action places the Government in a position to shape the final product. It also reflects different intensities of government involvement within each type of action. For example, demonstration programs with a minor percentage of Government funding and control will not significantly constrain the final product, since the outcome will be determined by normal economic and market forces. On the other hand a demonstration program completely funded by the Government, as depicted by the right hand extreme on the scale, represents a high degree of Government control over the product.

The criteria for rank ordering each possible Government action and the intensity scale within each activity are closely realted. The step-like graph in Figure 4-1 illustrates this relationship. As the government action moves down the vertical scale and towards the right of the horizontal scale, there is increasing governmental influence over the final product.

Other changes will also typically accompany the movement down the diagonal: whereas the action's outcome is more immediate and visible, the cost per program also grows significantly. In a sense moving down the diagonal from the upper left to the lower right of Figure 4-1 involves increasing Government support for immediate technological change.

4.3 PRODUCT CHARACTERISTIC INTERVENTIONS

The array of possible Government regulatory actions (Figure 4-2) range from relatively weak persuasion to the fine detail of controlling the specific technology of a product through regulation. While the latter is potentially the most powerful option for immediately influencing product technology, its long run effects on technological progress are still not well understood.

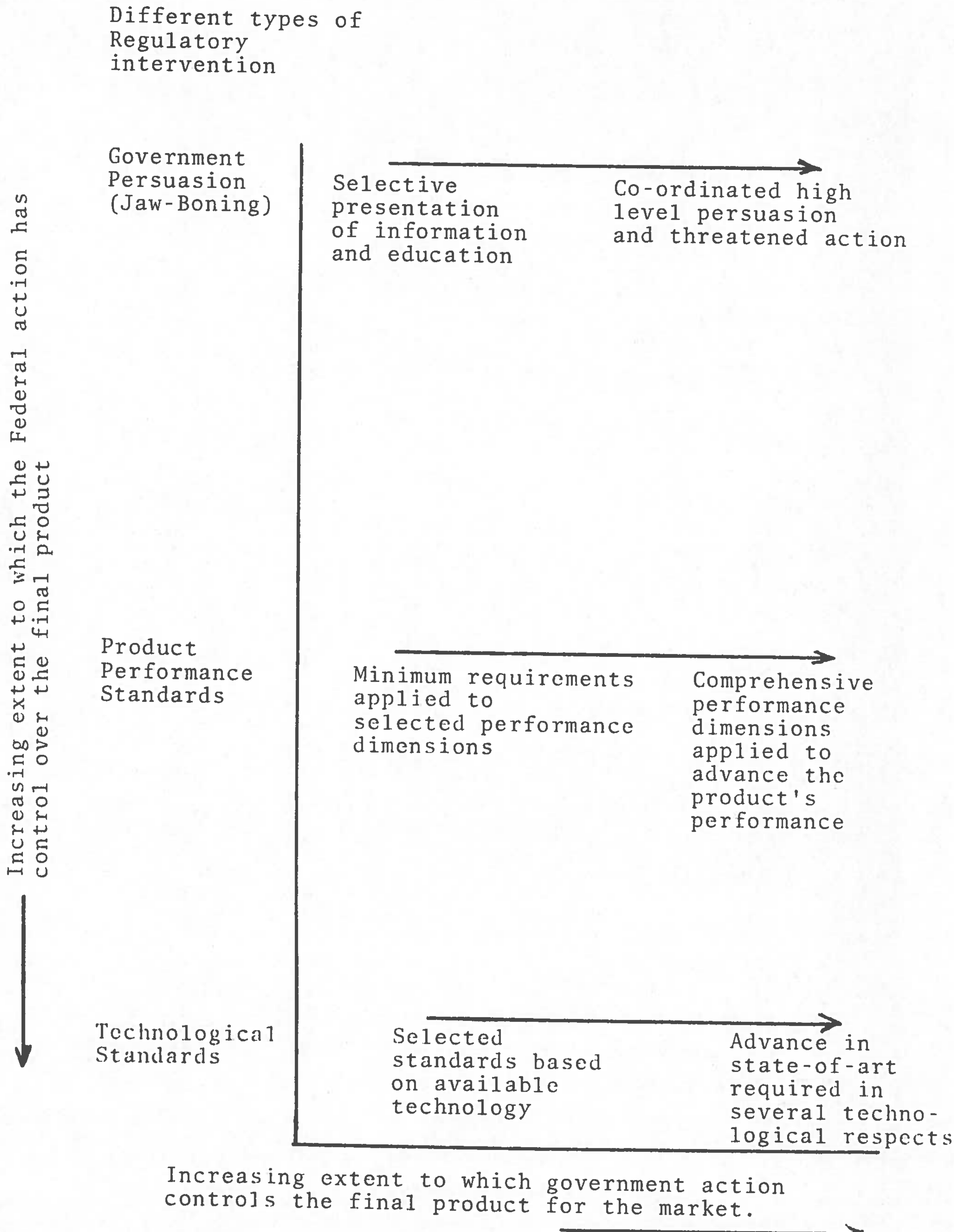


FIGURE 4-2. PRODUCT INTERVENTION THROUGH REGULATORY ACTIONS

Rubenstein and Ettlie's recent study [Ref. 5] of 32 innovations by automotive suppliers shows that Federal laws or regulations affected innovation at the detailed component level, as both the most important barrier and stimulant to change. They acted as a barrier in 47 percent of the cases, and as a stimulant in 44 percent (multiple response possible). If this pattern is generalizable, although the regulations are recent, there is reason to question what their effect may be if standards are not constantly updated. A plethora of specific standards might well impare future technological progress in industry.

As in the previous figure, the movement along the diagonal represents government control over changes in product characteristics.

4.4 MARKET MODIFICATION INITIATIVES

Government initiatives that may be used to influence or direct technological change through market pressures are suggested in Figure 4-3. As with the prior category, this figure is arranged to suggest increasing direct government influence over the final product. Rigorous enforcement of Restraint of Trade Legislation, shown as the first initiative in the upper left corner of Figure 4-3, is expected to bring about product change through increased competition. It is shown to offer the least control because this form of action does not provide a mechanism for the government to shape the form of the technological outcome. A more competitive industry structure would place more control in the hands of traditional market mechanisms. On the other hand, the establishment of selective information bases for use by the market (for example, publishing miles per gallon ratings for cars) may create incentives that shape technologies in intended directions.

Clearly the greatest potential for market modification is realized when the government itself represents 100 percent of the market. In his recent study of Department of Defense influences on innovation in the electronics industry, James Utterback [Ref. 6] describes the important role of procurement as follows: "Defense

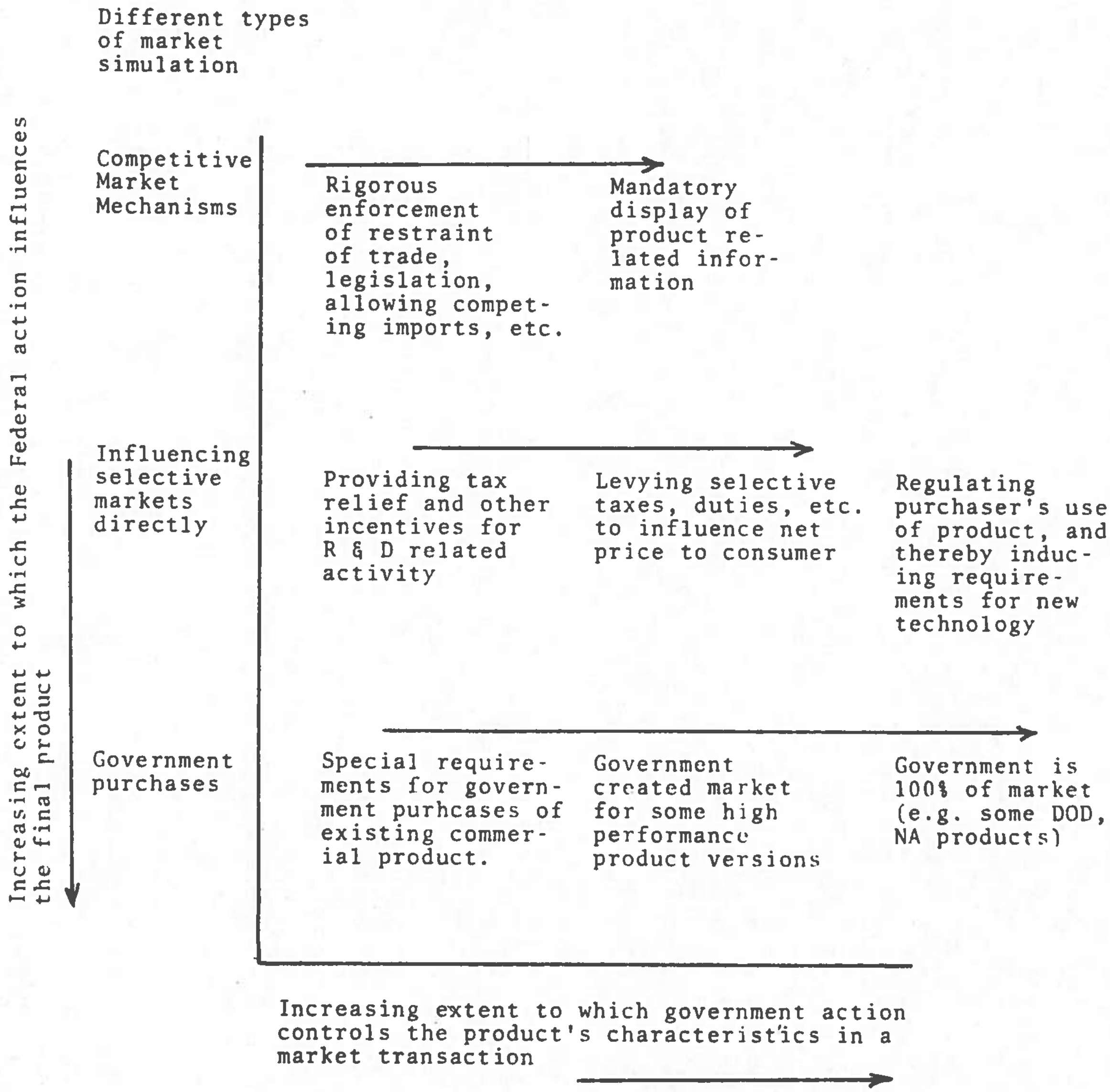


FIGURE 4-3. MARKET MODIFICATION INITIATIVES

demands have strongly focused and have tended to be the pacing element of change in the industry as a whole". His findings suggest that the government's purchases of high performance products supported innovation and the initial, leading edge, entry of highly significant products like jet aircraft, computers, advanced semiconductors and even polyethylene film.

4.5 JOINT EFFECTS

Notwithstanding the absence of precise measures to quantify the effects represented in the three figures discussed thus far, they collectively represent the elements of a conceptual scheme that can be used to explore the joint effects of Federal acitons in influencing technological change. Though ideally, the influence of each of the three forces should be considered separately, some major interactions are revealed when we reduce them to two, which is necessary for graphical representation on a two dimensional scale. Technology creation initiatives represent the Federal Government's best participation in R&D. However, market modification and product intervention actions both stimulate the industry and its affiliates to perform R&D in response to the Federal initiative--a market pull response. Therefore, the three types of Federal actions can be grouped together as follows:

1. Direct technology push initiatives (DTP) comprising technology creation efforts.
2. Indirect technology pull initiatives (ITP), comprising both market modification action and product characteristic interventions. The term market pull is also used, synonymously to describe these forces and is synonymous with ITP.

The roles of both DTP and ITP categories are more apparent when their implications are considered in an industrial context. The impetus for change within a particular industry can be described aggregately for a particular product in terms of the two dimensions discussed above; the degree of direct technology push (DTP) and indirect technology pull (ITP). The more urgent the national goal and the longer the time span of normal industry response, the greater the political pressure for increased intensity of Federal action. This framework is illustrated in Figure 4-4 for a hypothetical product influenced by strong technology pull and weak technology push actions. In the next chapters, the conceptual approach will be used to evaluate the effects of alternative Federal initiatives.

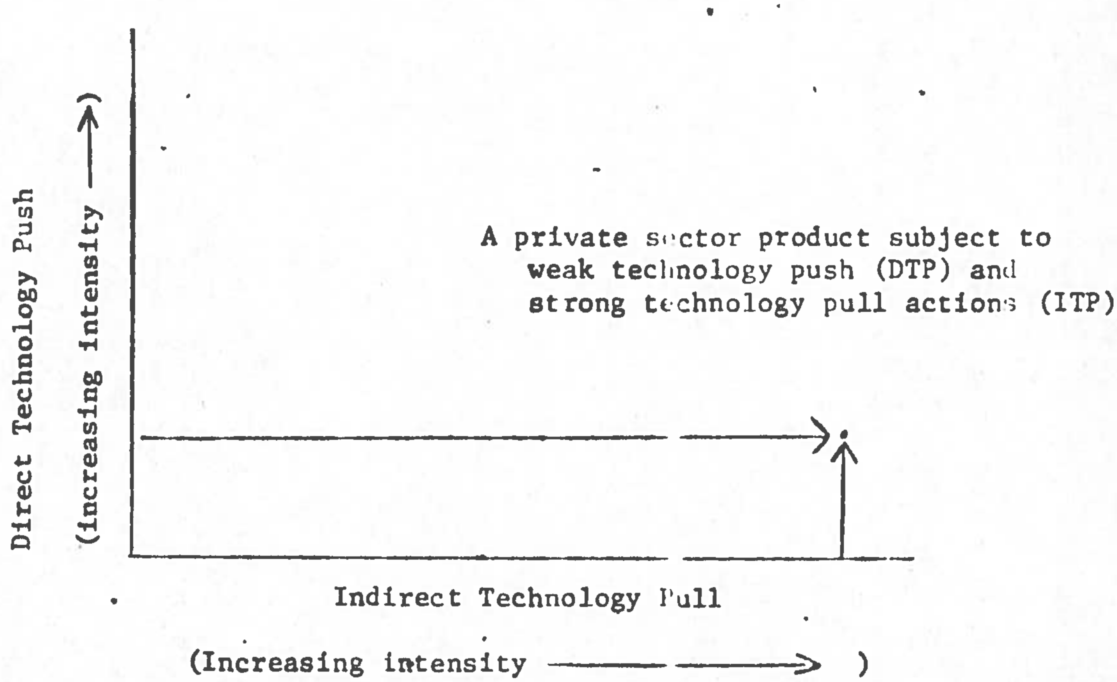


FIGURE 4-4. ILLUSTRATION OF TECHNOLOGY PUSH AND PULL INDUCED THROUGH GOVERNMENT ACTION

4.6 SUMMARY AND CONCLUSIONS

Three types of forces have been identified as driving the innovation process: (1) technology push, (2) product characteristic interventions and (3) market modification actions. Within each category there exists a spectrum of Federal initiatives; these have been organized in terms of intensity of the action and degree of governmental influence over the final product. Industry's response to any Federal initiative can be determined from the equilibrium of the above forces. However, a literature search revealed that no suitable predictive model existed, and therefore a predictive framework was developed. The approach incorporates the concepts of technology push and technology pull, and can be used to examine joint effects of Federal actions in influencing technological change.

REFERENCES

1. R. Eugene Goodson, "Federal Regulation of Motor Vehicles, A Summary of Actions through Fuel Economy Legislation, March 1977.

2. Kenneth J. Arrow, "Economic Welfare and the Allocation of Resources for Invention," in The Rate and Direction of Inventive Activity: Economic and Social Factors, Princeton Princeton 1962.

3. Richard R. Nelson, "The Allocation of Research and Development Resources: Some Problems of Public Policy," in Defense, Science, and Public Policy - Edited by Edwin Mansfield, W. W. Norton and Co., 1968.

4. Battelle, "Interactions of Science and Technology in the Innovative Process," National Science Foundation Report NSF-BCL-C-567-73, Columbus, Ohio, March 1973.

5. A. K. Rubenstein and John E. Ettlie, "Analysis of Federal Stimuli to Development of New Technology by Suppliers to Automobile Manufacturers," Final Report to U.S. Department of Transportation, March 1977.

6. James Utterback and Albert Murray, "The Influence of Defense Procurement and Sponsorship of R & D on the Development of the Civilian Electronic Industry," MIT, Center for Policy Alternatives Report, 77-5, June 1977.

5. ANALYSIS OF THE EFFECTIVENESS OF PAST FEDERAL DEMONSTRATION PROGRAMS

5.1 INTRODUCTION

A wide diversity of opinion surrounds the question of the effectiveness of alternative Federal initiatives as tools for spurring innovation. Insight into this issue was gained by applying the framework described in Chapter 4 to a set of past Federal projects whose circumstances are documented and whose outcomes have already been evaluated. The recent study by the RAND Corporation [Ref. 1] of Federally funded demonstration projects provided a particularly useful data base for this analysis. The fifteen cases examined are listed in Table 5-1, and represent a wide range of technologies, federal agencies, project sizes, and pre-project uncertainties relating to technology, markets, and institutional impediments to adoption.

The characteristics of each project, as described in the report include: the rate of cost sharing by industry (sometime most of the costs were borne by industry); the initiating organization; special types of control exercised by government; special stimulating factors in the environment; an assessment of initial technological and market uncertainity; the reduction in technological uncertainty which the project achieved and special institutional factors that effected the success or failure of the project.

As part of its evaluation, RAND assessed the success of each project in terms of its a) information success, b) application success and c) diffusion success. The first measure,

*Based on the forthcoming report, "Technological Change in the U.S. Automobile Industry - Assessing Pool Federal Initiatives," by William J. Abernathy and Balaji S. Chakravarthy. This work was sponsored by the Auto Technology Program.

TABLE 5-1. FIFTEEN FEDERAL DEMONSTRATION PROJECTS

	Approximate Cost to Federal Agencies ($000,000)	Identifying Abbreviation
Nuclear Ship Savannah	$100.000	NSS
Scottsdale Arizona's Mechanized Refuse Collection	0.184	REFUSE C.
Shipbuilding R&D Program	14	Ship R&D
Fish Protein Concentrate Program	3.5	Fish C.P.
Haddonfield N.J.'s Dial - A - Ride	10	D - A - R
Yankee Nuclear Power Reactor	8.3	Yankee N.R.
St. Louis' Refuse Firing Demonstration	2.6	REFUSE F.
HUD's Operation Breackthrough	72.2	BREAKTHRU.
Morgantown W.V.'s Personal Rapid Transit	61	PRT
Veteran Administration's Hydraulic Knee Prosthetic Devices	0.91	H. Knee
Poultry Waste Processing	0.198	PWT
Chicago's Expressway Surveillance & Control	5.7	Expressway S.
Commercial Maritime Satellite	8.2	M. Satellite
Point Loma Saline Water Conversion Plant	2.3	Salt W.P.
Tri State's Automatic Vehicle Identification	0.046	AVI

*Source: Baer, Walter, S.; Johnson, Leland, L.; Merrow, Edward, W.; Analysis of Federally Funded Demonstration Projects, RAND Corporation, Santa Monica, April 1976.

information success, was satisfied when all uncertainties were reduced to a point where lack of information did not prevent adoption. In the study's conceptual framework, see Figure 5-1, five types of information uncertainty were identified:

1. Technological uncertainty: uncertainty about the feasibility of a technology for a particular use.

2. Cost uncertainty: uncertainty about the monetary costs of manufacturing a product or operating a process using the technology.

3. Demand uncertainty: uncertainty about the benefits (private or public) that will accrue from use of the technology.

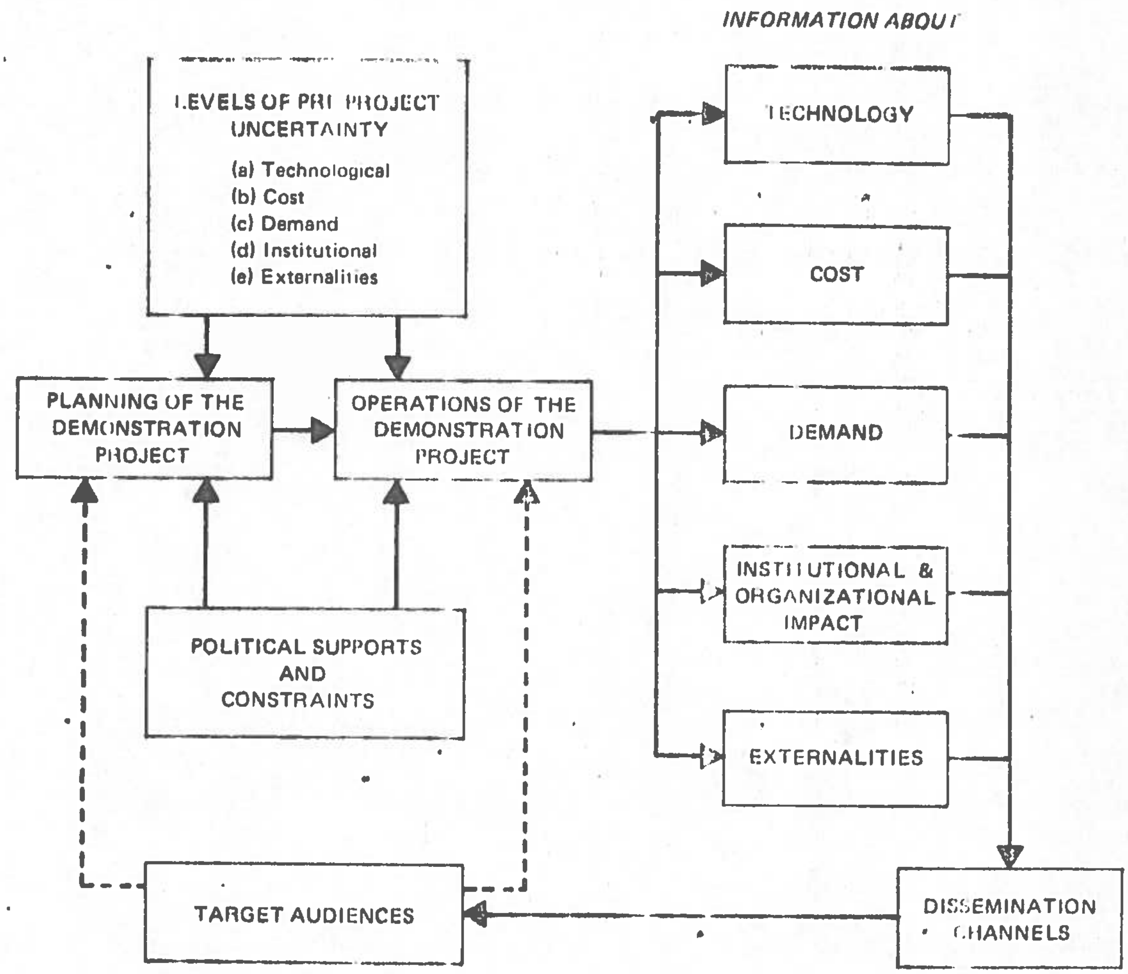
4. Institutional uncertainty: uncertainty about how adoption will affect a) the functioning and structure of the adopting organization; and b) the adopting organization's relationships with other organizations, such as labor unions or competitors.

5. Uncertainty about externalities: uncertainty about the health, safety, environmental, and other effects that are not accounted for in the price of either factor inputs or outputs.

The second criteria, application success, was fulfilled when the technology being demonstrated worked well in the local setting. It is worth noting that information and application success are laregely dependent measures, and one can be achieved without the other.

The third criteria, diffusion success, was defined as the extent to which the technology passed into general use as a result of the demonstration project. This measure was employed selectively by RAND, based on the project's objective as follows:

"Diffusion success is not applicable to demonstrations aimed solely at meeting 'high policy' goals, nor to regulation-oriented projects in which decisions about the technology's use are made



Source: Baer et al, Analysis of Federally Funded Demonstration Projects, [Ref. 1]

FIGURE 5-1. A MODEL OF NEW INFORMATION FLOWS IN DEMONSTRATION PROJECTS *largely by a regulatory agency and not by potential adopters. But for all market-oriented demonstrations, diffusion can be considered the pay-off measure of success."*

The conclusions from the RAND study are summarized in Table 5-2, and could serve as guidelines for Federal R&D efforts in the automotive area. Particularly noteworthy is item 5, which suggests the importance of involving automotive suppliers and vehicle manufacturers in future Federal automotive projects.

5.2 INTERPRETATION OF DEMONSTRATION PROJECT RESULTS USING THE ANALYSIS FRAMEWORK

The results of the demonstration projects were examined from the perspective of the analysis methodology developed in Chapter 4. First, from judgments based on project histories and associated data, each project was positioned along the two dimensions of Government policy. Figure 5-2 graphically illustrates the pattern that emerges when the projects are cast in such a framework.

Success or failure of each project, measured in terms of diffusion, is indicated by the type of dot on the graph. A solid dot is a success, a circle is a failure and partially shaded dots indicate degree of success. Even though a continuous scale is used for each axis of the figure, it is important to recognize that the projects have been positioned judgmentally, rather than in any precise or analytic sense. The illustration is conceptual since neither the data nor the definition of the scales are sufficiently precise to support analytic treatment. However, the framework and data are considered adequate to allow partitioning of the cases into high and low categories; as will be seen subsequently, this treatment is sufficient to support several interesting conclusions.

A definite pattern of interaction between the two categories of government initiatives is apparent in Figure 5-2. Considering the top half alone, representing projects with stronger technology push, the presence or absence of market pull would seem to be critical for project success.

TABLE 5-2. ATTRIBUTES OF PROJECTS SUCCESSFUL IN DIFFUSION*

1. A technology well in hand. Projects showing significant success were those in which the principal technological problems have been worked out beforehand.

2. Cost and risk sharing with local participants. The cases showing significant diffusion success involved nonfederal cost sharing, while those funded entirely by the federal government resulted in little or no diffusion.

3. Project initiative from nonfederal sources. Demonstration projects originating from private firms or local public agencies enjoyed greater diffusion success than did those directly pushed by the federal government.

4. The existence of a strong industrial system for commercialization. Diffusion proceeded more rapidly when there were obvious manufacturers and purchasers of the new technology, and when markets for similar products existed.

5. Inclusion of all elements needed for commercialization. Demonstrations showing significant diffusion success included in their project planning and operations potential manufacturers, potential purchasers, regulators, and other target audiences.

6. Absence of tight time constraints. Demonstrations facing externally imposed time constraints fared less well than did the others.

Source: Baer et al, Analysis of Federally Funded Demonstration Projects, [Ref 1]

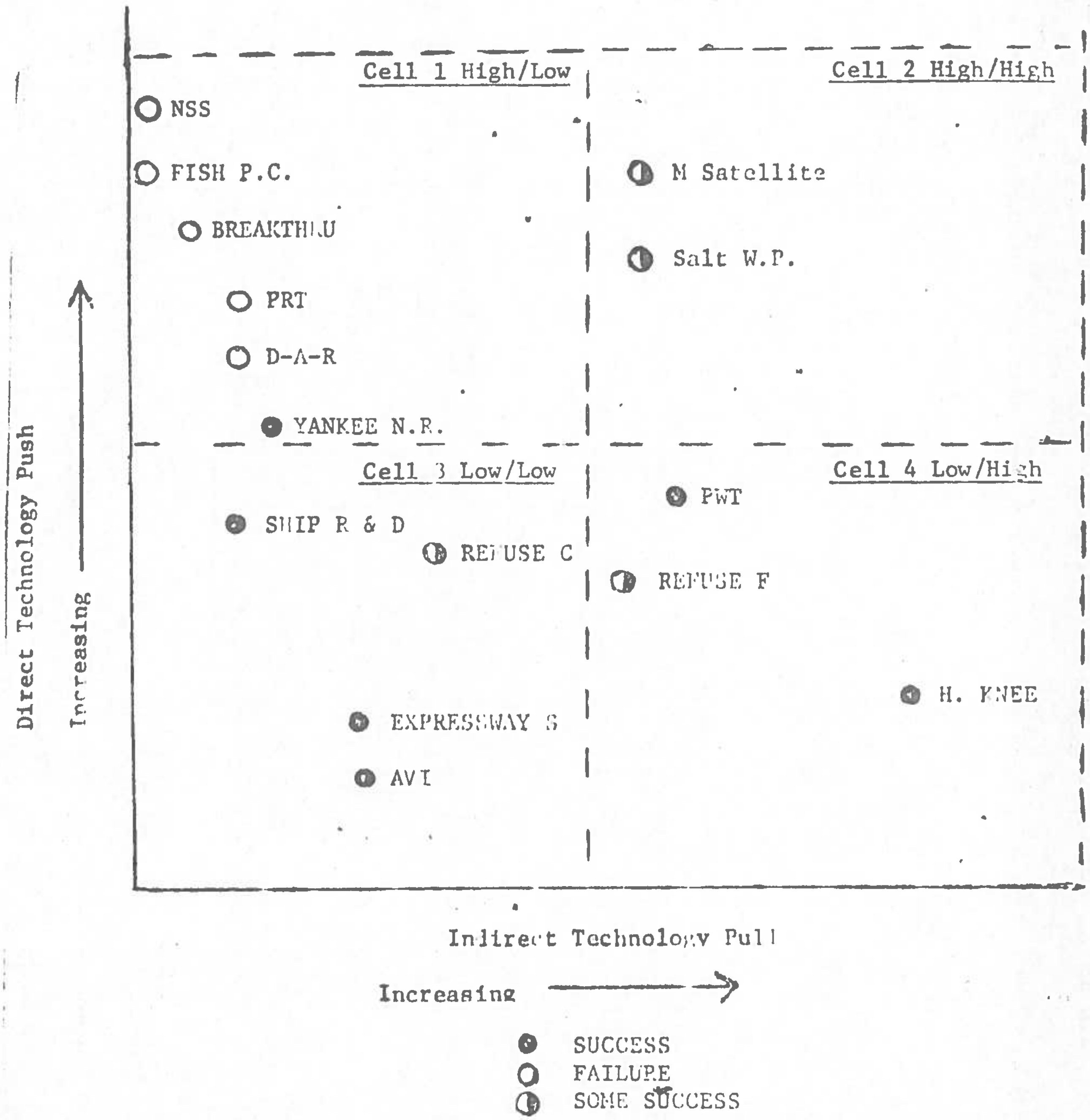


FIGURE 5-2. PROJECT SUCCESS AND FAILURE PATTERN VS. DEGREE OF TECHNOLOGY PUSH/MARKET PULL

Failure is the predominant outcome in the upper left cell, where there is intense technology push, but no corresponding market pull. This cell includes the Nuclear Ship Savannah, Operation Breakthrough, Dial-A-Ride, the Fish Protein Concentrate Plant, and Personal Rapid Transit. These projects uniformly represent situations where there was little or no changes in market incentives to encourage and support the adoption of a new technology. On the other hand, for the upper right cell, (high/high) government procurements actually supported the market for many of these proects, creating a strong modification action, whether intended as such or not. The Commercial Maritime Satellite was supported through the Navy's purchases of navigational satellite services, while the Loma Point Saline Water Conversion Plant was actually acquired by the Department of Defense for use at a Navy base during the demonstration project.

The successful Yankee Nuclear Power Reactor appears the one exception to the pattern that is otherwise so apparent in the upper cells. Actually even in this case, from a historical perspective the same generalization applies. Although the market for nuclear generated electric power, per se, had not been altered through government intervention at the time of this project, the market for nuclear products had in general been created earlier through purchases by the Atomic Energy Commission and Department of Defense. As in the other cases, the government modified or created the initial market through purchases for its own use. Beyond the issue of success or failure a second distinctive characteristic of the two upper cells is that they are populated by radical products, or if successful they led to major innovations. These projects envisioned major changes in practice within the industry where they were to apply. In doing so new organizations were stimulated to enter the field. The demonstration projects here may be characterized as big gambles to introduce major changes.

The two lower cells, represent situations where the government has been less venturesome in a technology push sense. However, the ratio of success appears much higher. From the case data it would also appear that the innovations which result under these conditions are much more incremental than for the upper cells.

Cell four, representing low intensity technology push but strong market pull (low/high), includes three projects. Of these, the Poultry Waste Processing and Refuse Firing Demonstration projects both represent successful attempts to solve waste disposal problems under conditions of tightening environmental controls and concerns. Both also represent projects that were initiated by organizations unrelated to the Federal Government but closely linked to the problem. They also did not rely heavily on Federal funds. In the Hydraulic Knee case the Veterans Administration used its market for the project to stimulate the innovation and dealt skillfully with the broader problems of market acceptance. In all three cases RAND characterized the initial technological uncertainty as low to moderate.

The cases in cell four seem to represent situations where the normal process of innovation has been accelerated through government action that directly or indirectly affected the market. These changes stimulated organizations which were already functioning within the respective fields to propose new solutions and seek out Federal R&D support. The results were a successful acceleration of incremental innovation through established organizations.

Cell three (low/low in Figure 2-5) includes four mostly successful projects involving municipalities, shipyards, the Tri State Port Authority and State governments. Unlike large, technology-based industrial enterprises, these types of organizations are often technologically less active. Certainly they cannot rely on the same level of industrial infrastructure that was present to support innovation in the prior health and food processing industry cases. In effect, the presence of a low intensity Federal program served as a catalyst for creating the necessary infrastructure to support technological innovation. According to the RAND report, the one partial success in this cell (Scottsdale's Mechanized Refuse Collection), resulted from the lack of an adequate industrial infrastructure for successfully refining and transferring the concepts to other cities.

5.3 JOINT EFFECTS OF TECHNOLOGY PUSH AND MARKET PULL

The joint effects of direct Government technology push, and market pull, as discussed above, are illustrated by the two-by-two matrix in Figure 5.3. Each cell is summarized in turn.

Direct Federal Technology Push	HIGH	1 Extreme Risk (High Failure Rate)	2 Radical Innovation (High Risk/High Payoff when successful)
	LOW	3 Normal Process Of Industrial Innovation-Enabled (Moderate Success)	4 Incremental Innovation-Accelerated (Moderate Success)

FIGURE 5-3. INTERACTION OF FEDERAL INITIATIVES

1. <u>Intense Technology Push, Weak Market Pull</u>. The troublesome failure to achieve success that is so apparent in the high/low cell is not just an artifact of the particular sample of cases that have been used to illustrate the present framework. Earlier experiences with other programs, the Eisenhower Administration's Atomic Aircraft program, the Breeder Reactor, the Super sonic Transport, are suggestive of the present pattern. This does not imply that all Federal programs which undertake a technology-based initiative are failures. For example, from a broad perspective the space program might be characterized as a successful Federal action of this type, and on a different level so might TVA and the

original Atomic Energy Program. The outcome of these programs has certainly been important, but even so subsequent diffision has come very slowly. Programs where technology push alone has been successful seem to have involved funding levels measured in fractions of the Gross National Product.

On balance it seems appropriate to characterize normal projects within this category as extremely risky. This does not mean they should not be undertaken since the benefits to society may greatly outweigh the cost even when adjusted for risk.

2. High Technology Push, High Market Pull. This cell is perhaps the most interesting. Beyond the present sample this category represents the environment of origin for many major innovations that have strenghened the US economy in the post-World War II era. For products like the computer [Ref 2], the jet engine [Ref. 3], and advanced semi-conductor devices [Ref. 4] as well as the present cases, the Federal government has played a major role in the innovation process through its joint initiatives in market modification and direct investments in technology. In particular, within the market modification category government procurement seems to have been critically important in creating a market for new technologies at a time in their life-cycles when they were characterized by high prices vis-a-vis competitive technologies, and a limited range of applications. Such support during the technology's infancy stage nutured evolutionary development to the point where broad-based commercial applications were economically feasible.

Government efforts within this category were not only a significant factor in major innovations in the 1950's and 1960's, but also served as an important influence for many less-known innovations in the more distant past as well as the present. For example, in his classic study of the radio industry [Ref. 4] McLaurin reports that government support was critical in the early development of that industry at the turn of the century.

Today we find evidence of innovative stimulation through the combination of government investment in technology and procurement even in a relatively mature industry like motor vehicles. One illustration of this is the FMC Corporation's New Choker Arch High Speed Logger, which has recently increased productivity in commercial logging operations. This equipment is able to operate at twice the speed of conventional tracked loggers through the use of a torsion bar suspension system that was originally developed by FMC for the US Army's MII3 Armored Personal Carrier. Data concerning this innovation suggest that both military and commercial customers have benefited from technology transfers within the divisions of FMC. An important aspect of the successful technology transfer in this case is that the firm which undertook the Federally sponsored R&D also had the capability to serve industrial markets. The significance of this dual role should not be overlooked under present circumstances where there is a definite need to infuse advanced technology in the automobile industry, and the history of successful technology transfers is somewhat obscure.

The FMC logger case also focuses attention on the important relationship between government action and industry infrastructure. This same aspect is also evident in the previous RAND data. In the Mechanized Refuse Collection case difficulties arose because such industrial infrastructure was lacking. Successful diffusion of an effective concept was thwarted because the relevant segments of the equipment supply industry were not involved in the innovation.

Government initiatives to stimulate technological change are apperently most effective when they directly influence the manufacturers of product components that embody the technology. It was important that FMC was a principal source of the component's technology for both the government and commercial markets. These ideas are consistent with the conclusions Burton Klein [Ref. 6] has drawn from his studies of government R&D policies underlying the successful development of high performance aircraft in the United States. He argues that to effectively promote a high rate of technological change it is important to support the development of innovative components by skilled manufacturers before advanced performance requirements are rigidly established. It would not seem sufficient to just undertake the most appropriate type of technology creation action. That action must also involve firms within the industry infrastructure that can serve the necessary markets with the component technology.

3. Weak Technology Push, Weak Market Pull. The effect of Federal initiatives in the third cell would seem to enable the normal process of industrial innovation in industrial environments where it is otherwise retarded. In terms of government policy goals this may be an important achievement. In some industries, notably segments of electronics or high technology segments of the medical equipment industry, existing competitive conditions already induce a high rate of innovation. In other industries, such as those which are highly fragmented or technologically stagnant, additional stimulus may be needed to encourage innovation. Under these latter conditions intense regulatory or market modification actions would probably not have a favorable effect. It is encouraging to note that in these cases moderate policies acted to stimulate higher levels of innovation.

4. Weak Technology Push, Strong Market Pull. The effect of Federal initiatives which induce strong market pull relative to technology push would seem to be an acceleration of technological change but through incremental innovation. The emphasis in this mode is on perfecting and refining established technologies rather than innovating with new ones.

The innovations in this cell acted to perfect and refine approaches and equipment that had already been introduced. This pattern of response would seem to be more pervasive than might be suggested by just the few cases that have been presently considered. Solutions required by safety, water and air pollution regulations have frequently been sought by capital equipment manufacturers through add-on components, minor adaptions and incremental changes. The effect is most pronounced in mass production industries, like automobiles where the cost of change is very high [Ref. 7]. One industry where product innovation is competitively important, that has recently come under increased regulation, is pharmaceuticals. Emerging performance trends here suggest that government action may have increased the cost of major technological change in the product and thereby slowed it [Ref. 8]. A similar chilling effect of regulation on major automotive innovation was predicted by Jacoby and Steinbruner in their book, Clearing the Air [Ref.9], which made the point in the context of pollution control and the internal combustion engine. They argued that intense pressure for rapid change would act to increase the risk of failure from undertaking new approaches and thereby lead to an entrenchment in established technologies. In other words the prospects for the introduction of a radically new technology are likely to be weakened by intense pressure for change. Another explanation for this entrenchment phenomenon arises from typical patterns of competitive response in other industries. When established firms find their traditional markets invaded by radical new products, as did mechanical calculator and vacuum tube producers some years ago, the response is often to compete through cost reductions and incremental innovations in established technologies. Incremental innovation is accelerated under this pressure, and in some cases the current advantage of established technologies over prospective new competing ones may actually be widened further in the process [Ref. 10]. Intense pressure for modification can therefore postpone the application of a technology that might be superior in the long run.

6. ASSESSMENT OF THE EFFECTIVENESS OF PAST FEDERAL EFFORTS INTENDED TO BRING ABOUT CHANGES IN AUTOMOTIVE TECHNOLOGY*

6.1 FEDERAL TECHNOLOGY CREATION EFFORTS

The scope and content of Federal Research and Development (R&D) programs relevant to automotive technology are difficult to identify. Projects are carried out by several agencies with funding provided by different sources, while reporting is fragmented. In the face of these difficulties a special approach had to be developed to define even rudimentary characteristics. A profile of relevant Federal R&D activity was created by compiling and analyzing a broad sample of automotive-related R&D projects. This sample of R&D projects was prepared from two sources. The first was the Inventory of Energy Research and Development 1973-75, prepared for the task force on Energy Research Development and Demonstration of the Subcommittee on Science and Technology, U.S. House of Representatives (Volume II). The second was the larger Smithsonian Scientific Information Exchange (SSIE) computer-based file of R&D projects. This second source helped to update the data base to 1977 and provide product safety-related R&D projects. Contact with SSIE personnel suggests that most government projects are included but that many industry-funded projects are omitted because firms did not report all their work to the SSIE file.

A list of projects in the data base, covering the period 1973 through 1977, appears as an Appendix in Reference 1. The number of projects sponsored by the various Federal agencies (e.e. the Department of Transportation (DOT), Department of Defense (DOD), Federal Energy Administration (FEA), Environmental Protection Agency (EPA), etc.) was used as a surrogate for government support for automotive-related R&D. From descriptions provided or from the

*Based on the report by William J. Abernathy, and Balaji Charkravarthy, [Ref. 1].

abstract of each research project, classifications were made in respect to: the technology addressed, sponsoring organization, performing organization, cost, and type and technical focus of the work.

1. Type of research was broken down into five categoreis:

   -survey work
   -basic research
   -applied research
   -development
   -or support of Federal rulemaking.

2. The focus of the research was represented by three major categories:

   -fuel economy (including advanced fuels and engines)
   -pollution control
   -product safety

3. Institutional structure concerns the type of organizations that sponsored and performed the research:

   -government agency
   -major automobile firm
   -automobile supplier
   -other industrial firm
   -university or consulting firm

6.1.1 Analysis of R&D Projects by Type

The nature of Federal R&D support by type and focus of project is summarized in Table 6-1, for each of the three major areas of interest. Some projects had a multiple focus, and we tabulated more than once. In addition, the data on safety may not be them representative of all Federal projects since the basic data source did not include comprehensive coverage of R&D projects in this category.

TABLE 6-1. TYPE AND FOCUS OF FEDERAL AUTOMOTIVE R&D PROJECTS

Type of Research	Number of projects sponsored by Federal agencies for:							
	Fuel economy		Pollution control		Product safety		Total	
	No.	%	No.	%	No.	%	No.	%
Survey research	12	14	4	6.5	8	18	24	12.5
Basic research	8	9	11	18.0	3	7	22	11.5
Applied research	35	41	25	40.0	2	5	62	32.0
Developmental research	14	16	9	14.5	1	2	24	12.5
Research to support Fed. rule making	17	20	13	21.0	30	68	60	31.5
Total	86	100	62	100.0	44	100	192	100.0

Table 6-1 shows that 44 percent of all Federally-sponsored projects did not undertake the type of work that promises to directly advance technology. Thirty-one percent of the projects supported Federal regulatory efforts and the other twelve percent were for surveys of various types. The government has invested heavily in applied research (32 percent of all projects), virtually neglecting basic research. In terms of dollars, the emphasis is even more biased toward applied research since applied projects tend to be more expensive than basic research. In the area of safety, there has been a very strong emphasis on R&D to support regulatory action, as opposed to work that might more directly support innovation.

Table 6-2 shows the distribution of projects by sponsoring agency. Of the government agencies supporting research, it is mainly the National Science Foundation, in its traditional role, that shows an interest in basic research. The major thrust of research and development by DOT has been to either sponsor R&D to back regulation or to undertake development work, most frequently to improve existing technology.

TABLE 6-2. TYPE OF R&D PROJECT BY SPONSORING AGENCY

Type of Research	Number of projects sponsored			
	DOT	DOD	NSF	Others
Survey	13	-	2	9
Basic	4	-	16	2
Applied	18	11	5	28
Development	8	8	1	7
Regulatory support	44	-	5	11
Total	87	19	29	57

The vast majority of R&D projects have sought improvements based on technologies that are either currently in mass production or that rely on well-established concepts. A general idea of the project breakdown by the type of technology is provided in Table 6-3. While some errors may have been introduced in classifying the projects in this way, (we are under the impression), the underlying distribution is not far from the one suggested in this table.

TABLE 6-3. ANALYSIS OF FEDERAL R&D PROJECTS BY TECHNOLOGICAL OBJECTIVE*

Objective	Projects with Fuel Economy Focus (%)	Projects with Emission Improvement Focus (%)
1. Improvements for current technology	61.0	72.1
2. Incremental advances based on current technologies	4.3	4.9
3. Different combustion technologies		
a) External combustion	2.4	5.7
b) Rotary engine	1.8	1.6
c) Turbine	4.9	7.4
4. Electric vehicle and related technology	11.0	4.1
5. Fuel research	13.4	4.1
6. Weight reduction by material substitution	1.2	——
Total	100.0%	100.0%

*Based on analysis of projects in sample.

Over eighty percent of the projects supported by both NSF and DOT sought advances related to conventional technologies, in both the fuel economy and emissions categories. Other government organizations, notably DOD, ERDA and EPA, sponsored a larger percentage of projects concerned with unconventional technologies. The automobile manufacturers and automobile supplier firms seem to have supported a larger precentage of projects related to unconventional technologies. A note of caution is appropriate here for the data would suggest that most firms in the automotive industry do not seem to have reported many of their internal projects.

6.1.2 Resource Commitments

On the average the reported spending per project by the Federal agencies has been appropriate for survey research, legislative support and other analytical work but quite modest for achieving significant technological development.

Table 6-4 summarizes expenditures by agency for fuel economy and pollution control projects.

TABLE 6-4. AVERAGE R&D EXPENDITURES BY AGENCY FOR FUEL ECONOMY AND POLLUTION CONTROL PROJECTS

Federal Agency	Average R&D funding ($ in 000)	
	On fuel economy	On pollution control
DOT	349	247
DOD	571	498
NSF	117	77
Others	604	425

These data should be interpreted as sample statistics since funding levels were not available for nearly half of the R&D projects reported in the data base. The probable bias induced by the missing data is an overstatement of the average funding levels, since it is more likely that cost figures were omitted for smaller projects as opposed to fewer big ones. In those projects which have been funded the emphasis seems to be on modest improvements in existing technology, survey research and regulatory support, rather than the more expensive ground-breaking work required to bring new concepts near the realm of practice. Additional information on the level of resource commitments is provided by Table 6-5.

TABLE 6-5. DISTRIBUTION OF PROJECT FUNDING LEVEL BY SPONSOR

R&D Funding Category (in $1000)	Percent of Federal Projects by Funding Level							
	Fuel economy				Pollution control			
	DOT	DOD	NSF	Other Fed.	DOT	DOD	NSF	Other Fed.
20	48.4	10.0	5.9	42.9	50.0	20.0	21.4	37.0
20-150	32.3	20.0	76.5	17.9	21.4	20.0	64.3	25.9
150-1000	16.1	60.0	17.6	28.6	21.4	50.0	14.3	29.6
1000	3.2	10.0	-	10.7	7.1	10.0	-	7.4

Over 95% of all projects sponsored by Federal agencies on fuel economy, pollution control, and safety involve expenditures of less than a million dollars. Only 9 projects in all, in out data base, of 192 Federally-sponsored projects, were supported at levels over one million dollars. Not much in the way of serious development work can be done with such modest resource investments. Focusing on the efforts of the Department of Transportation, around fifty percent of all DOT sponsored projects were funded at levels under $20,000 per project.

6.1.3 Institutional Structure

Finally there is the question of the institutional context in which the projects were sponsored and conducted. The sample data on which the analysis is based suggest that the bulk of the

Federally sponsored R&D projects were carried out by universities, research organizations, industry associations or other organizations not in the mainstream of the automobile industry. Table 6-6 is a matrix showing the sponsor and performer of R&D in the auto industry, derived from the present sample of projects.

It is clear from Table 6-6 that Federally funded automobile R&D has not included organizations within the industry, whether they be manufacturers or suppliers. While the data base does suffer from incomplete information on the projects sponsored and performed by the auto manufacturers and suppliers, we believe it is accurate to state that all projects which received Federal assistance would have been reported. Conversely, the unreported ones are largely privately sponsored. Therefore, the incompleteness of data does not detract from the conclusion that the Federal sponsors in general, and DOT, in particular, have not involved the auto industry in Federal R&D activities.

To the extent that Federal R&D programs intend to stimulate technological change in future cars, failure to involve major production firms in this process is of serious concern. The problems of successful technology transfer to mass production industries loom larger than those which arise in carrying out laboratory-oriented research work in the first place. Lessons from the aircraft and electronics industry suggest that innovative component developers must be intimately engaged in the process of successful system innovations. The whole question of appropriate institutional involvement in the conduct of R&D is a question worthy of close examination if the role of Federal R&D is to be considered.

A revealing difference among R&D funding patterns of three important agencies (DOT, DOD, and NSF) is suggested by an earlier table (Table 6-5). It is fair to say that the Department of Defense probably has the longest history, and the most extensive experience, in successfully reducing technological concepts to practice under both routine and crisis conditions. Although it is not principally concerned with regulatory issues, it is an agency whose R&D programs must be responsive to the needs of a large operational capability; in this sense its funding patterns are somewhat comparable with DOT's. Would the Department of Defense's relative emphasis on larger projects and on applied R&D be appropriate to bring new concepts to practice? The National Science Foundation on the other hand has a mission to support more fundamental research in the disciplines. It has a distinguished history of supporting important work underlying many innovations. It is not surprising that NSF tends to fund many projects at lower levels of funding, while DOD seems to focus its efforts directly on larger projects, taking them closer to practice than does DOT.

APPENDIX A
SELECTED BIBLIOGRAPHY ON INNOVATION

Abernathy, W.J., Rodgers, W.

Technological Innovation in Industry: The Issue of Direct Government Intervention

Harvard Business School 75-15, June 1975

Judging from experiences with previous regulatory action, this study concludes that certain parameters governing such actions have been improperly or incorrectly assessed. The report singles out the fact that past attempts have based the criteria of cost and feasibility on political perceptions, ignoring technological and economic constraints; that emphasis has been placed on political perceptions ignoring technological and economic constraints; that emphasis has been placed on rapid technological change without a full understanding of its particularly vis-a-vis slow evolutionary change; that the parameters determining technological change have been too rigid; and that the internal characteristics of the particular industries have been overlooked.

Amihud, Yakov

"The Efficiency of Taxes and Subsidies in Reducing Emission by a Risk-Averse Firm."

Kylos, Vol. 29-1976 - Fasc. 1. 113-117.

Through the use of a mathematical proof, this paper examines the comparative effect of two alternative policies aimed at impelling firms to reduce their polluting emissions. These are a tax per unit of emission or a subsidy per amount withheld. The proof that is presented assumes that when firms are faced with uncertainty and their decision makers are risk-averse, short run production decisions depend on the total profit of the firm.

The author concludes that (1) a subsidy is always less efficient than an equal-rate tax in curbing emission and (2) in some extreme cases, a subsidy may even cause the firm to increase, rather than decrease, its emission.

Averich, Harvey and Johnson, Leland

"Behavior of the Firm under Regulatory Constraint"

American Economic Review, May 1973

This paper develops a model of the firm's behavior under a regulatory constraint which limits the return on capital investment to a level specified by a Government regulatory body. Major assumptions of the model are (1) the firm seeks to maximize profit, (2) the market cost of capital is constnat, (3) the allowable rate of return exceeds the cost of capital and (4) no regulatory lag exists.

Given these assumptions use of the model leads to the conclusion that the capital-labor ratio is greater than that which would minimize cost at the level of output selected by the firm, and the firm may have an incentive to serve competitive markets even if revenues fall below incremental cost in those markets. The difference is more than compensated for by increased net revenues resulting from price increases for the firm's monopoly services.

Baumol, William J.

"On Taxation and the Control of Externalities"

American Economic Review, June 1972

In this paper Baumol advocates taxation as an effective method for controlling pollution. He supports his premise by citing an example where smoke emissions from a factory affect neighboring laundries. Baumol presents a two-step procedure for controlling the externalities created by a polluter and uses the factory-smoke emission as a case in point to demonstrate its potential effectiveness. The first step consists of setting standards which include the level of pollution considered to be tolerable. The next step is to design a system of taxes and effluent charges whose rates are shown by experience to achieve the selected standards of acceptability. He states that the method will lead to an efficient allocation of the required reduction in emissions among the offending firms even if they are neither pure competitors nor profit maximizers. The methodology he uses to prove this is a general equilibrium model. His general conclusions are that when the tax on the externality producer is set properly, the externalities themselves control the size of the adjacent population: a high tax rate will discourage smoke and hence, drive residents away. Therefore, the government can achieve any desired pollution level simply by setting a per unit tax rate for each type of pollution.

Binswanger, H.P.

"A Microeconomic Approach to Induce Innovation"

Economic Journal, December 1974

In this paper Binswanger shows through the use of a model, invention possibilities are reformulated using research processes that have different cost indications for rates and biases of technical change. He uses a comparative static model to show that a firm maximizes present value of an investment project by the choice to build a plant of existing design or to improve it by research. Research costs and present value of factor cost were found to influence the research mix.

A rise in any labor cost component leads to a more pronounced labor-saving bias, except when innovative possiblities are very restrictive.

Buchanan, J.M. and Tullock, G.

"Polluters', Profits and Political Response: Direct Controls Versus Taxes"

American Economic Review, March 1975

This paper indicates that direct controls are observed more frequently than penalty taxes. A positive theory for the predominance of direct controls is developed both for production and consumption externalities. Firms in the affected industry will prefer direct controls because of the profit opportunities. The analysis also suggests that direct controls introduce higher policing costs than taxes. With consumption externalities, some consumers will prefer direct controls for distributional reasons, and all consumers may prefer direct controls under certain assumption about the use of tax revenue.

Bunch, Howard; Kubacki, Michael

An Analysis of Industry Responses to Federal Regulations in Safety Requirements For New Automobiles

HSRI Report UM-HSRI-77-14, March 1977,
Prepared for the U.S. Department of Transportation

The authors examine the response of the automobile industry to Federal safety regulations promulgated since the vehicle safety act of 1966. The report found a) The most common objection to a proposed standard is the lack of sufficient lead time b) In instances where industry questioned the value of a standard, promulgation was hasty and without sufficient R&D c) Standards lead to product uniformity, while manufacturers wish to preserve product differences d) There is a need to develop a process for continually reviewing the benefits and costs of existing standards.

Charles River Associates Incorporated

"Inducing the Development and Adoption of Socially Efficient Automotive Technology"

CRA Report No. 322, April 1977

The basic premise of this study is that "Alternative regulatory policies exist, placing greater reliance on market forces, product information, and fiscal incentives, which are more likely to lead to the development and introduction of socially more effective automotive technology than present mandatory standards." In a direct reference to the incentives for innovation, the reports argue that use of standards limit innovation by providing great penalties for failure to meet the goals, even if by a small amount, and does not provide any incentives to exceed the standards.

Comanor, W.S.

"Market Structure Product Differentiation, and Industrial Research"

Quarterly Journal of Economics, vol 81, Nov. 1967, pp 639-57.

In this study Comanor attempts to support his theory that a principal goal of research activity is creation of entry barriers through product differentiation, thus resulting in low research outlays where high entry barriers of other forms were present. The study compares, through regression analysis, average research personnel - adjusted by firm size - with industry variables reflecting industry concentration, opportunities for product differentiation, and levels of entry barriers. Comanor concludes that innovation rate appears lowest when entry barriers are either quite high or quite low. The highest rate occurs at an intermediate point where entry barriers preclude rapid imitation but do not foreclose entry.

Hoffer, George, Marchand, James, and Albertine, John

"Pricing in the Automobile Industry: A Simple Econometric Model"

Southern Economic Journal, July 1976

This paper presents a single equation model, along with the estimation of that model, which tests the importance of various cost factors to the determination of auto prices. The time series used are annual data over 23 years beginning in 1953. The independent variables employed (1) a measure of expected growth in production and sales and (2) a composite cost index based on the Bureau of Labor Statistics wholesale price index for the category.

The conclusions were (1) the cost variable was significant at the .01 level. Further, approximately 90% of the observed variation in auto price changes is explained by costs. (2) Wholesale prices were found to be a direct function of the anticipated strength of demand in the auto market. (3) Market forces have become a stronger influence on auto prices more recently.

Jewkes, John; Sawers, David; and Stillerman, Richard

The Sources of Innovation

MacMillan and Co. Ltd., London 1960

This work represents an effort to identify and analyze the major factors affecting the innovation process. Basing their conclusions on numerous and well documented case histories of major technological innovations, the authors tackle the entire gamut of related issues giving particular emphasis to: Modern views of invention, the individual inventor, invention in the industrial corporation, and the general developmental process of invention.

Lerman, F.

"Standards Versus Taxes - The Political Choice."

Regulating the Automobile, by Heywood, J.B.; Jacoby, H.D.; and Linden, L.H.,

M.I.T Energy Laboratory Report 77-007.

Mr. Lerman attempts a comparison between the two methods of implementation, taking into account their socio-political acceptability. In doing so he points out that implementation of market-like arrangements faces several important barriers such as: The determination of market incentives is as complex as standards setting, the uncertainty of market response remains great, taxes lack the necessary symbolic reassurance, they appear too indirect and too complicated, they are often viewed as a "License to Pollute" or a "Tribute for Wrong Doing." Nor do they have a direct appeal to the individuals with legal backgrounds who comprise a majority of the legislative branch.

Maclaurin, W.R.

"Technological Progress in Some American Industries"

American Economic Review, vol 44, May 1954, pp 178-89

This is a study of the effect of market structure on innovation, comparing 13 U.S. industries by their innovations during 1925-1950, with ranking by the extent of monopolization in 1950. These rankings take into account the size of industry price leaders and ease of entry. Another ranking was based on the number of patents issued, number of scientists with doctorates, and the presence or absence of a research department with responsibility for development. Maclaurin's conclusion was that while some degree of monopoly power is necessary, it is not sufficient. Ease of entry, entreprenurial leadership, a competitive spirit, and the base of knowledge were considered essential.

Nelson, R.R.,

"The Simple Economics of Basic Scientific Research"

Journal of Political Economy, Vol 67, June 1959, pp 297-306

One of the premises discussed by Nelson in this work is the ability of large firms to undertake diversified research in order to minimize the risks associated with any particular project. The large firm will also be able to find a broader range of uses for a particular innovation, while the smaller, single-product firm will not be able to exploit any new product not directly linked to its primary output.

Rubenstein, A.

Federal Stimuli to Development of New Technology By Suppliers

Final report prepared for the U.S. Dept. of Transportation, March 1977

In this work the author identifies barriers and facilitators to innovation by suppliers to the auto industry. The findings of the study are:

Barriers to Innovation include: Federal Regulation/Cost/Technical reliability/market considerations/Vehicle Integrity Concerns/Absence of Suitable Test Procedure/Lack of Management Support
Facilitators of Innovation include: Federal Regulations, existence of a persistent problem, market potential, Government R&D, technological capability of suppliers, and federal financial incentives

The study recommends: a) the establishment of consistent test procedures b) consideration of vehicle integrity issues in policy making and c) provision for adequate lead time requirements, for both manufacturers and suppliers, in setting regulatory schedules.

Scherer, F.M.

"Market Structure and the Employment of Scientists and Engineers"

American Economic Review, Vol 57, June 1967, pp 524-31

In this work Scherer attempts to contradict the theory that R&D input (employment) is directly related to firm size. By using 448 of the 500 largest firms Scherer compared, mathematically, 1955 R&D employment and sales. He found that the relationship had an inflection point, with R&D increasing faster than firm size among smaller firms but slower among larger firms. Scherer postulated that R&D employment might actually fall with increasing size among the largest of firms.

Schultze, Charles L.

"The Public Use of Private Interest"

Brookings Institution, May 1977

In this famous paper Schultze presents an eloquent argument in favor of the use of marketlike arrangements for the implementation of certain societal goals. In doing so he suggests that the practice of standards setting is an inferior tool because of several factors, including: The process of standard setting is extremely complex and virtually beyond the capability of a central administrative agency; the product oriented approach is quite costly; standards are often the result of an intense struggle which are ultimately decided by political and social factors at the expense of economic considerations, standards do not involve the use of incentives, the creation of market analogues, or the promotion of competitive institutions. Marketlike arrangements, on the other hand, stress incentives, minimize the need for coercion and allow a certain freedom of choice on the consumer and manufacturer.

Schumpeter, J.A.

Capitalism, Socialism, and Democracy

3rd Edition, Harper and Row, New York, 1950

Schumpeter is the foremost advocate of the concept that monopoly power and size spur innovative activity. He envisions the economy as an organism with cells constantly dying and being replaced by better ones. Regeneration is achieved by replacement of existing products and processes with better ones. Schumpeter considers the quest for profits through innovation as the motivating force behind this process. However, innovation requires a sizeable commitment of resources and a commensurate rate of returns to make it worthwhile, and only firms of considerable size and monopoly power will find innovation attractive.