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INDUCING THE DEVELOPMENT AND ADOPTION OF SOCIALLY EFFICIENT AUTOMOTIVE TECHNOLOGY

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16. Abstract

Federal policies for inducing the development and adoption of innovative automobile technology are examined using a welfare economics framework. Socially efficient technology is defined, and criteria are identified for evaluating public policies; these include (a) feasibility and efficacy, (b) mechanism for tradeoffs, (c) information requirements, (d) incentives for information generation, (e) incentives for optimizing technology, and (f) effects on uncertainty. Current and alternative policies are evaluated by the criteria. Policies which place greater reliance on market forces, product information, and fiscal incentives can overcome many of the barriers to innovation which confront performance standards.

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PREFACE

The energy crisis, coupled with the goal of a cleaner environment and a reduction in traffic fatalities, has created an unprecedented national requirement for the development and implementation of socially efficient auto technology. In response to this urgent need, alternative Federal policies for inducing innovation are being assessed under the Auto Technology Program. This is a complex task, encompassing Regulatory Interventions, R & D Incentives, Economic Incentives, and Institutional Incentives for both the buyers and producers of automobiles. The current study will, with its focus on criteria for evaluating alternative Federal policies, provide an important link in addressing these questions.

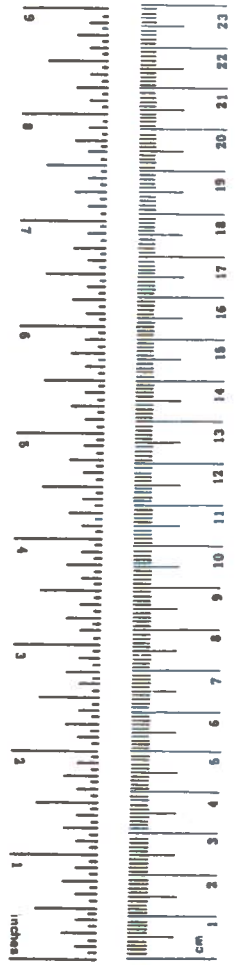
The current program traces its origins to the Automotive Energy Efficiency Program which was started in 1974 to evaluate the capability of the automotive industry to improve the fuel economy of their production vehicles, and to assess the energy, safety, economic, and environmental effects. The importance of these objectives was 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 GVW was delegated to NHTSA, and the present project was born, with its focus on significant issues of technological innovation as influenced by Federal Policies.

This work was carried out as part of the Auto Technology Program (OS-714) at the Transportation Systems Center, under the sponsorship of Mr. William Devereaux, Office of the Secretary of Transportation. The contract technical monitors were Mr Robert Ricci and Dr. Bruce Rubinger.

METRIC CONVERSION FACTORS

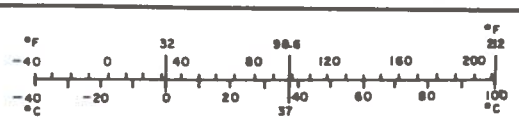
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

The development and introduction of socially more efficient automotive technology have been of increasing interest to Federal policy makers, as Federal regulation of automobiles has expanded over the last decade. Opportunities for innovation surely exist. For example, a recent study by a Federal Interagency Task Force concluded that reductions in automobile (and light truck and commercial vehicle) fuel consumption could be achieved by development and introduction of presently known engine and vehicle technology, and that the resultant fuel consumption savings and economic payback would be large.[1] A widely quoted, study by Jet Propulsion Laboratory has concluded that development of either the Stirling or Brayton (gas turbine) engines would result in gains in fuel economy, reductions in emmissions, and reductions in automobile capital and operating costs, relative to further development of the conventional Otto (internal combustion) engine.[2] Major Federal policy problems are the identification of impediments to the development and introduction of socially more efficient technology, and the design of policies which encourage rather than inhibit desirable innovation.

Federal regulation of automotive design and technology dates from the Highway Safety Act of 1966. Subsequent legislation and regulation have added emissions, damageability, fuel

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* For a bibliography of other studies of alternative automotive engine technologies, see General Motors' Analysis of the Jet Propulsion Laboratory Report "Should We Have A New Engine?" Environmental Activities Staff, General Motors Technical Center, November 1975.

economy, and (when regulations are promulgated under existing legislation) noise to the list of attributes subject to regulation. The most significant of these regulations are mandatory product standards on performance and design attributes, which must be met by cars sold in the United States.

We contend 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 efficient automotive technology than present mandatory standards. These alternative policies shift more of the burden for tradeoffs among competing private and social utilities onto those with the best information on costs and utilities, manufacturers and their customers, while providing proper incentives in those instances where market incentives do not fully reflect gains and losses to society as a whole.

1.2 APPROACH AND SCOPE

This paper does not attempt to assess alternative technologies, or to identify socially desirable innovations. Rather, it provides a definition of "socially efficient technology," proffers criteria for evaluating public policies designed to encourage socially efficient technology, summarizes what is known about market and regulatory forces which can aid or impede its development and introduction, and assesses present and alternative policies.

The paper analyzes market and regulatory forces which make it attractive for the private sector to introduce socially more efficient technology and for the private sector to innovate, rather than government policies to support research, development and demonstration of new automotive technology. The basic rationale for government sponsorship of basic research is well known, since the benefits of basic research accrue not only to the firm which sponsors it. These external benefits, however, tend to recede as the research becomes more applied. Public support for research, development and demonstration (R, D and D) can lower the costs and risks of innovation, but the major forces

shaping the development and introduction of new technology will continue to be market and regulatory forces.

Modern welfare economics is an analytical tool which identifies when producers and consumers, acting in their own interest in a market setting, are likely also to act in a broader social interest, and when markets are likely to fail to achieve this desired result. Welfare economics also postulates a criterion of social interest, based on the aggregate of individual interests, and a principle for inferring valuations based on the choices made by individuals when confronted by alternatives.

The welfare economics framework gives a rationale for government intervention, based on the fundamental valuation criteria of individual preferences and valuations, when markets fail to make the appropriate tradeoffs. However, this framework is a poor predictor of actual federal policy. While some *types* of federal intervention (e.g., emissions regulations) can be rationalized within a welfare economics framework, the degree of such controls, and the mechanism by which the degree of control is arrived at, cannot be so rationalized. Other types of controls, such as damageability (bumper) standards and fuel economy standards, are difficult to rationalize within a framework which emphasizes individual preferences.

We have adopted in this paper a definition of socially efficient automotive technology which is based on a welfare economics criterion. Present and alternative public policies are evaluated with respect to this definition of socially efficient technology. An alternative approach would have been to identify socially efficient technology with the present mix of automotive regulatory policies. However, we have not succeeded in discovering any underlying and unifying principle which Congress is seeking to maximize. Like most public policies, automobile regulations represent a series of political compromises among conflicting goals. It seems best, therefore, to adopt a welfare economics definition of social efficiency, leaving it ultimately to policy makers, as influenced by their

constituents, to decide whether, and to what degree, social efficiency is a desirable goal of public policy.

1.3 SUMMARY

Section 2 defines "socially efficient" technology, based on the fundamental criterion that individuals' evaluations of goods and services are revealed by the choices they make when confronted by alternatives. Criteria for evaluating the extent to which public policies may contribute to socially more efficient automotive technology include feasibility and efficacy, mechanism for tradeoffs, information needed to optimize policy, incentives for information generation, incentives for optimizing technology (including incentives to innovate), and effects on uncertainty.

Section 3 identifies the prospect of profit as the major force which drives innovative effort, and discusses possible impediments to innovation of socially more efficient technology. The presence of externalities can inhibit development and introduction of socially more efficient technology (for example, a new engine which has lower emissions, the benefits of which do not accrue to the car's purchaser). Information difficulties can inhibit the purchaser's choice of a car which is best for him, thus inhibiting innovations which are difficult for the purchaser to evaluate. Uncertainty can be an impediment to innovation, and mandatory standards can increase uncertainty. Market power and alleged social irresponsibility of manufacturers are found not to be impediments to the development and introduction of socially more efficient automotive technology.

Section 4 summarizes some empirical evidence on external diseconomies of automotive design. Clear externalities exist for emissions and noise. Safety externalities exist, but might be substantially reduced by insurance rate reform. External diseconomies are found not to exist in areas now regulated by damageability and fuel economy standards, assuming that the price of fuel reflects its social cost.

Section 5 presents a conceptual framework which arrays regulatory policies in a spectrum; specification of product

characteristics, mandatory performance standards, fiscal incentives, mandatory product information, and market forces alone. Major regulatory laws are summarized, and present regulations are listed. Most regulation consists of mandatory performance standards or product characteristics specification. No support was found for the hypothesis that Congress, in establishing a framework for automotive regulation, was seeking to internalize external diseconomies, or to achieve greater social efficiency.

Section 6 presents alternative policies, and evaluates them according to the welfare economics criteria outlined in Section 2. The alternative policies are a new car emissions tax and safety information with insurance rate reform. We argue, based on our brief analysis of these alternatives, that feasible alternatives to mandatory standards exist. These alternatives rely more on market forces and individual choice, and have the potential for better inducing the development and introduction of socially more efficient automotive technology.

2. SOCIALLY EFFICIENT TECHNOLOGY

2.1 WELFARE ECONOMICS FRAMEWORK

In this section, "socially efficient' technology is defined, and criteria for evaluating alternative public policies are derived. The definition is based on the premise that people act in their own self interest and reveal that self interest in their marketplace decisions. However, as is shown in Section 5, it is not possible to rationalize current public policy toward automobiles within this welfare economics framework, either in terms of stated policy goals or in terms of the actual content of regulatory policies.

The basic premise of modern welfare economics holds that people act in their own self interest, and that the choices they make in the market reveal their values. A decision maker, whether a producer or a consumer, acts to maximize his own utility, subject to a budget constraint. Choices are made among alternative courses of action, including the purchase and use of automobiles, based on the costs and benefits to the chooser. In theory, there is a one-to-one correspondence between the statements "Mr. X is better off (has a higher level of welfare) in situation A than in situation B," and "Mr. X chooses A in preference to B."

This basic premise supports the use of competitive market prices as measures of marginal value or benefit to consumers and producers, and is the foundation of benefit-cost analysis.

Harberger has formalized the premise into the following two basic postulates of applied welfare economics:

1. "The competetive demand price for a given unit measures the value of that unit to the demander;
2. The competetive supply price for a given unit measures the value of that unit to the supplier."[3]

A third postulate of applied welfare economics, which also underlies benefit-cost analysis, states that the analysis is neutral with respect to income distribution. Benefits and

costs are summed algebraically irrespective of "to whomsoever they may accrue." Policy I, which reduces Mr. X's welfare by $1.00 and increases Mr. Y's welfare by $1.50, would have the same net benefits as Policy II, which increases the welfare of both by $.25. Formally:

3. "When evaluating the net benefits of a given action (project, program or policy), the cost and benefits accruing to each member of the relevant group (e.g., a nation) should normally be added without regard to the individual(s) to whom they accrue."[3]

Despite the obvious limitations which this third postulate imposes on the usefulness of benefit-cost analysis, it is not an arbitrary postulate. It is much easier to calculate aggregate benefits and costs of a given action than to trace the diffusion of these benefits and costs throughout the economy in order to determine their ultimate incidence on individuals.[4]

Benefit-cost analysis of public policies is controversial. The arguments against its use may be characterized either as arguments against the postulates themselves or arguments that the actual application of benefit-cost analysis is impossible because information about benefits and costs is absent or imperfect. In this paper, we accept the above postulates, but explicitly recognize that information needed to optimize policies is costly and that policies have to be formulated in the absence of perfect information.

The basic postulates support, as a first approximation, competitive market institutions as devices for maximizing social welfare. For our purposes, it is useful to focus on those areas where this first approximation does not hold. These include externalities and other forms of market failure. The basic ideas are well developed in the economic literature. We will apply these ideas to examine public policies to stimulate development and adoption of automobile technologies which are socially efficient in a specific sense, i.e., they give people more of what they want, as revealed by their choices

(taking into account all costs and benefits, including those imposed on people other than the immediate chooser, and not weighting costs or benefits to one group or individual differently from those to another).

2.2 CRITERIA FOR POLICY EVALUATION

This section discusses criteria for judging the degree of success or failure of alternative policies designed to encourage socially more efficient automotive technology. The criteria are based on the welfare economics definition of socially efficiency. Section 6 analyzes present and alternative regulations, using these evaluation criteria

2.2.1 Feasibility and Efficacy

The policy ought to be administratively feasible, and ought to produce desirable results. Proposed policies ought to be evaluated with reference to present policies or to some other realistic baseline, and not to some ideal standard. Important parts of administrative feasibility and efficacy are the cost of enforcement, and the difficulties associated with ensuring compliance.

2.2.2 Mechanism for Tradeoffs

The policy ought to have a specific mechanism for trading off different amounts of goods or utilities. A major shortcoming of present automobile regulatory policies is their lack of such an explicit mechanism. Just as consumers must make tradeoffs among competing goods, public policies must balance the attainment of one type of good (the benefits of a policy) against the sacrifice of other goods which it entails (the cost of a policy). In principle, the ultimate judge of costs and benefits would be individuals revealing preferences in the marketplace.

For those goods not having markets, one would look for surrogate mechanisms for making tradeoffs. For example, although individuals cannot purchase environmental quality in a marketplace they can buy homes or accept employment where the air is cleaner. Their willingness to pay a premium for cleaner

locations or accept lower wages in cleaner surroundings, other things being equal, is a measure of willingness to pay for environmental quality.

Lack of a mechanism in a particular regulatory policy for making tradeoffs between competing goods, or lack of success in making tradeoffs so as to maximize net benefits, would be evidence of regulatory failure to induce socially efficient technology as defined above.

2.2.3 Information Needed to Optimize Policy

Not only must the policy mechan-sm allow for tradeoffs among utilities, but the information needed to calibrate the regulation to bring about an improvement in social welfare should be reasonable in extent and cost. Optimal policy must achieve the desired social results at least cost, and also maximize net benefits.

If Congress or an administrator were in possession of complete information about the full range of consequences of different kinds and levels of mandatory standards, it would be feasible to design an optimal set of standards. Since public officials are not omniscent, policies ought to consider information requirements needed to optimize or come reasonably close to an optimum policy. It is argued in following paragraphs that optimal fiscal and informational policies require less information than mandatory product standards.

2.2.4 Incentives for Information Gathering

The policy should provide incentives to the private sector to generate both information which would help to optimize public policy, and information which would help both persons and firms in the private sector to more nearly maximize their own utilities. The present regulatory framework contains adverse incentives for information generation. Whether or not automobile manufacturers mislead policy makers and the public about the costs of regulations, many people distrust manufacturers' pronouncements of costs. These people perceive an adverse incentive in that predictions of high costs may tend to

decrease the probability of a particular regulation being imposed or to decrease the severity of the standards. Moreover, the present system of mandatory standards contains no mechanism by which consumers can reveal their own valuations of automobile attributes which are regulated by the standards.

It may well be that market forces do not induce producers to disseminate the optimal amount and quality of information about products. There is a long history of regulation of weights and measures, labeling and laws against fraud and misrepresentation. Advertising often seems to contain biased or incomplete information. Therefore, policies to encourage or require better information may help the consumer decision process and improve the social efficiency of markets.

2.2.5 Incentives for Optimizing Technology, Including Incentives To Innovate

The policy ought to encourage both the adoption of existing technology which is socially efficient and innovation to create socially more efficient technology. While mandatory standards encourage changes in automobile attributes, they can stifle innovation. This is due to the great penalities associated with failures to meet the standards, if only by a small amount, and the lack of rewards for exceeding the standard, no matter by what amount.

2.2.6 Effects on Uncertainty

The policy ought to reduce, not increase, uncertainty faced by the public and private sectors. Uncertainties faced by policy makers include the cost and other effects of different levels of the policy, such as the effects on automobile prices and consumer acceptability, and the effects on such social goals as reducing fuel consumption, accident deaths and injuries, and air quality. Uncertainties faced by manufacturers include costs of new technology, consumer acceptance, and the nature and magnitude of future regulations. Uncertainties faced by consumers include operating costs, performance, and other attributes of the automobile. Policies can be designed to reduce these uncertainties, rather than to exacerbate them.

3. INCENTIVES AND IMPEDIMENTS TO INNOVATION

3.1 FORCES WHICH DRIVE INNOVATION

What forces drive innovation in general, and automotive innovation in particular? Is there reason to suspect that these forces, left to themselves, might not call forth socially efficient automotive technology? This section seeks to identify the major incentives and impediments to innovation of socially efficient automotive technology.

Evidence leads us to conclude that the possibility of reward is the major force which induces firms in all industries to invest in research, development, and introduction of new technology. Kamien and Schwartz summarize their survey of the empirical economics literature on innovation as follows:

> "...A picture of the relationship between resource allocation and technical advance, albeit fuzzy, does emerge from these studies. The quest for profit and devotion of resources does influence the rate and direction of inventive activity, despite the large role of serendipity and other goals motivating discovery. Moreover, the relationship appears bi-directional, with the state of knowledge shaping and being shaped by profit opportunities and availability of resources..." [5]

If the prospect of profit induces firms to innovate, then the absence of profit would be an impediment to innovation.

The following sections discuss several such possible impediments to the innovation of socially efficient technology. Externalities, information difficulties and uncertainties are found to be impediments to the development of socially efficient automotive technology, while alleged monopoly power and social irresponsibility of manufacturers are found not to be impeding factors.

3.2 EXTERNAL DISECONOMIES

According to the Penguin Dictionary of Economics,[6]

> Externalities in consumption exist when the level of consumption of some good or service by one consumer has a direct effect on the welfare of another consumer, as opposed to an indirect effect through the price mechanism (note "goods" are defined very broadly to include anything which yields utility). Production externalities exist when the production activities of one firm directly affect the production activities of another firm...[6]

If the direct effect of ones action on another reduces his welfare, the action is said to create an external diseconomy. External diseconomies arise from the use of automobiles because certain resources, including the waste absorption capacity of the environment, are common property resources without priced services. Thus, a driver pays for gasoline, operating costs, depreciation, and perhaps road use, but not for his use of the absorptive capacity of the environment. Without explicit government policy, he has neither the incentive to economize on the use of this scarce resource by investing in anti-pollution gear for his automobile, nor the incentive to reduce undesirable effects on others whose health or welfare may be impaired by the noise and gaseous emissions of vehicle operation.

External diseconomies may also arise in safety related areas, if the costs of accidents are not borne by those whose actions contribute to the probability of their occurrence. Use of motor fuel can also create external diseconomies if the price paid by users is less than the cost to society. Some evidence on the nature and magnitude of external diseconomies of automobile use is presented below in Section 4.

If automobile users have no incentives to reduce external diseconomies of auto use, then manufacturers will have no incentives to seek out and introduce changes in automobile technology which will reduce them. Even if a technological change has other benefits which accrue to the purchaser and user of the automobile (e.g., lower maintenance costs, better performance, better fuel economy, greater durability), the demand for such innovations would reflect only these private benefits.

Without some form of government intervention, then, adoption of existing technology (and modification of driving behavior) to reduce external diseconomies, including emissions, noise, and (as will be discussed later) some safety-regulated activities, will not occur. For the same reason, investment in research and development to find external diseconomy-reducing technologies will not happen. Externalities will be too high, judged by the welfare economics criterion.

3.3 INFORMATION DIFFICULTIES

The first Harberger postulate states that consumers reveal their preferences by choosing one set of alternatives over another. For example, if car A gets 25 miles per gallon and car B gets 12 miles per gallon (implying that car B's annual fuel costs are $260 higher for 10,000 miles of operation at $.60 per gallon), and if the consumer chooses car B over car A, then it is implied that owning car B rather than A is worth more to the consumer than the $260 per year in other goods and services foregone to purchase the extra fuel. This could be for a variety of reasons including differences in other costs of operation and ownership, comfort, performance, size or prestige.

The consumer is assumed to know not only what is good for him (or what he wants) but also something about the important characteristics of alternative automobiles. Finding out more about the characteristics of alternative automobiles, including selling price and fuel economy, reduces the chance of choosing a car with the "wrong" characteristics, but involves time and trouble, as well as other costs. It would not be rational to obtain "perfect" information, even if this were feasible, because information is costly.

People are willing to bear some risk of making the "wrong" choices rather than give up the other goods and services needed to obtain "better" information. However, shoppers for costly items such as automobiles do typically invest in some information. Consumers trade off the costs of increasing the risk of mistaken choices with the costs of better information.

This implies that consumer welfare would be improved if government policies reduced the cost of information on automobile characteristics. A good example is the fuel economy labeling program, which includes both a standardized test for measuring fuel economy, and standardized methods of reporting the results, to reduce the costs of acquiring comparable fuel economy information on alternative cars.

Other areas where consumers might have difficulty in "cheaply" obtaining reliable information include safety, damageability, repairability, and maintainability. Indeed, a case possibly could be made that "cheaper" information about any characteristic important to the consumer (except perhaps styling?) would improve consumers' ability to choose autos in accordance with their own desires. The government could facilitate this by establishing, by law or regulation, uniform ways of measuring characteristics and presenting the results. There is ample precedent for this, ranging from such familiar examples as the uniform system of weights and measures and the requirement that net weights be labeled on food packages, to automobile fuel economy testing and labeling.

If information costs retard the introduction of existing technologies even in cases where they would directly benefit the consumer, then surely information costs could inhibit the development of improved technologies which would be in the consumer's interests.

3.4 UNCERTAINTY

Uncertainty exists at every stage of the innovative process. In basic research there are uncertainties about whether a true principle of physical, biological or social knowledge will be discovered, and whether it eventually will be useful, either to the firm or to society at large. Applied research or invention involve uncertainties about the technical outcome and cost. Development and commercialization are marked by uncertainty about demand, the extent of the market, and possible actions of competitors.[5,7] Those uncertainties are especially important in

automobile manufacture, a mass production industry where achieving low unit costs requires large production runs to amortize development, plant, and equipment costs.

The effects of "normal" uncertainty are exacerbated by uncertainty over future mandatory standards. For marketable attributes, a shortfall in meeting goals of a development program may mean somewhat higher costs or a slightly less desirable product than planned. If, on the other hand, the new technology misses the mandatory standards by a small amount, the result may be much higher costs or even a product which may not be sold at all.[7,8]

This is illustrated by the debate over 1978 emissions standards. Congress adjourned in late 1976 without resolving clean air legislation. Without an amendment the law would provide for implementation of the original, strict statutory standards, but manufacturers, expecting the standards to be changed, were readying design for production which would not meet those standards. The *Wall Street Journal* characterized the situation as a "game of legislative 'chicken'."[9]

Thus, mandatory standards, while acting to induce manufacturers to adopt technology which market forces would discourage, can also retard innovation. Alternative policies, particularly mandatory information for consumer-desired attributes and fiscal incentives where external diseconomies are present, can also induce manufacturers to introduce socially more efficient technology, but without an increase in uncertainty.

3.5 MONOPOLY, OLIGOPOLY AND MARKET POWER

The American automobile industry is made up of a few large firms. In 1976, General Motors accounted for 58 percent of U.S. passenger car production and 48 percent of U.S. sales (including imports); the Big Three together accounted for 97 percent of production and 84 percent of sales.* Measured by dollar volume of sales, GM, Ford and Chrysler are respectively numbers 2, 4, and 10 on Fortunes's 1975 list of the 500 largest U.S. industrial firms; American Motors is number 87.[10] It is

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* Motor Vehicle Manufacturers Association, Statistics Department.

therefore worth investigating whether firm size and/or market structure have significant influences on technological innovation.

There is no 'a priori' theoretical reason to expect incentives for innovation to depend on market structure or firm size. Suppose a new engine reduces the cost of manufacture by $100, but is otherwise exactly equivalent to existing engines in every respect important to consumers. Standard economic theory predicts that the engine would be introduced and that automobile price would fall by some amount between zero and $100 (depending on cost and demand elasticities), whether the industry were under the polar extremes of perfect competition or perfect monopoly. Similarly, if a new engine cost no more to produce but increased the automobile's value to customers by $100, either a monopoly or a competitive industry would introduce it. On the other hand, if customers are unable to find out about the benefits to themselves (information difficulties), or if the $100 in benefits accrues to those not purchasing cars (externalities), then neither the monopolist nor the competitive industry would introduce the new engine. Furthermore, both monopolistic and competitive firms, in evaluating the innovation, would compare the variable costs of producing the old technology with the total costs of producing the new technology, and would ignore sunk costs.

The real issue here is not the incentives to innovate, but rather the extent to which firm size and market concentration influence inventive effort and output. Two competing hypotheses may be cited. Schumpeter believed that a certain amount of monopoly power was necessary for firms to enjoy, for a time, the fruits of an innovation.[11] Hicks, on the other hand, believed that "the best of all monopoly profits is a quiet life,"[12] implying that monopoly power might inhibit progress. Firm size may exert an independent effect on innovation, or may indirectly be correlated with innovation because of a correlation with market concentration.

Kamien and Schwartz have surveyed the literature on the relation of market structure and firm size to innovation.[5] They found that innovational effort is correlated with innovational

output although other factors, especially technological opportunity in the form of relevant basic knowledge, also play a role. Size of firm, beyond a certain minimum, seems to have no empirical effect on either innovational effort or output, with the possible exception of the chemical industry. The empirical evidence on the relationship of market concentration and research effort is mixed and inconclusive, as is the relationship of concentration and innovative output. There is no evidence that profitability or liquidity influences innovative effort or innovative output. There is no conclusive evidence that product diversification influences innovation.

Thus, there is no theoretical or empirical support for the hypothesis that large firms or small numbers of competitors, such as found in the automobile industry, inhibit technological progress. There is also no support for the argument of Jacoby and Steinbruner that the decentralized structure of large automotive companies inhibits technological progress.[13] Rather, the evidence supports the hypothesis that prospective rewards in relation to cost and risk are the driving forces of innovation.

3.6 SOCIAL IRRESPONSIBILITY, INCOMPETENCE, AND LACK OF VISION

It has been argued that social irresponsibility of automobile manufacturers has inhibited both the adoption of existing technology in the public interest and the search for more socially efficient technology. That auto manufacturers lack credibility in the public arena is well known. Nader has eloquently stated the social irresponsibility argument:

> "A great problem of contemporary life is how to control the power of economic interests which ignore the harmful effects of their applied science and technology...Highway victims cost the automobile companies next to nothing and the companies are not obligated to make use of developments in science technology that have demonstrably opened up opportunities for far greater safety than any existing safety features lying unused on the automobile companies shelves.
>
> A principle reason why the automobile has remained the only transportation vehicle [in the early 1960s] to

> escape being called to meaningful public attention is that the public has never been supplied the information nor offered the quality of competition to enable it to make effective demands through the marketplace and through government for a safe, nonpolluting and efficient automobile that can be produced economically. The consumer's expectations regarding automotive innovations have been deliberately held low and mostly oriented to very gradual annual styling changes."[14]

Nader cites numerous alleged instances of failure to adopt or innovate socially efficient technology in safety and emissions, and of alleged misleading statements by manufacturers' spokesmen on the seriousness of the safety and emission problems and the costs and efficacy of proposed technology to alleviate the problems. A later report by a Nader Task Force[15] expands on these themes, and even quotes an alleged statement by a GM researcher that "they already had the conclusion [that the steam engine was not a feasible alternative] and we were told to prove it..."

The view that automobile manufacturers are socially irresponsible, or that they are incompetent or lack vision to adequately innovate, is widely held, and has surely influenced public opinion and Congress. Drucker has argued that the public's perception of manufacturer inattention to social impacts of the automobile has created a scandal and resulted in punitive legislation.[16] He cites both safety and emissions legislation; he could have cited damageability or fuel economy regulations as well.

Self interest is a powerful if not dominant motivating force for both individuals and corporations. A corporation also has a legal and moral fiduciary responsibility to its stockholders. Public policy may wish to include the possibility of motivations beyond self interest, but institutions which align self interest with the public interest are most likely to result in the public interest being served. This is the fundamental insight of Adam Smith on the social efficacy of competition's "invisible hand."[17]

We argue that markets do a tolerable job of calling forth that aspect of social responsibility which involves producing

cars with attributes desired by consumers at reasonable costs. Policies to provide better product information (and to provide for enforcement of contracts, to discourage fraud, etc.) can improve the functioning of markets in this respect.

As for attributes of automobiles which are not desired by consumers per se (externalities), we adopt the position of Peter Drucker that the social responsibility of manufacturers is not to introduce cleaner etc. automobiles in a way that places them at a competitive disadvantage, but rather to lobby for a regulatory framework which would reward the introduction of cleaner, etc., automobiles. Drucker's argument is that this is in the manufacturer's self interest, because the alternative is an eventual public scandal, followed by punitive regulation.[16]

Reasonable people may disagree as to whether social irresponsibility of manufacturers, independently of the other impediments discussed above in this chapter, has inhibited socially more efficient automotive technology. Regardless, it would be unwise to depend on sudden and dramatic increases in altruism on the part of manufacturers and their customers to improve the social efficiency of cars. Policies which seek to make the innovation, production and purchase of socially more efficient automobiles more in the interests of manufacturers and their customers are likely to produce surer results.

4. EVIDENCE ON NATURE AND MAGNITUDE OF EXTERNALITIES

4.1 GENERAL

The previous section identified externalities, information difficulties, and uncertainties as potential impediments to the development of socially efficient automotive technology. This section discusses the evidence on the nature and magnitude of externalities. We have not attempted to search out evidence on information difficulties and uncertainties relevant to automotive technology, but it is likely that more is known about externalities than about the other two areas.

Clear and unambiguous external diseconomies exist with respect to automotive emissions, noise, and (to some extent), safety. Therefore, policies to control or internalize externalities may be indicated in these areas.

Damageability and fuel economy benefits and costs accrue to the purchasers of automobiles, as do many safety benefits and costs. Therefore, policies to improve information about relative characteristics of different automobiles in these areas may be indicated. Safety regulations are an interesting case, because of the difficulty of separating external costs and benefits from those which are borne by the automobile owner, the interaction of vehicle characteristics and behavior, and the question of whether individuals can or should choose the proper amount of safety when confronted with information about the safety consequences of their actions.

4.2 EMISSIONS AND NOISE

Automobile emissions and noise impose external diseconomies on the community; these externalities provide a classic rationale, within the welfare economics framework, for government intervention to abate emissions and noise. However, although noise and emission controls abate externalities, there is little evidence that control of externalities was a motivating factor behind the actual adoption of such controls (see Section 5).

A number of estimates of the cost of automotive emissions

to society and the benefits from the emission abatement have been performed. A definitive study was conducted by the National Academy of Sciences for the Senate Public Works Committee, published in September 1974. Volume 4 of that study estimated the costs and benefits of automobile emission controls.[18] This project also issued a comprehensive survey of the literature on social and economic costs and benefits of automobile emission abatement.[19] The NAS study examined the effects of different amounts of pollution and other factors on the market value of houses and on wage rates. It also examined the evidence on health effects, vegetation effects, and damage to property. The authors apparently regarded the wage differential and property value differential studies as yielding independent estimates of amenity valuation, and, therefore, added the wage or property valuation benefits (which are found to be approximately equal) to the health benefits and material and vegetation damage benefits.

Other estimates of the degree of pollution disbenefit appear in Dewees[20] and in the RECAT study;[21] the list is by no means exhaustive. There is ample evidence that the unabated automobile produces significant amounts of pollution, that this pollution causes damages to people and property, and that there are therefore large benefits to abatement. However, the NAS study also presents convincing evidence that net benefits of auto emissions control would be larger with less strict standards.[18]

4.3 SAFETY

There are several studies of the economic costs of highway accidents,* but few distinguish costs borne by the owner of an automobile from costs imposed on others in society. A study by the Center for Environment and Man (CEM) attempted to estimate indirect motor vehicle accident costs including overhead, police expense, courts, prosecution, probation, jails, coroners and medical examiners, welfare and social

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* See, for example, References 22 and 23.

security overhead, motor vehicle agencies, and highway department costs. The bulk of the estimated indirect cost (1969 data) were for insurance overhead (89 percent), almost all of which was automobile insurance. Police, courts, prosecution, probation, jails, coroners and medical examiners accounted for 9 percent of the accident-consequent cost, motor vehicle agencies for 2 percent, and welfare and social security overhead for the remaining 1 percent.[24]

Unfortunately, the CEM study does not distinguish between external and internalized costs. If a person decides to purchase a safer automobile, then he reduces the expected cost to himself of automobile accidents, in the form of reduced pain and suffering, reduced lost wages, and lower probability of death for himself and other automobile occupants. Some of these costs may be compensated by his insurance. To the extent that he does not pay the higher costs of accidents due to a less safe car, or his insurance payments do not increase to reflect the higher expected loss from the less safe automobile, an externality exists. The driver will not have the proper incentive to purchase the safer automobile. Since a large fraction of external costs are apparently associated with insurance overhead and, by implication, insurance claim payments, many safety externalities could be internalized by revising pricing policies for automobile insurance. This is further discussed in Section 6 below.

Driving behavior can also affect safety, both one's own and that of other motorists and pedestrians. There is some evidence that improvements in automobile safety may induce off-setting changes in behavior, tending to increase external diseconomies. Peltzman presents econometric evidence that the decline in the highway death rate since the 1960s can be explained by changes in the age composition of drivers and other demographic variables, and that vehicle safety standards shift the burden of the highway death toll somewhat from automobile occupants to pedestrians.[25] Using a utility maximization model, Peltzman theorizes that this evidence

is consistent with rational behavior on the part of the automobile drivers. As safety devices make motoring less risky, drivers are motivated to drive less carefully and more intensively. They tend to take part of the benefits of safety devices, not in the form of reduced risk of death and injury, but in the form of more intensive driving.

Parry presents psychological evidence that many drivers gain satisfaction by driving in an aggresive manner, and enjoy "beating" or "cutting off" other drivers.[26] An implication of this finding is that safer automobiles, by reducing the risks of driving aggressively, may encourage this type of behavior.

It is well-known that there are fewer accidents per vehicle-mile on limited-access highways than on rural roads. Accidents caused by intersecting traffic should be virtually eliminated, and head-on collisions may also be reduced. However, the "Peltzman hypothesis" suggests that drivers will take part of the benefits of the safer road, not in the form of reduced accidents, but in the form of faster or less attentive driving (reduced driving effort), and that accidents associated with running-off-the-road and rear-end collisions should increase. We know of no hard evidence on this hypothesis, but research on it would shed additional light on whether people do in fact make rational tradeoffs between risk of automobile accident losses and other utilities.

While safety externalities exist, they are minor, compared to the costs and risks borne by the occupants of the auto. Indeed the externalities may be exacerbated by safety regulation, rather than reduced. A welfare economics rationale for product standards or fiscal incentives in safety, as opposed to better product information, must rest on a finding that people, even when confronted with adequate information, make worse tradeoffs in their own interest than would safety regulators.

4.4 FUEL ECONOMY AND DAMAGEABILITY

Externalities are minimal in areas regulated by fuel economy and dameageability standards, and present regulatory

policies are, in any event, not designed to internalize cost and benefits in these areas. The externalities argument is not a rationale for regulation of automobile fuel economy, since any externality exists because the price of gasoline is below its social cost. In 1975, Congress rejected policies which would have allowed the price of gasoline to rise, suggesting that the automobile fuel economy regulations adopted instead were not motivated by a desire to internalize externalities.

Bumper externalities may exist whenever a non-standard-height bumper inflicts damage on other vehicles by over- or underriding a standard height bumper. Bumper standards tend to reduce such externalities, but only as an unintended by-product; their purpose is to reduce damage to one's own vehicle rather than to reduce damage to other vehicles. Moreover, the bumper height standards do not apply to trucks and multi-purpose vehicles, many of which have bumpers much higher than automobile bumpers, thereby increasing the risk of substantial property damage from otherwise minor collisions.

5. POLICY TYPES AND PRESENT POLICIES

5.1 SPECTRUM OF POLICY ALTERNATIVES

This section discusses generic policy alternatives, major legislation, and present regulations based on this legislation. Our general conclusion is that each piece of legislation tends to rather single-mindedly maximize one set of goals, and that inadequate mechanisms exist to trade-off one social utility against other social or private utilities. In Section 6 below, we argue that restructuring public policies more away from the direct regulatory end of the policy spectrum and more toward the market end would increase the role of individual preferences in trading off various private and "social" objectives.

Policies which encourage the adoption of socially efficient automotive technology also have implications for research and development. The policy types can be arrayed in a spectrum ranging from more to less government intervention, as follows:

1. Specification of Product Characteristics or Technology. Examples of present regulations include a large number of present safety standards (including requirements for a friction-type mechanical parking brake system, a hoodlatch system, and head restraints). Regulations to require or ban a particular type of engine or to require per se air cushion restraint systems in automobiles would also fall under this type of option.
2. Mandatory Performance Standards, either for components of an automobile or for the vehicle as a whole. Examples in present regulations include emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen, stopping distance, and fuel economy.
3. Fiscal Incentives. An example may be the manufacturers' fuel economy penalties contained in the 1975 Energy Policy and Conservation Act (but, see the discussion of fuel economy legislation below). Another example, discussed in Section 6, is an emissions tax.

4. Mandatory Product Information. Examples include fuel economy labels or information on damageability, crashworthiness, and repairability.
5. Market Forces, with no specific government intervention. Most characteristics of automobiles are not subject to specific government intervention, although normal regulation of markets (antitrust, law of contracts, etc.) applies.

These five types of regulation are a continuum rather than mutually exclusive alternatives.

5.2 MAJOR LEGISLATION

This section discusses major legislation which provides for regulation of automobile safety, emissions, damageability, noise, and fuel economy. The major features of this legislation and the stated rationales of Congress are examined.

Each piece of legislation seeks a narrowly-defined set of goals. Although cost and feasibility are given varying weights in setting regulations, there are really no mechanisms for trading off one set of benefits against another (e.g., safety against fuel economy), or against other utilities (i.e., costs). There is no evidence that the intent of Congress was to internalize externalities, or to improve the social efficiency of automotive technology (as defined by a welfare economics criterion based on individual choice), although abatement of externalities has often resulted from regulation. We have been unable to discover in the legislative choices of the last dozen years any underlying, consistent concept of social utility which Congress is acting to maximize.

5.2.1 Safety

Automobile safety standards are issued under the authority of the National Traffic and Motor Vehicle Safety Act of 1966, as amended.[27] Its stated purpose was "to provide for a coordinated National Safety Program and establishment of safety standards for motor vehicles in interstate commerce, to reduce

traffic accidents and the deaths, injuries, and property damage which occur in such accidents..."[28]

The Senate Commerce Committee found that market forces were not providing a sufficient degree of safety. Citing "evidence that the automobile industry has made commendable progress in many aspects of automotive safety," the Committee's report, nevertheless, goes on to state:

> But the committee met with disturbing evidence of the automobile industry's chronic subordination of safe design to promotional styling, and of an overriding stress on power, acceleration, speed, and 'ride' to the relative neglect of safe performance or collision protection. The Committee cannot judge the truth of the conviction that 'safety doesn't sell,' but it is a conviction widely held in the industry which has plainly resulted in the inadequate allocation of resources to safety engineering.[28]

The Committee report mentions lags in installation of safety door latches, resistance to the installation of seat belt fittings, the existence of interior design features which could inflict unnecessary injuries in crashes, exterior design features which create "needless hazards to pedestrians," and inadequate notification of car owners about safety-related defects.[28] The Committee therefore concluded that mandatory vehicle standards were needed at the federal level, that there should be federal requirements for notification about and curing of manufacturing defects, and that both industry and government had a responsibility to provide information which would allow consumers to evaluate the comparative safety of competing model cars.[28]

The Secretary of Transportation, in promulgating a safety standard, is required to consider whether such a standard is "reasonable, practicable, and appropriate for the particular type of motor vehicle"; the Committee acknowledged that reasonableness of cost, feasibility and adequate lead time would also be considered. It is clear that cost was to be a subordinate criterion: "the committee intends that safety shall be the overriding consideration in issuances of standards under this bill."[28]

In summary, the Senate Commerce Committee found that market forces resulted in automotive design which was unnecessarily hazardous both to pedestrians and occupants. It rejected the notion that consumers could, in fact, adequately judge the relative safety of different automobiles. The rejection of cost as an important criterion for standard setting, the condemnation of automotive design in existence in the mid-sixties, and emphasis on safety improvements per se, indicated that Congress doubted the desirability of allowing individual choice and market forces to trade off safety against other utilities.

An alternative interpretation would be that Congress felt that, even though consumers ought to trade off driving risks and safety features against other utilities and costs, lack of information and/or the ability to adequately process such information would frustrate such choices. In addition, safety regulators might be better able to specify design features in the interests of consumers than the consumers themselves. However, the rejection of a strong cost criterion, so long as some safety improvement could be demonstrated, and the lack of any mechanism for trading off safety against other vehicle attributes or other utilities, are arguments against this interpretation.

5.2.2 Emissions

Federal automobile emissions standards were specified in Clean Air Amendments of 1970.[29] The purpose of the legislation, as set out in House Report Number 91-1146, was to "speed up, expand, and intensify the war against air pollution in the United States with a view to assuring that the air we breathe throughout the nation is wholesome once again."[29] The bill provided that carbon monoxide and hydrocarbon emissions from light duty vehicles for the 1975 model year and thereafter be reduced at least 90 percent from 1970 standards, and that 1976 model oxides of nitrogen emissions be reduced 90 percent from the actual 1971 model emissions (both deadlines have since been extended.[29] Statutory standards were contained in the Senate

version of the bill, and administrative standards in the House version; the Conference Committee chose the Senate version. The Conference Committee also rejected the House bill proposal that automobile emission standards be based on a test of technical and economic feasibility.[29] The tough statutory standards were explicitly designed to force the development of improved automobile emission control technology.[21,30]

The rejection of cost as a consideration in setting automobile emission standards (as well as the rejection of cost as a consideration in the setting of national ambient air quality standards) supports the hypothesis that Congress is rejecting the Harberger postulates of valuation based on individual choice. Alternative hypotheses are that Congress doubted the feasibility of actually computing benefits of cleaner air, or that it regarded the benefits of cleaner air (or the costs of dirtier air) as so high in relation to any conceivable cost of abating emissions that tradeoffs and calculations would be a waste of time. However, based on these interpretations, Congress would have been equally severe on other sources of pollution; it was not.

5.2.3 Damageability

Mandatory product standards designed to limit the susceptibility of automobiles to damage from low speed impacts were first established under the guise of safety regulations. Since the 1966 Act did not authorize damageability standards, the standards were promulgated under the guise of protection of safety-related equipment (e.g., lights) from damage.[21,31]

Title I of the Motor Vehicle Information and Cost Savings Act of 1972 gave the Secretary of Transportation authority to set bumper standards designed to reduce motor vehicle property damage per se. The report of the House Committee on Interstate and Foreign Commerce showed dissatisfaction with perceived deficiencies in bumper design:

> In the last several years, there has been an ever increasing public impatience with the soaring cost incurred in repairing damage to vehicles which have been involved in only minor collisions. This

> public dissatisfaction undoubtedly has been amplified by the knowledge that a large portion of this repair bill appears to be attributable to the fragile design of contemporary automobiles and could in large measure be avoided if manufacturers equipped their vehicles with functional bumpers . . . . Your committee was presented with clear evidence that the technology already exists which would allow manufacturers to equip their vehicles with bumpers which would prevent any damage to the vehicle at barrier equivalent impacts speeds of five mph. Unfortunately, however, most manufacturers have been slow to respond to the public's demand for better bumpers.

The committee cited the National Traffic and Motor Vehicle Safety Act of 1966 as an example of legislative authority which had brought about beneficial changes in automotive technology.[32]

The Conference Committee rejected a criterion contained in the Senate version, which would have established a property loss reduction standard, rather than a bumper standard. It also rejected the Senate provision that the cost of the standard be reasonable compared with the benefits, in favor of the House language which provided for "maximum feasible reduction in cost to the public and consumer, taking into account the cost of implementation and the benefits to be obtained; the effects on insurance costs and legal fees; savings in time and convenience; and considerations of health and safety."[33]

The Committee was apparently also influenced by tests by the Insurance Institute for Highway Safety which indicated large repair bills for cars crashed forward and backward into barriers at 5, 10, and 15 miles per hour. Several cars incurred repair costs of over $400 dollars in the frontal five-mile-per-hour barrier collision.[32] The Committee did not document consumer willingness to pay for stronger bumpers, nor did it discuss why manufacturers would not find it in their interest to provide such bumpers if indeed the consumers were willing to pay more than the added cost.

Externalities are not at issue in this regulatory area. Actual bumper standards, and their predecessor safety standards, insure standardized automobile bumper heights, since the com-

pliance test requires the bumper to be struck by a pendulum of the same weight as the automobile, moving at five miles per hour, and with a protruding lip a specified distance above the ground. However, trucks and other vehicles are not required to meet the damageability standards, and there is no provision for standardized bumper height among these vehicles. If reduction in external diseconomies were intended, the legislation and standards would have been written to design cars so as to reduce collision damage to other vehicles, rather than to the vehicle itself. Such a specification probably would have resulted in standardized bumper heights as well as limitations on protrusions especially likely to cause damage.

The Act also provides, in Title II, for the publication of consumer information comparing different makes and models of automobiles in terms of their resistance to damage, their crashworthiness (ability to protect occupants from harm in crashes), and ease of repair and diagnosis. The Secretary of Transportation was directed to conduct a one-year study, to make the design comparison, and to disseminate the information to the public (i.e., by the end of 1973). Auto dealers were also required to disseminate information on differential insurance premium rates, to be furnished by the Secretary of Transportation.[33]

Title IV prohibited tampering with motor vehicle odometers, thus assuring the purchasers of used automobiles of more accurate information about the prior usage of such automobiles. While there has been little problem in implementing Title IV's odometer provision, the consumer information program provided for in Title II has never been implemented. Consumer information on safety and damageability is discussed further in Section 6. below.

5.2.4 Noise

Although noise emission standards for automobiles have not yet been promulgated, the Noise Control Act of 1972 provides a statutory framework for such regulations. The objective of the Noise Control Act is "to promote an environment for all Americans free from noise that jeopardizes their health or

welfare".[34] The Act requires that the Administrator of EPA publish noise criteria which identify the effects on health and welfare of different quantities and qualities of noise, and requires the Administrator to identify and publish a compilation of products which constitute major noise sources.[34]

The Administrator is also required to establish noise emission standards, according to a statutory timetable, for construction equipment, transportation equipment, motors or engines, equipment of which motors and engines are integral parts, and electrical or electronic equipment, provided that they have been identified as major noise sources, and that noise emission standards are feasible.[34]

Automobiles would qualify either as transportation equipment or as equipment containing an engine, and there is some evidence that automobiles are a major source of community noise.[35] One problem with the feasibility of automobile noise standards is that the currently available SAE Test (J986a) for noise emission specifies full throttle acceleration. Automobiles are rarely operated in this mode, and performance on the SAE Test is likely to be poorly correlated with actual community noise.[35]

The Act also requires informative labeling for products which are significant noise sources and for products sold to abate noise.[34]

The Report of the House Committee on Interstate and Foreign Commerce expressed concern about the physiological and psychological effects of noise. Included were "permanent hearing loss, interference with speech communication, stress reactions which could have significant long-term health implications, interference with communication and disturbance of sleep." Also cited are possible sociological impacts and damage to buildings.[36]

This list suggests a concern with the external diseconomies of noise, especially since the focus of the Act is nonoccupational noise. However, the Report singles out as "especially disturbing to the Committee" testimony concerning high frequency hearing losses among students between 16 and 21 years of age.

On the basis of current evidence, they will have much more serious hearing problems in their middle years than the present population. However, "most of these hearing disorders probably were attributable to exposure to music at intense levels."[36] In other words, this damage to hearing is self-inflicted and not an example of external diseconomy. Moreover, the Act is not designed to reduce the loudness of music enjoyed by young people.

The Committee Report also states that:

> The Committee found that there is a lack of adequate information regarding the cost of noise control for some products and thus included in the bill the requirement that in establishing final standards for noise sources, appropriate consideration must be given to the economic cost of such standards. The Committee also fully expects that adequate consideration be given to the technical capability of industry to meet noise control requirements.

However, there is no explicit guidance within the statute indicating what weight should be given to cost, relative to effectiveness in reducing community noise. Nor is there any specific statutory guidance on how to trade off noise reduction against cost (in other words, against other benefits thereby sacrificed). Nevertheless, it appears that Congress intended that cost be given a greater weight in noise control than in automobile emission control. This may be because Congress perceived community noise problems to be concerned with matters of quality of life rather than public health.

The Noise Control Act gives scant support to the thesis that Congress is motivated by social efficiency. There seems to be no explicit recognition of the role of externalities in community noise, nor has a formal mechanism for trading off noise control against other utilities been established. Nevertheless, the Act does seem somewhat less single-minded than the safety or emissions statutes in pursuing its goal.

5.2.5 Fuel Economy

Automobile fuel economy is regulated under the Energy Policy and Conservation Act of 1975. Title V of the Act

provides for statutory fuel economy standards for passenger automobiles and other light-duty vehicles. For passenger automobiles, standards are set for model years 1978, 1979, and 1980 at 18, 19, and 20 miles per gallon (mpg) respectively. Standards for the 1981 through 1984 model years will be set administratively by the Secretary of Transportation at the "maximum feasible average fuel economy level," and a 27.5 mpg standard applies in model year 1985 and thereafter.[37] If the sales-weighted average mpg of any manufacturer is less than the applicable standards for that year, the law provides for a civil penalty equal to $5 for each excessive tenth of a mile per gallon.[37] For example, if a particular manufacturer falls short of the standard by 1.5 miles per gallon, the civil penalty would be $75 times the number of cars produced by the manufacturer during that model year.

The law also contains some measure of flexibility whereby the Secretary of Transportation may adjust the fuel economy to take account of stricter emissions, safety, noise, or damageability standards. The Secretary is also given authority to adjust the standard for 1985 and thereafter within the range of 26 to 27.5 miles per gallon, depending on his determination of the maximum feasible average fuel economy. Standards outside the range are subject to disapproval by either House of Congress within a 60 day period.[37]

Title V requires that each automobile manufactured after the 1976 model year be labeled so as to indicate the fuel economy of the automobile, the estimated annual fuel cost of operating the automobile, and the range of fuel economy of comparable automobiles.[37] Fuel economy is determined by EPA as part of its testing for emissions standards compliance, and separate mpg results are reported for an urban driving cycle, a highway driving cycle, and a composite figure based on a weighted harmonic average of the urban and highway cycle. The wide advertisement of EPA fuel economy estimates indicates that manufacturers believe that this is an attribute which is desired by consumers.

Fuel economy standards conceivably could be rationalized within a welfare economics framework. If the price of gasoline does not reflect the marginal cost to society, then consumers will demand and manufacturers will produce automobiles which, from a social efficiency point of view, consume too much gasoline. One might argue, therefore, that Congress intended to redress this distortion by legislatively mandating changes in automobile fuel economy which would be socially efficient, and which would have been chosen by consumers and manufacturers if the price of gasoline reflected its marginal costs to society.

However, Congress has explicitly rejected other policy alternatives which would have increased the price of gasoline, and which could have removed any shortfalls between price and marginal social cost. Among the alternatives which Congress rejected were increases in the gasoline tax, and decontrol of domestic crude oil and petroleum product prices. Instead, Congress continued price control policies which keep the price of crude oil in the United States below the world market price.

A question exists whether the civil penalties in the 1975 Act are properly characterized as fiscal incentives or whether the intent is to punish non-attainment of goals. One interpretation is that, since the penalties are fairly modest, and since there is some administrative flexibility in the standards for 1981 and later, Congress intended the legislation to encourage more fuel efficient cars, but the standards were desirable targets rather than mandatory standards. However, an official of a major automobile company told CRA that he thought it likely that Congress would substantially increase the penalties if it thought the standards might not be met. The rhetoric surrounding the passage of the 1975 Act supports this view, as do the automobile fuel economy provisions in President Carter's energy policy proposals of April 1977.

5.3 PRESENT AUTOMOBILE REGULATIONS

Table 5-1, based on a Department of Transportation report,[31] displays specific major intervention policies in present law

TABLE 5-1. PRINCIPAL PRESENT REGULATIONS OF AUTOMOBILE DESIGN (Sheet 1 of 5)

Regulation[1]	Type of Policy[2] Technology or Product Characteristic	Performance Standard	Fiscal Incentive	Mandatory Information	Market Forces
SAFETY					
1. Lighting Devices and Electical Equipment					
FMVSS 108 - Number, type, strength, location of lights, reflective devices and related wiring.	X	X			?
2. Brakes					
FMVSS 105 and 105-75 - Hydraulic brake performance and design, including split braking system, parking brake, brake indicator lamps, fluid reservoir.	X	X			?
FMVSS 106 - Design and performance of brake tubing and hoses.	X	X			?
3. Glazing Materials and Window Construction					
FMVSS 205 - Glazing materials	X				?
FMVSS 212 - Windshield retention		X			?
FMVSS 103 and 104 - Windshield defrosting, defogging, wiping, and washing.	X	X			?
FMVSS 118 - Power-operated windows and partitions					?

FIGURE 5-1. PRINCIPAL PRESENT REGULATIONS OF AUTOMOBILE DESIGN (Sheet 2 of 5)

Regulation[1]	Type of Policy[2]				
	Technology or Product Characteristic	Performance Standard	Fiscal Incentive	Mandatory Information	Market Forces
4. Fuel Systems					
FMVSS 301 and 301-75 - Fuel system security and integrity.	X	X			?
FMVSS 215 - Fuel and cooling system crash performance		X			?
5. Interior Features and Crash Protection					
FMVSS 201 - Design of interior components for impact protection of occupants	X	X			?
FMVSS 203 and 204 - Steering system impact performance		X			?
FMVSS 206 - Crash performance of doors and locks		X			?
FMVSS 207 - Seats and components	X?	X?			?
FMVSS 202 - Head restraints	X				
FMVSS 208 - Occupant restraints		X			?
FMVSS 209 and 210 - Seat belts and anchorages		X			?
6. Exterior Strength and Crash Protection					
FMVSS 214 and 216 - Side door and roof crush resistance		X			?

FIGURE 5-1. PRINCIPAL PRESENT REGULATIONS OF AUTOMOBILE DESIGN (Sheet 3 of 5)

Regulation[1]	Type of Policy[2] Technology or Product Characteristic	Performance Standard	Fiscal Incentive	Mandatory Information	Market Forces
FMVSS 215 - Front and impact resistance		X			?
7. Tires and Wheels					
FMVSS 109 and 109a - Dimensions and lab test standards		X			?
FMVSS 110 - Tire size selection		X			?
FMVSS 211 - Restrictions on type of hub caps, wheel parts, wheel discs.	X				
8. Miscellaneous Safety					
FMVSS 124 - Accelerator return system	X	X			?
NHTSA Consumer Information Regulations - Acceleration and passing, stopping distance				X	?
FMVSS 101 - Location, identification and illumination of steering wheel, horn, transmission shift lever, ignition switch, headlamp switch, turn signal, illumination intensity control, windshield wiper control, manual choke, driver's sun visor	X				?

FIGURE 5-1. PRINCIPAL PRESENT REGULATIONS OF AUTOMOBILE DESIGN (Sheet 4 of 5)

Regulation[1]	Type of Policy[2]				
	Technology or Product Characteristic	Performance Standard	Fiscal Incentive	Mandatory Information	Market Forces
FMVSS 302 - Material flammability		X			?
FMVSS 111 - Inside and outside mirrors	X				?
FMVSS 107 - Reflecting surfaces on driver's field of view		X			?
FMVSS 113 - Hoodlatch systems	X				?
FMVSS 102 - Transmission shift lever positions, transmission braking effect, and starter interlock	X	X			?
DAMAGABILITY					
Motor Vehicle Information and Cost Savings Act					
1. Bumper Standards[3]		X			X
2. Information on damage susceptibility, crashworthiness, repairability, and associated costs[4]				X	?
3. Information on insurance costs based on damageability[4]				X	?

FIGURE 5-1. PRINCIPAL PRESENT REGULATIONS OF AUTOMOBILE DESIGN (Sheet 5 of 5)

Regulation[1]	Type of Policy[2]: Technology or Product Characteristic	Performance Standard	Fiscal Incentive	Mandatory Information	Market Forces
EMISSIONS					
Clean Air Act, as amended: Statuatory Emissions standards for carbon monoxide, hydrocarbons, and oxides of nitrogen		X			
NOISE					
Noise Control Act of 1972: Noise emissions[5]		X			
FUEL ECONOMY					
Energy Policy and Conservation Act of 1975: Statuatory fuel economy standards and labeling		X?	X?	X	X

[1]Based on information contained in Glater, David, and Redfield, Sarah. *Federal Legislation Affecting Motor Vehicle Design*. Interim Report. Prepared by the Transportation Systems Center for the U.S. Department of Transportation, Office of the Secretary. Cambridge, Mass.: Transportation Systems Center, March 1975. Distributed by NTIS.

[2]CRA judgement.

[3]See also FMSS 215 under "Exterior Strength and Crash Protection," *Supra*.

[4]Provided for in Act, but not issued.

[5]Automobiles are expected to be designated by the Administrator of EPA as a major noise source, subject therefore to regulation under the Noise Control Act.

along with our characterization of their position in the spectrum of policy types presented above in this section.

Specification of particular devices or product characteristics are found in safety standards, many of which are quite detailed. Performance standards appear in all regulated areas, including safety, damageability, emissions, noise and fuel economy. Fiscal incentives appear only in fuel economy regulation in the form of graduated civil penalties based on shortfalls of a manufacturer's sales-weighted fuel economy from the statutory standard. (But, see the discussion of fuel economy legislation above.) Penalties provided for in other acts (e.g., up to $10,000 per car in the Clean Air Act) appear to be designed as punishments or deterrants to insure that the standards are met. Mandatory product information appears in safety (acceleration and braking performance) and fuel economy (fuel economy labeling). Market demands for safer automobiles may well have caused manufacturers to adopt some or all of the requirements of particular Federal Motor Vehicle Safety Standards. Similarly, since at least some benefits (as well as costs) of more damage-free automobiles and of improvements in fuel economy accrue to owners of vehicles, observed changes subsequent to damageability and fuel economy regulation may also be due in whole or in part to market forces. Market forces would not lead to abatement of emissions or noise.

6. POLICY ALTERNATIVES

6.1 GENERAL

This section outlines several policies which are alternatives to present automobile regulatory policies. They include a new car emission tax to abate emissions, and safety information and insurance rate reform to improve automotive safety. The policies are evaluated according to the welfare economics criteria discussed in Section 2 above: feasibility and efficacy, mechanism for tradeoffs, information needed to optimize policy, incentives for information generation, incentives for optimizing technology (including incentives to innovate), and effect on uncertainty. The intent is to outline some alternatives, rather than to present and exhaustively analyze a detailed policy blueprint.

The conclusion is that policies which rely more on market forces and less on mandatory product standards have potential for offering greater encouragement to socially more efficient automotive technology. Where externalities are present, a fiscal incentive system would be an appropriate alternative to mandatory standards. Where the problem is one of information difficulties with respect to attributes valued by automobile purchasers, a mandatory product information policy would be an appropriate alternative.

The same reasoning can be extended to automotive fuel economy. If the price of gasoline reflects its marginal social cost, then consumers are given an incentive to demand, and manufacturers to produce, a range of cars with the socially optimal mix of fuel economy and other attributes. Mandatory product information, in the form of existing fuel economy testing and labeling, provides a feasible mechanism for allowing manufacturers and consumers to make tradeoffs among competing utilities. Although price controls keep the average price of domestic crude oil about $.11 to $.12 per gallon below world market prices, and depress petroleum product prices perhaps $.05 to $.06, state and federal gasoline excise taxes more than

eliminate the discrepancy. However, world market prices may understate the social cost of foreign oil, because of supply insecurity. Nevertheless, any discrepancy between price and social cost could be redressed by higher prices for petroleum, if the object of the policy were the elimination of externalities and improvement of the social efficiency of oil consumption.

6.2 NEW CAR EMISSION TAX

An emissions tax on new automobiles as a replacement for present mandatory emissions standards has been proposed, and implementation details have been presented by Dewees and by Anderson and Mills.[20, 8] The proposed tax would be feasible, since it would use the same testing procedures and administrative structures as present regulations. New automobiles would continue to be tested by EPA in the manner now used to determine compliance with the mandatory emissions standards. The test is designed to estimate average lifetime emissions per mile of the three regulated pollutants, for each make and model of automobile, and for each engine, transmission, and final drive ratio combination.[38] The results of the test would be used to determine, not whether an automobile can be sold or not, but the emissions tax that would be levied. This tax would be a powerful, yet flexible incentive to introduce existing technology on a timely basis. It would also serve as an incentive to innovate so as to reduce the costs of abatement and to improve the emissions performance of automotive technology. The policy would be both feasible and efficacious in reducing emissions.

The emissions tax would encourage tradeoffs among different utilities, including emission abatement. Manufacturers would have to balance the emissions tax against the cost of emission abatement technology and other attributes of the automobile, including size, weight, and engine technology, which might be associated with emissions performance. Consumers would also be faced with similar tradeoffs among price and automobile attributes which are valuable to them. If the emissions tax were applied to other mobile and stationary

sources, on an equal basis, all sources would be under equal marginal incentives to seek out and introduce abatement techniques.

If there were only one source of emissions, if there were no prior history of emissions abatement, and if there were no uncertainties associated with the cost and performance of future and existing abatement technology, then the information needed to optimize a mandatory standards policy would be approximately the same as the information needed to optimize an emissions tax policy. However, it is administratively and politically infeasible to develop a set of standards and timetables for different types of automobiles, automobiles and trucks, and mobile and stationary sources which would minimize the cost of a given improvement in air quality. Indeed, Anderson and Mills, Downing and Watson, Bingham, and Crenshaw and Basala each present evidence of significant differences in the marginal cost of abatement of the same pollutants from different sources, indications that costs to society of emissions abatement to achieve present levels of air quality are much higher than they need to be.[8,39,40,41]

It is much easier to equalize emissions taxes across sources, or to scale them differentially according to the relative impact on people of emissions from different sources, than it is to equalize marginal costs by selecting the appropriate standards and timetable for each source. Furthermore, the actual response of emittors to an emissions tax provides valuable information about the cost of abatement at the margin, including the cost of speeding up abatement. This is particularly important in the automotive sector, since the normal practice with innovations is to phase them in gradually, first gaining experience with technology and production techniques, and gearing the introduction to major changes in automobile design and the model year. Introducing changes outside this normal cycle imposes significant added costs, which are very difficult for the policy maker to accurately estimate.[7]

The emissions tax alternative gives manufacturers and customers incentives to reveal by their actions, when faced with the necessity to choose among alternatives, the true marginal costs of abatement and the true valuation of other utilities which have to be sacrificed in order to achieve abatement. Mandatory standards policies actually provide perverse incentives to manufacturers to conceal or misrepresent information, and provide no mechanism by which consumer preferences concerning attributes which are in conflict with emissions control can be revealed. Thus, the emissions tax alternative requires less information initially to optimize policy, and provides continuing incentives to the private sector to generate information needed to optimize policy.

Even though the 1970 Clean Air Act Amendment contained statutory emissions standards designed to "force" the development and introduction of more effective automotive emission abatement technology than was in existence when the law was passed, many authorities now believe that the law has retarded the development of innovative engines.* The major retarding effect has come about because of increased uncertainty. If the new engine fails to meet even one emission standard, it cannot be sold. It is not known what the allowable grams per mile for HC, CO, and NO_x will be over the next 5 to 15 years, or what additional pollutants will be regulated. On the other hand, it is virtually certain that standards will never be set to a level which would precipitously outlaw the majority of one's competitor's engines. Even if the new engine should succeed in being much cleaner than a controlled conventional engine, there is no particular advantage to overachieving the standard.

In contrast, the emission tax reduces rather than increases uncertainty. Since the tax can be announced in advance without the prospect of having to change it later should the pace of technological advance be faster or slower than predicted, uncertainties over the level of future regulation would be reduced. Policy makers would be relieved of some of the

* See, for example, References 8, 13, and 42.

uncertainties which are exacerbated by the adverse incentives mandatory standards give manufacturers to conceal information about future technological prospects. For manufacturers, uncertainties about whether new technology will be allowed to be sold at all would be replaced by normal technological and market risks.

However, if auto emissions are subject to a threshold effect, with great harm for small amounts of emissions above the threshold, and zero harm for any amount below the threshold, then uncertainty over exact amounts of automobile emissions could be a matter of some concern. We are aware of no evidence suggesting a sharp discontinuity in the benefits from abatement. Rather, our understanding is that more is worse, and less is better, with respect to air quality, and that there are not sharp discontinuities in marginal social damages near statutory emissions standards.

6.3 SAFETY INFORMATION AND INSURANCE RATE REFORM

Title II of the 1972 Information and Cost Savings Act contains a statutory mandate for the development of information on the relative crashworthiness, damageability and repairability of competing makes and models of automobiles. It may be that feasible insurance rate reforms could reduce if not eliminate the bulk of the external diseconomies associated with automobile crashworthiness. Thus, this information could substitute for mandatory safety standards for occupant crash protection and accident avoidance. Unanswered questions include the extent to which people can and do choose in accordance with their own best interest when risk of death or injury is present, compared to the optimality of choices made by safety regulators.

Title II seems never to have been implemented. A study by General Electric for NHTSA, published in 1976, attempted to develop a methodology for rating automobiles under the law.[43] The study found that damage susceptibility could be inferred from insurance company data on accident damage, and that crashworthiness could be inferred from insurance company data on

accident injuries, but not without considerable difficulty. There would, of course, be the further problem of *ex ante* predictions so that prospective purchasers would have the information on a new model or a model with new safety features when it is first marketed rather than several years later. Problems were identified with use of math modeling and crash testing, to predict crashworthiness and damageability. Preventive maintenance could be forecast by reference to manufacturers' recommendations, but unscheduled maintenance prediction would be most difficult, according to the study.[43]

An implication of this research is that a meaningful comparative rating system for damageability, crashworthiness and maintainability is not feasible. In other words, it is too difficult to predict, on the basis of the characteristics of automobiles, aided by analysis of past accident data on the same and similar autos, math models, and crash testing, which automobiles are safer and which more dangerous, which are more damage prone, and which cost more to maintain. If this were literally true, then there would be no basis for issuing mandatory standards, since there would be no basis for predicting the effects of different designs on loss of life, injury, and property damage. It is necessary to estimate the improvement in safety or damageability whether a technological change is made in response to a mandatory standard or in the hope of achieving an improved safety rating. While we suspect that a rating system is feasible, definitive specification of such a system would require some additional work.

Transmitting comparative safety information to consumers in a way which would be meaningful to them, and which would improve their ability to make tradeoffs, would be difficult and challenging. For damageability, this process would be made simpler if insurance pricing practices were reformed so that collision premia for different makes reflected damageability as well as driver characteristics, value of the car, place of residence and other characteristics now used. Then, the expected damage cost could be displayed on a label as the sum of insur-

ance premia plus expected "minor" damage of less than a typical insurance deductible.

For crashworthiness, an alternative would be to label automobiles according to where they fall in a hierarchy of safety standards. An example of such a hierarchy is contained in the "Goals" report, which postulated two levels of safety, Level I and Level II, depending on the severity of a number of individual standards.[1] The concept could be extended to perhaps six different safety levels, ranging from more severe to less severe than the two levels in the "Goals" report, perhaps including intermediate levels. Cars would be labeled "Level I, II,..., VI," depending on which set of standards they met.

Another suggestion for a safety hierarchy on which to base comparative ratings is presented by Carlin, based on safety performance of the car as a whole rather than individual components:

> Perhaps the most readily understandable and useful system would be one based on the probability of being injured at specific speeds. Under this approach standards might be set up, for example, to correspond with at least a 90 percent non-injury rate for each occupant for accidents in which the car under test was being driven at speeds of say 20, 30, 40 miles per hour, etc. The overall probability of injury for each passenger would be the sum of the probability that the passenger would be injured by an accident in which the car tested was struck from each possible direction multiplied by the probability that the car would be struck from that direction. Injury prediction would presumably be defined in terms of whether standardized dummies experienced greater than specified "safe" decelerations or struck any part of the vehicle with greater than a specified "safe" force. Certain ancillary standards regarding brake performance and other-safety related components would also be specified for each speed level.44

It is a truism among safety professionals that the risk of accidents and the expected losses from accidents are jointly determined by the driver, the vehicle, and the highway environment. The driver can influence the risk of accident and its consequent losses, not only by his driving behavior, but by his choice of automobile and, to some extent, by his choice of route. A proper scheme of insurance would tend to increase pre-

miums for those drivers who behave so as to increase the expected losses to others and, when compensated by insurance, to themselves, and to reward safe drivers. Unfortunately, it is often difficult to discern which drivers drive safely and which drivers do not. To the extent that insurance premiums reflect actual accident experience, part of the rationale of insurance, that of reducing risks due to purely random factors, is defeated. However, there is no reason why the insurance premium on a particular make and model cannot be graduated according to the "level" of auto safety achieved by that automobile. Since insurance overhead, and, by implication, insurance claims, are a large fraction of the "indirect" costs of accidents,[24] this may remove the bulk of the externalities associated with crashworthiness.

If replacement of mandatory safety standards with better product information is feasible and efficacious, then this is likely to be a better policy according to the welfare economics criteria listed in Section 2. Consumers would be able to trade off risks and costs of different designs, and manufacturers would have incentives to produce an "optimal" level of safety (or, conceivably, different cars would offer different levels of safety to satisfy differences in taste), and to innovate. The information needed to optimize policy would be less than with standards, since it would only be necessary to predict the safety consequences of alternative designs, and it would no longer be necessary, in addition, to estimate the optimal level of safety. Information about the true safety and cost consequences of alternative designs would be more readily available, since standards give both manufacturers and regulators incentives not to produce such information. Uncertainties about the safety performance of alternative designs, and about future requirements facing manufacturers, would be reduced.

Although safety information policies are likely to be superior to mandatory standards, when judged according to welfare economics criteria, it is essential to recall that these criteria are based on the proposition that consumers' valuations

are revealed by their choices. If consumers, even with good information, choose less well than regulators, by the consumers' own rights, then the above arguments lose their foundation. Put differently, all (or a vast majority of) consumers may choose a system which requires them to make inherently difficult choices. Whether consumers, with good information, can and do serve their own interests better or worse than standards-setters is a question for research.

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APPENDIX B

REPORT OF INVENTIONS

This report investigates the opportunities for innovation in automotive technology and analyzes the effect of this innovative technology on automotive fuel consumption reduction. Although no new inventions have occurred, this report analyzes the different factors which affect the evaluation of innovations.

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