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THE COSTS OF AUTOMOBILE MODEL CHANGES SINCE 1949

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I. INTRODUCTION: AIMS OF THE STUDY

This paper reports estimates of the costs to the consumer of the changes in private automobile specifications that took place during the 1950's. Throughout we concentrate on the costs that would not have been expended if cars with the 1949[1] model lengths, weights, horsepowers, transmissions, and other specifications had been produced in every year. As there was technological change in the industry, we are thus assessing not the expenditure that would have been saved had the 1949 models themselves been continued, but rather the expenditure that would have been saved had such cars been continued but been built with the developing technology.

We count as costs not only the costs to the automobile manufacturers themselves of special retooling for new models, but also the direct costs of producing larger, heavier, and more powerful cars, plus the costs of automatic transmissions, power brakes, and the like. Finally, we include the secondary costs not paid out by the automobile companies but paid nevertheless by the consuming public in the form of increased expenditures for gasoline necessitated by the "horsepower race."

This procedure clearly counts as "changes" *all* changes in those specifications which directly relate to the appearance or performance of the automobile. We do not count alterations in design of the car that do not *directly* change the package the consumer thinks he is buying. Thus, we assume that horsepower is a dimension of the car that enters directly into the utility function of the car-buyer, but that engine displacement is not. This is not to say that changes in engine displacement are not relevant; it is to say that such changes are relevant only insofar as they influence one of the performance or appearance variables under consideration.

We have mentioned a consumer's utility function. The use of this concept carries with it the clear implication that the

[1] 1949 is the earliest year for which all necessary data are available. It will be evident from the data that choice of 1950, 1951, or 1952 as the base year would not substantially alter the results.

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changes we consider may all have been desired by the car-buying public.[2] The question thus naturally arises: why not cost only those changes which were essentially "frills"? Why include in the estimates such things as automatic transmissions that were quite arguably improvements? The answer is that there is always a presumption of consumer sovereignty in the market economy and that it would be wholly arbitrary for us to say "this change was an improvement, and this was unnecessary" without detailed information on the utility functions of consumers. If tailfins were a frill, what about increased horsepowers? What about *extremely* increased horsepowers? Where there are costs, there are likely to be benefits as well, and, while the automobile market is not perfectly competitive, it seems likely to us that for most of the period in question the car manufacturers were giving the public what it wanted, save perhaps for overshooting in some respects.

We thus wish to avoid having this study taken as an indictment of the automobile companies. We are rather in the position of one who observes another man drinking various liquors. We do not blame the bartender for anything save that he occasionally gives the man more than he asks for of some expensive drink; nor do we question the man's right to drink; nor do we distinguish between "good" liquors and "bad." We do, however, present the bar bill. Since the argument is sometimes advanced that the resources spent on automobile model changes could be put to better use in the public sector,[3] it is clearly worth investigating the order of magnitude of the resources involved.

Section II considers the direct costs of model changes as well as the effect on advertising expenditures. Section III discusses retooling expenditures, and Section IV gasoline consumption. The results are combined and summarized in the final section, where we return to the question whether the estimated costs were worth incurring.

II. DIRECT COSTS AND ADVERTISING EXPENDITURES[4]

In this section we present estimates of the increases in consumer expenditures on automobiles associated with the changes in size and horsepower that have occurred since 1949. We discuss here how much more it cost to produce the, say, average 1958 car, given the 1958 levels of costs and technology, than it would have cost (at 1958 prices and with 1958 retooling expenditures) to produce a car of 1949 average specifications with the average 1949 level of "attachments." We shall treat the additional cost of the 1958 technology (above the 1949 level)—and the cost of retooling—in Section III. The "cost" estimates in this section consist of estimates of the increase in price due to increases in size and horsepower; the increase in expenditures due to the wider use of automatic transmissions, power steering, and power brakes; and the increase in price due to the increase in advertising expenditures above the 1949 levels.[5]

[2] We say "may," not "must," for the market in question is far from perfect.

[3] See, for example, J. K. Galbraith. *The Affluent Society* (Boston: Houghton Mifflin Co., 1958), p. 352 and elsewhere.

[4] We are indebted to G. S. Maddala for research assistance with this section. Some of the computations reported in this section, originally designed for other purposes, were supported by a grant from the National Science Foundation to the University of Chicago to allow Griliches to engage in econometric studies of technological change.

[5] The last item belongs more properly in the section dealing with the cost of a given "technology"

Only the effects of changes in size and horsepower present a difficult estimation problem, and hence only the solution to this particular problem will be discussed in some detail here. Ideally a group of engineers and cost accountants could produce the appropriate estimates of what it would cost to produce an average 1949-specifications car in each of the subsequent years. Unfortunately, we lack both the specialized knowledge and the resources required for such calculations. Instead, we make use of the apparent close relation between selected dimensions (specifications) of an automobile and its price at a point in time to estimate what the price would have been, at the same point of time, for a car with a different set of specifications.[6]

Table 1 presents the results of annual regressions of the logarithm of car prices (list) for different makes and models on the horsepower, weight, and length of these cars, and on a set of classificatory ("dummy") variables for other "qualities" such as whether a car has a V-8 engine, whether an automatic transmission is included in the list price (is "standard" equipment), and so forth. As can be seen from these results, the use of three numerical variables (horsepower, weight, and length) and several dummy variables explains, on the average, 90 per cent or more of the cross-sectional variance in the logarithm of list prices at a point of time. While the coefficients of particular dimensions are not very stable, the direction of their change over time (for example, the fall in the relative "price" of horsepower[7] and length) is consistent with other evidence and what we know about the industry.[8]

The regressions presented in Table 1 are used to estimate what would have been the list price of a car with the specifications of the average 1949 car each year since 1949.[9] This series and that of the average list prices of the cars actually produced move closely together until about 1954 when they begin to diverge, the difference (shown in col. [1] of Table 2) reaching its maximum in 1959 and then declining slightly. During the 1956–61 period the difference between the average list price of the cars actually produced and the predicted price for the

but is discussed in this section for reasons of convenience.

[6] For a more detailed discussion of the problems associated with relating cross-sectional differences in the price of a commodity to differences in "quality," dimensions, or specifications see Z. Griliches, "Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change" (Bureau of the Budget-NBER Price Statistics Review Committee Staff Report No. 3, printed in United States Congress, Joint Economic Committee, *Government Price Statistics*, Hearings . . . January 24, 1961, [Washington, Government Printing Office, 1961], pp. 173–96), and the literature cited there.

[7] In particular, the fall in the relative "price" of horsepower clearly stems from the technological change in horsepower-engine size relation studied explicitly in Sec. IV below.

[8] Similar regressions were also run in linear form (rather than the semi-log form reported here) and using "piston displacement in cubic inches" as an additional variable without any improvement over the reported results. The "insignificance" of the displacement variable is due to its extremely high correlation with horsepower. Since we are primarily interested in costing horsepower, we introduce it here directly rather than going through a circuitous procedure such as that necessary in Sec. IV.

Estimates were also made using several cross-sections at a time, imposing the condition that the various slope coefficients be the same for different years, but allowing the level of average prices ("technology") to shift "neutrally" over time, by assigning a separate constant term for each cross-section. The results were similar to those reported here and, since they do not lead to substantially different estimates or interpretations, are not reproduced here. Some of these estimates have been presented in Z. Griliches, "Hedonic Price Indexes . . . ," *op. cit.*

[9] In view of the form of our regressions, if profit margins and wholesale-retail markups are roughly constant in percentage terms, or at least uncorrelated with the various specification variables, this is also an estimate of "costs."

average 1949 car averaged approximately $450 per car, or about 17 per cent of the actual average list price.

The calculated price differences shown in column (1) of Table 2 are subject to several reservations. First of all they are based on list prices and may not represent the trend of actual prices adequately. In particular, if actual prices paid fell relative to list prices, the actual difference in price will be overestimated by our procedure. If, for example, discounts from

TABLE 1

COEFFICIENTS OF SINGLE-YEAR CROSS-SECTIONAL REGRESSIONS RELATING LOGARITHM OF NEW UNITED STATES PASSENGER-CAR PRICES TO VARIOUS SPECIFICATIONS, ANNUALLY 1950–61

Model Year	No.	Constant	Coefficients* of H	W	L	V	R^2
1950	72	1.2709	.158 (.048)	.0484 (.0285)	.832 (.115)	−.024 (.014)	.892
1951	55	1.4329	.117 (.054)	.017 (.031)	.818 (.116)	.012 (.013)	.909
1952	51	1.7174	.097 (.042)	.105 (.030)	.578 (.127)	−.020 (.015)	.927
1953	54	1.9328	.113 (.044)	.103 (.038)	.471 (.136)	−.034 (.020)	.891
1954	65	2.3766	.202 (.037)	−.026 (.042)	.398 (.106)	−.024 (.014)	.857
1955	55	2.4570	.118 (.059)	.095 (.050)	.202 (.128)	−.050 (.026)	.871
1956	87	2.3359	.065 (.027)	.163 (.027)	.192 (.079)	−.052 (.016)	.907
1957	95	2.7370	.051 (.013)	.059 (.017)	.171 (.057)	−.011 plus significant (.010) coefficients for T, A, P, B	.967
1958	103	3.0389	.007 (.018)	.142 (.026)	−.073 (.092)	.005 plus T, A, P, B (.021)	.906
1959	87	3.1077	.052 (.013)	.103 (.017)	−.068 (.065)	−.031 plus T, A, P (.016)	.939
1960	78	2.9723	.052 (.009)	.059 (.020)	.065 (.073)	−.017 plus T, A, P, C (.011)	.951
1961	99	2.2530	.026 (.011)	.132 (.017)	.309 (.080)	.011 plus T, P, C (.012)	.940

* Dependent variable—logarithm of "list" (advertised delivered) price. Logarithms to the base 10. To convert the results to natural logarithms multiply all coefficients by 2.3. The resulting coefficient, if multiplied by 100, would measure the *percentage* impact on price of a *unit* change in a particular specification or "quality," holding the other specifications constant.

H, advertised brake horsepower, in 100's.
W, shipping weight in 1,000 pounds.
L, over-all length, in hundreds of inches.
V, 1 if the car has a V-8 engine; 0 if it has a 6-cylinder or less engine.
T, 1 if the car is a hardtop; 0 if not.
A, 1 if automatic transmission is "standard" equipment (included in price); 0 if not.
P, 1 if power steering is "standard"; 0 if not.
B, 1 if power brakes are "standard"; 0 if not.
C, 1 if the car is designated as a "compact"; 0 if not.

Source: *Specifications and prices, 1949, 1951–53:* Annual statistical issues (March 15) of *Automotive Industries* and annual issues of *Automotive News Almanac. 1954–60:* Various issues of National Automobile Dealers Association's *Used Car Guide*, Washington. *1955–58*: Data are from the February issue of the corresponding year. For 1954 models, figures are taken from July, 1959, issue; for 1959 models, from January, 1959, issue: and for 1960, from December, 1959, issue. *1950 and 1961: Red Book: Official Used Car Appraisals* (Chicago: National Market Reports, Inc.). November 14, 1956, and January 1–February 14, 1961. Some 1961 data are also based on *Car Fax* (Vol. VI, No. 1, 1961 ed., New York). Power brakes data for some years are taken from various issues of *Ward's Automotive Yearbook*. Prices of automatic transmissions, power steering, and power brakes are taken from various issues of *Automotive News Almanac* and from October 1–November 14, 1958, issue of the *Red Book*.

Production Data: 1956–60 by model years by makes is taken from *Automotive Industries*, March 15, 1961. 1961 model-year data are from *Automotive News*, August 7, 1961. For 1955 it was assumed that the model year began in November of the previous year; for 1954 that the model year was January–October, model-year production by makes was computed from monthly production figures by make given in the 1955 and 1956 March 15 issues of *Automotive Industries*. For 1949–53 it was assumed that the model year coincided approximately with the calendar year; calendar-year production data by makes were taken from *ibid*. Data on models within makes and on V-8 engine, automatic transmissions, and power steering and brakes installations were available only for calendar years based on registration data (*Ward's Automotive Yearbook*, various issues). These data were transformed into percentages of a particular make, and these calendar-year within-make percentages were used to break down the model year production figures by makes to arrive at model-year production figures by makes *and* models. For 1961 we used 1960 calendar-year data on models within makes to break down the 1961 model-year production data by makes.

list price increased from zero in 1949 to an average of about 15 per cent in 1960, then the average figure given for 1956–61 should be about $380 per car rather than the estimated $450.[10] On the other hand, we have priced *all* cars at their four-door sedan prices, not taking into account the faster growth in the number of higher priced station wagons, convertibles, and other car models. Since our equations make percentage changes in price depend on changes in absolute specification levels, a higher "true" average price would lead also to a higher estimate of the difference.

Third, these and later calculations are based on "predictions" from statistically estimated equations that do not fit the data perfectly and hence are subject to error. The probable magnitude of this error can be calculated, however. The standard error of the regression line (the "standard" prediction error at the mean levels of the independent variables) is quite high for any one year. It averaged about $170 in the 1956–61 regressions. Thus, there is some doubt whether any *one* particular annual difference is statistically significantly different from zero. The consistency in the sign of these differences leaves little doubt, however, about their significance for the 1956–61 period as a whole. The quoted figures should thus provide a good estimate of the orders of magnitude that are involved here, since in no case were the average 1949 specifications outside the range of the observed variation in the specifications of later model-year cars. We are always interpolating rather than extrapolating to get at our "predictions."

TABLE 2

TOTAL "DIRECT" COSTS OF AUTOMOBILE CHANGE SINCE 1949

Model Year	Per Car Cost of Increase in						Total Passenger Car Production (000's)	Total "Direct" Cost of Model Change† ($ Millions)
	Size and Horsepower*	Use of Optional Equipment			Advertising Expense	Total		
		Automatic Transmission	Power Steering	Power Brakes				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950	$−13	$12	....	....	$−3	$−4	6,659	−27
1951	17	33	$ 2	....	−2	50	5,331	267
1952	58	38	9	$ 1	0	106	4,337	460
1953	11	35	22	3	0	71	6,135	436
1954	160	55	21	7	3	246	4,359	1,072
1955	279	70	23	9	10	391	6,201	2,425
1956	377	72	14	6	14	483	6,295	3,040
1957	518	86	25	9	13	651	6,218	4,048
1958	410	86	31	10	16	553	4,256	2,354
1959	520	87	30	9	14	660	5,568	3,675
1960	447	75	31	9	13	575	6,011	3,456
1956–60 average	....	....	....	....	....	584	....	3,315

Source: See Table 1.

* The regressions presented in Table 1 were used to predict the price of a car with average 1949 specifications. The specifications of the average 1949 car used in these predictions were: horsepower—104.24, weight—3,289.5 pounds, length—200.84 inches, and fraction with V-8 engines—0.4067.

† Col. (6) × col. (7).

[10] For data on discounts see A. F. Jung, "Price Policy and Discounts in the Medium- and High-priced Car Market," *Journal of Business*, October 1960, pp. 342–47.

The next set of "cost" estimates is very simple. Columns (2)–(4) of Table 2 present the estimated cost (per car) of the increased use of automatic transmissions, power steering, and power brakes. In each case we took a time series of list prices, a time series on the increase in the percentage use of these items (since 1949) as optional equipment (not already included in the price as "standard" equipment), and computed the "cost" per car as the product of these two series. Again, these "costs" reach their peak in 1958 or 1959.

Column (5) of Table 2 presents the estimated increases in advertising expenditures associated with the above-described model changes. We took a time series of advertising expenditures per car (for calendar years) from *Advertising Age*. These data are of doubtful quality but are used for lack of a better source. The main difficulty here is to devise a measure of the 1949 *quantity* of advertising per car in subsequent prices. We attempt to approximate such a measure by inflating the 1949 average advertising expenditures per car by the implicit GNP deflator. This deflator probably rises less than advertising *rates*, but the real cost of reaching and informing a particular consumer must have fallen somewhat during this period. Television rates, for example, have clearly not risen in proportion to the increase in the number of viewers. If anything, these calculations probably underestimate the "real" increase in the *quantity* of advertising per car. We estimated the "cost" of increased advertising as the difference between current advertising expenditures per car and the 1949 advertising expenditure level in current prices. Again these "costs" reach their peak in 1958.

The total direct cost of model changes (col. [8]) is estimated for each year by totaling the above described estimates (col. [6]) and multiplying them by the annual passenger-car production figures (col. [7]). For 1956–60 these costs averaged about $3.3 billion annually. This is probably an underestimate since we have left out of our calculations such other changes as the optional purchase of higher horsepower engines, power seats, power windows, various optional "trim" items, and so forth. On the other hand, allowing for the growth of discounting would reduce this figure to about $2.8 billion annually. In addition, the "prediction error" (two standard deviations) associated with these figures could lead them to be too high *or* too low by about $1.0 billion.

III. RETOOLING EXPENDITURES[11]

The most obvious cost of automobile model changes is the expenditure by the automobile manufacturers for the new tools, jigs, and dies needed to produce new models. Were models to remain unchanged, such expenditures would clearly be reduced to the level necessary to replace existing equipment as it wears out.

Of course, such expenditures on the physical equipment of production are not the only ones directly associated with model changes. There are, in addition, the costs of research and development and of design of the new models. Unlike the expenditures for retooling, however, the latter costs are not available, and we shall thus not be able to include them in our estimates. The exclusion of these costs, however, is not *wholly* undesirable. In the preceding section and in the following one we charge as "costs" expenditures that could have been avoided by

[11] We are grateful to Lloyd Dollett, of the Securities and Exchange Commission, for his courtesy and assistance. The computations in this section were performed by Felicity Skidmore. We are indebted to members of the Harvard Research Seminar in Quantitative Economics for suggestions.

producing cars with 1949 specifications *with the current technology*. It would clearly be inconsistent to charge also the costs of securing that technology. Since the development in which we are interested has been largely in engine design (see the next section), taking the form of reducing the "cost" of horsepower, it seems likely that the costs of securing that technology are a much larger part of research and development and design costs than of retooling expenditures. It follows that we are largely avoiding double counting here.[12]

It may appear, however, that we are double counting by including retooling expenditures as well as the direct costs discussed in the last section. Retooling expenditures are costs to the automobile companies and are presumably reflected in the prices of new cars which we already used in the regressions and computations of the previous section. It seems to follow that we have already included retooling expenditures (and research and development and design costs) implicitly in our estimates of direct costs. This is not the case, however. We used the regressions of the last section to estimate the direct costs of producing cars with 1949 specifications with current technology. But the costs of retooling (which are reflected in our regressions) are also reflected in such estimates. Hence our estimated direct costs for 1949 specification cars are *overestimates* of the costs that would have been incurred had no model changes taken place, since in the latter event the prices of all cars would have been lower because of the elimination of retooling costs. It is thus not double counting to add retooling expenditures at this point.[13]

As our estimates of retooling expenditures, we took the expenditures for special tools included in additions to plant and property reported by the automobile firms to the Securities and Exchange Commission[14] and charged by them to current costs. The relevant figures are available by calendar year; for the most part we have interpreted them as applicable to the model year following that calendar year.[15] The figures are available for the full period we consider, save that the Ford figures are only available beginning with the 1953 model year, and figures for Studebaker are not available before the merger with Packard. These problems were handled as follows:[16]

[12] Since we are not estimating "secondary" costs other than gasoline consumption, we feel safe in saying that the inclusion of retooling expenditures leaves our estimates on the low side.

[13] One qualification is necessary. If the recoupment of retooling costs in car prices is correlated with specifications, we have already counted some of it. In view of the semi-logarithmic form of our regressions, however, this effect will cancel out if it is roughly proportional to car price. This seems likely, since retooling expenditures per car are probably greater for high-priced models. In any case, such a bias in our results cannot be large, for despite the huge increase in retooling expenditures over the period, our regressions show declining "prices" for specifications even after technological change in engine design practically ceased (as evidenced by our results of the next section). Moreover, the double counting engendered by this effect applies only to a part of the full retooling expenditure. We therefore feel fairly safe in neglecting it.

[14] Form 10K, Schedule V.

[15] The only exceptions are Willys-Overland and Nash and later American Motors, which report for the year ended September 30. (Neither of these is a large part of the total, and the first is clearly negligible.) We have still assumed that such expenditures took place at the *end* of the reporting year and were for the *following* model year. This seems clearly to have been the case since about 1955 but is less certain before that time. Readjustment to account for this (if needed) would be only one of timing and would make very little difference in the industry totals in any case.

[16] Figures for Hudson in 1953 and Kaiser in 1950 are also missing. We did not bother to adjust the totals for this, because the first figure was clearly only about 1 per cent of the total at the most, and the second was much less.

Ford.—In 1953, Ford retooling expenditures were 10 per cent of the total. We have added 10 per cent to the totals for the preceding years.

Studebaker.—In 1954, expenditures by Packard were 1.3 per cent of the total (adjusted to include Ford). In 1955, expenditures by Studebaker-Packard were 3.7 per cent. We therefore added 2.4 per cent to the total for each year before 1955.

Clearly, the first adjustment is the only one of any importance; it seems conservative in view of higher Ford expenditures in later years.

TABLE 3

RETOOLING COSTS OF MODEL CHANGES SINCE 1949

MODEL YEAR	MILLIONS OF CURRENT DOLLARS		COST PER CAR* (CURRENT DOLLARS)
	Total Expenditures for Special Tools (1)	Retooling Costs Attributable to Model Changes (2)	(3)
1950	175.3	19.6	2.9
1951	208.5	45.2	8.5
1952	262.8	81.7	18.8
1953	419.5	246.5	40.2
1954	439.1	263.5	60.5
1955	632.7	469.2	75.7
1956	523.3	336.2	53.4
1957	947.3	771.7	124.1
1958	827.8	625.7	147.0
1959	745.8	532.1	95.6
1960	756.5	536.6	89.3
1961	896.5	678.9	125.6
1956–60 average	760.1	560.5	98.9

* Production data 1950–60 from Table 2; 1961 estimated production from *Automotive News*, August 7, 1961.

To allow for normal replacement of worn-out equipment, we ignored the fact that 1949 was a year of substantial model change and assumed that all expenditure for that model year was for replacement of worn-out equipment; this yielded an upper limit of $190 billion for normal replacement expenditures. Taking into account model changes in 1949, $150 billion seems more than ample as an estimate of normal replacement expenditures (especially in view of the expenditure of only $175 million on retooling in 1950) and we used this figure adjusted for changes in the wholesale price index for metalworking machinery. The resulting costs and costs per car (including 8 per cent for taxes that would have been saved) are presented in Table 3.

IV. GASOLINE CONSUMPTION[17]

A. THE DATA

This section deals with the saving in gasoline consumption that would have been effected had the "horsepower race" not occurred—had 1949 specifications been continued. To estimate this saving

[17] We should like to thank our research assistants, Stephen A. Resnick and David Shapiro, who secured most of the data here discussed; George Delehanty, who computed the weights for the relative importance of makers' models within automobile makes; and Felicity Skidmore and Cynthia M. Travis, who performed most of the computations directly relevant to gasoline consumption. The materials in this section of the study are based on work done for other purposes under a grant from Resources for the Future, Inc., to Massachusetts Institute of Technology to allow Fisher to study quantitative aspects of the economics of supply and demand in the petroleum industry.

requires detailed data by model on miles per gallon performance of automobiles. The only such data available are the figures on miles per gallon during the period of ownership reported by Consumers Union and Consumer Research (principally the former) for 185 different models tested over the period 1948—July, 1961.[18]

B. FUEL ECONOMY AND ENGINE SIZE

There has been considerable technological progress in engine design over the last fifteen years. In particular, as the automobile manufacturers moved toward higher and higher horsepower cars in the middle and late fifties, they also redesigned engines to secure higher horsepower for a given engine size. This had the dual effect of reducing the extra gasoline consumption attendant on horsepower increases and (as noted in Sec. II) of reducing the direct cost of horsepower. Accordingly, we had to find some way of measuring such progress in engine design in order to estimate the gasoline consumption that would have occurred had cars with 1949 horsepowers been built in each successive year *with the developing technology.*

Since the available test statistics for any given year are too scanty to allow us to analyze each year's models wholly separately (as in Sec. II)—our solution was a compromise between the need for enough data to perform any analysis and the impossibility of pooling the test data in any simple way because automobiles with different types of transmission cannot be simply lumped together for such purposes. We proceeded to break the problem into two parts: the relation of engine size to gasoline consumption and the effect of horsepower on engine size. The former relation was studied by pooling all test data for cars with a given transmission; the latter effect was studied by analyzing engine data for each successive year separately. This procedure involved the assumption that technological change was largely restricted to changes in engine design or in the type of transmission employed (we were able to use a moderately fine breakdown by transmission types) rather than acting to alter the effects of existing transmissions without changing their type.[19]

Consumer Reports each year presents a statistic which they term "Fuel Economy Factor" and which we shall denote by F. This statistic is "the cubic feet of cylinder volume swept by the pistons on their suction strokes while the car travels one mile in high gear."[20] If engine displacement (D) is measured in cubic inches and the number of engine revolutions per mile in top gear is denoted by R, then:

$$F = \frac{R}{2}\left(\frac{D}{1728}\right). \qquad (1)$$

R, in turn, is dependent on wheel size and axle ratio, while D, as we shall see, is highly correlated with horsepower for a given engine type. Statements in *Consumer Reports* clearly imply that, if these data are segregated by type of transmission, they should be related to F.[21] This indeed turns out to be the case.

As already stated, F is defined for the performance of the car in its top gear. It would be possible to construct similar variables which measure performance in

[18] Other reported data are generally either for constant-speed tests, or highly aggregated.

[19] Visual inspection of the residuals from our regressions seems to bear this out, as there does not seem to be any tendency for the scatter in the relation of gasoline consumption to engine size, given transmission type, to change over time.

[20] "U.S. Autos 1961," *Consumer Reports*, XXVI, No. 4 (April, 1961), 176.

[21] *Ibid.*

lower gears, but these would of course be almost perfectly correlated with F, for either manual or automatic transmissions, given the limited number of forward gears. However, even if we were to use such similar variables for lower gears, it would still be incorrect to regress gasoline consumption on them, pooling observations for cars with a different number of forward gears; the distribution of mileage over the different forward gears will not be the same for a car with four such gears as for a car with three or two. It follows that the coefficients in such regressions will be different for cars with a different number of forward gears. This being so, our data must be segregated by the number of forward gears before F can be used as the only "displacement-type" variable in the regression.[22] Accordingly, we segregated the data into 2-speed automatics, 3-speed automatics, 4-speed automatics, manuals without overdrive, and manuals with overdrive. Fortunately, the test data are sufficiently numerous to support the ensuing analysis.[23] We therefore regressed gallons per 10,000 miles of car travel (denoted by G) on F for each of the five transmission categories.

As already remarked, the true relationship we are seeking is one between G and variables similar to F reflecting performance in various gears as well as during idling periods. Given our segregation by transmission type, such variables are almost perfectly correlated with F, and we thus use F alone. However, the goodness of fit of the true relationship—and, therefore, of our estimated one as well—clearly depends on the stability of the distribution of mileage over the various forward speeds or gears (and, less importantly, of the distribution of time between idling and motion) over the tests reported. Since this distribution is not very stable, we expect to find somewhat low (though statistically significant) correlations.[24] On the other hand, the relative stability of this distribution will depend on how much choice is left to the driver as to when to shift gears. We should, therefore, expect to find higher correlations for automatic-transmission cars than for manual-transmission cars, other things being equal. A similar argument leads us to expect higher correlation for 2-speed automatics than for 3-speed ones, for 3-speed automatics than for 4-speed ones, and for cars with manual transmissions than for those with overdrive.[25]

All these predictions as to the relative size of the R^2's are borne out by the results (Table 4). Their agreement with our predictions gives us some confidence in their relevance.

C. ENGINE SIZE AND HORSEPOWER[26]

The present section is concerned with the effects of horsepower on F, our meas-

[22] F can be used also as the sole explanatory variable in the regressions, because such other variables as automobile weight enter principally into the determination of the characteristics and especially the size of the engine.

[23] For the period 1949–61, there are almost no tests of semi-automatic transmissions, but the number of cars with such transmissions is negligible.

[24] Cf. comments on the test statistics in "Road-test Report on the Full-size 'Low-priced' V-8's," *Consumer Reports*, XXVI, No. 2 (February, 1961), 107.

[25] Since the variability of the distribution of mileage over forward speeds can be expected to be relatively high (*ceteris paribus*) when the number of forward speeds is large and the amount of shifting among them consequently great.

[26] We are indebted to A. R. Rogowski, of the Department of Mechanical Engineering at M.I.T., for preliminary discussion of some of the technical matters covered in this section. He is emphatically not to be held responsible for our opinions, conclusions, results, or especially errors, nor for the evidently rudimentary state of our information on automotive mechanics.

ure of engine size. These effects are assumed to operate only on engine displacement, D, the principal determinant of F, an innocuous assumption as the number of engine revolutions per mile, R, the other variable in equation (1), does not vary greatly from model to model.

As our measure of horsepower, we take "maximum advertised horsepower" (as in Sec. II), despite the fact that this variable is based on stripped engine performance rather than on actual power delivered to the rear wheels.[27] We considered the effects of transmission characteristics in the previous section. Moreover, if advertised horsepower is what the car-buyer thinks he is buying, it is advertised horsepower whose cost we wish to ascertain.

For a given type of engine and given engine efficiency, engine displacement (D) and horsepower (H) are theoretically proportional. Actual engines, however, were redesigned during the 1950's to permit the construction of high-horsepower engines at relatively lower displacements.[28] Accordingly, we did not pool observations from different years but estimated instead the relationship separately for each year.[29]

The fact that, for a given engine type, horsepower and displacement are roughly proportional implies that technological change takes the form of shifting a ray through the origin. Not all developments in engine design, however, can be applied to all horsepowers. Hence, while the points for a given engine type lie on a ray through the origin, not all points on that ray can represent actual engines. Successive technological changes which are aimed at higher horsepower engines become applicable at successively higher horsepower levels. Thus our regressions, save for the early years, are estimates not primarily of the relationship between displacement and horsepower for a given engine type but of the relationship between engine design and horsepower.[30]

TABLE 4

REGRESSIONS OF GASOLINE CONSUMPTION (G) ON *Consumer Reports'* FUEL ECONOMY FACTOR (F)

Transmission Type	Regression Equation	r^2	No.
2-speed automatic	$G=214+2.38^*F$ (0.287)	.748	27
3-speed automatic	$G=248+2.18^*F$ (0.179)	.693	68
4-speed automatic	$G=380+1.54^*F$ (0.359)	.368	35
Manual without overdrive	$G=240+1.79^*F$ (0.388)	.422	31
Manual with overdrive	$G=308+1.68^\dagger F$ (0.648)	.233	24

* Significant at 0.1 per cent level. † Significant at 2 per cent level.

[27] Cf. "U.S. Autos 1961," *op. cit.*, p. 176.

[28] This redesign took the form largely of raising compression ratios and of shifting the torque-rpm curve. The rising octane content of gasoline also helped.

[29] The observations in these computations were on engines rather than on cars. We eliminated observations on other models produced by a given company that had the same engine.

[30] Since the correlation between horsepower and displacement is so high for each year, and this is the relationship of interest, there is no need to introduce the effect on compression ratios as an explicit step.

We are estimating the effect of higher horsepower on the availability of displacement-horsepower ratio reducing techniques. The fact that we obtain such a good fit leads us to accept a linear form for that relationship, and our faith in it is further bolstered by the fact that in every year the range of horsepowers covered in the data is extremely wide. Further, the 1949 horsepowers are all inside that range, so that we shall be interpolating between actual figures in applying our results to them.

TABLE 5

REGRESSIONS OF DISPLACEMENT (D) ON MAXIMUM ADVERTISED HORSEPOWER (H)

Model Year	Regression Equation	r^2	No.
1948	$D = 0.738 + 2.30^{*}H$ (17.0) (0.155)	.880	32
1949	$D = 6.24 + 2.17^{*}H$ (12.0) (0.106)	.938	30
1950	$D = 6.29 + 2.14^{*}H$ (13.8) (0.120)	.908	34
1951	$D = 11.4 + 2.04^{*}H$ (11.1) (0.0963)	.930	36
1952	$D = 30.0^{\dagger} + 1.80^{*}H$ (11.1) (0.0900)	.917	38
1953	$D = 70.3^{*} + 1.42^{*}H$ (12.2) (0.0946)	.851	41
1954	$D = 82.2^{*} + 1.26^{*}H$ (14.1) (0.0987)	.798	43
1955	$D = 112^{*} + 0.938^{*}H$ (10.8) (0.0595)	.883	35
1956	$D = 103^{*} + 0.950^{*}H$ (10.4) (0.0505)	.912	36
1957	$D = 108^{*} + 0.860^{*}H$ (11.1) (0.0472)	.910	35
1958	$D = 109^{*} + 0.856^{*}H$ (11.6) (0.0444)	.921	34
1959	$D = 101^{*} + 0.914^{*}H$ (10.4) (0.0390)	.945	34
1960	$D = 109^{*} + 0.851^{*}H$ (19.2) (0.0783)	.797	32
1961	$D = 73.4^{*} + 1.07^{*}H$ (12.2) (0.0564)	.914	36

* Significant at 0.1 per cent level.
† Significant at 1 per cent level.

It is important to realize that the relationship between D and H is exactly what we want. To take a given engine type and extend the line for high-horsepower cars backward toward the origin would give a most misleading overestimate of the extent to which the developing technology could have been used to effect gasoline economies at 1949 horsepowers. The engine redesigns for high-horsepower cars simply could not have been applied to these lower levels. Our estimates, however, provide precisely the required information: the extent to which advances in engine design are applicable at *given* horsepowers.

The results of these regressions are presented in Table 5.[31] We report standard errors for the constant terms, as the question of whether the regression line passes through the origin is obviously of interest. These results show a clear pattern. Starting with the expected ray through the origin in 1948, there is a slight decline in the slope to 1950–51, without much change in intercept. From 1952 to 1955, the slope diminishes rapidly and the intercept rises substantially.[32] From 1955 through 1961 the coefficients remain roughly constant.[33]

This pattern is to be expected from the

[31] We present the results for the model years 1948–61 inclusive since the pattern seems of interest.

[32] Note that this change in the slope coefficients reflects itself (roughly) as a change in the direct cost of horsepower already reported in Sec. II.

[33] This pattern is not simply the result of sampling fluctuations. The hypothesis that all the regressions are from the same true relationship is emphatically rejected by covariance analysis, the relevant F statistic being 28.9, whereas the probability of observing an F even as high as about 2.1 if the hypothesis were true would be .001 (with 26 and 468 degrees of freedom). Moreover, such significant inhomogeneity is not merely due to the behavior of the intercepts. A further test of slope equality only yields an F statistic of 29.1, whereas the probability of observing an F even as high as about 2.7 if the slopes were all the same would be .001 (with 13 and 468 degrees of freedom). It is thus apparent that our results reflect real changes in structure for the period as a whole (similar tests would doubtless fail to reject the null hypothesis of no structural change for 1955–60).

preceding discussion. Starting with the ray through the origin which represents the displacement-horsepower relation for a given engine type, minor improvements took at first the form of lowering the slope of that ray slightly (making horsepower cheaper in terms of displacement). With the start of the horsepower race, this effect was accompanied by the introduction of new rays, with lower slopes, attainable only at higher and higher horsepowers. The result in regression terms is depicted schematically in Figure 1, with R_1, R_2, and R_3 representing three engine types, representative of a whole spectrum of techniques (largely higher compression ratios and efficient use of high octane gasoline) available at higher horsepowers. The dashed portion of each ray represents that part of the ray which is unavailable, while the dotted circle shows the range of observations on the ray. BC is the resulting estimated regression line. As the horsepower race progressed, new rays became available to the right of R_3 at higher horsepowers, while existing techniques were used to produce higher horsepower engines at given displacements. The effect of all this was to shift BC upward and lower its slope. Finally, with the slackening of the horsepower race and the introduction of the compact cars, existing techniques were used to produce the required lower horsepower engines, thus sliding the dotted circles back toward the origin, shifting the regression line BC downward and raising its slope slightly.

The magnitude of these effects is of some interest. Our results indicate that a car in the 80–90 horsepower range (slightly below the range encountered for most low-priced cars) would have had a roughly constant displacement up until 1961 when a very moderate decline in displacement would have occurred. At 100 horsepower, displacement fell from about 230 cubic inches in 1948 to 194 cubic inches in 1960 and 180 in 1961. At 200 horsepower, however, displacement fell from about 460 cubic inches in 1948 to about 280 in 1960 and 1961. At higher horsepowers, the fall was, of course, greater. In all cases, most of the reduction occurred in the 1951–55 period.

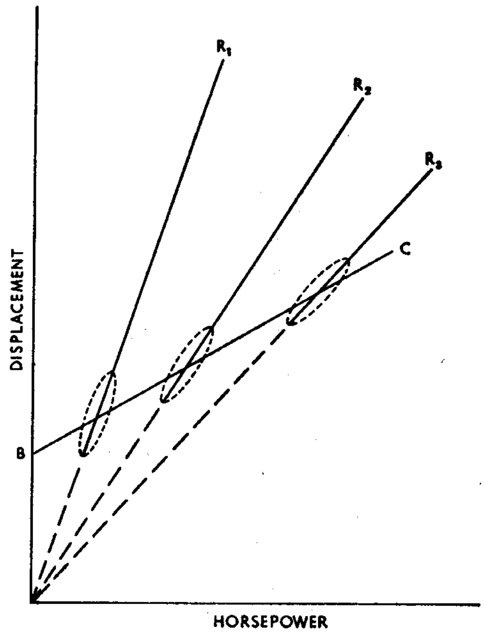

FIG. 1.—Illustration of technological change in the horsepower-displacement relationship.

D. GASOLINE COSTS OF MODEL CHANGES

The relations summarized in Tables 4 and 5 were used to estimate the saving in gasoline consumption that would have been expected had 1949 specifications been continued. First, we estimated the gasoline consumption per 10,000 miles of each actually produced automobile model. Where Consumer Union test data were unavailable, we estimated ("predicted") it from the appropriate equation in Table 4, using "fuel economy factors" computed from published engine displacement and rpm data. These "predictions," together with the actual test data, where available, were then aggregated to produce comparable figures for company brand names such as Chevrolet, Ford, and Dodge, using (as in Sec. II) weights constructed from model-year production data where available and from calendar-year registration data otherwise.[34] These figures were in turn averaged to secure average figures for the industry for each model year, 1949–60, using as weights actual production data by brand name, where available, or registrations as of July 1 of the year following the close of the model year.

TABLE 6

MILES PER GALLON PERFORMANCE OF NEW ACTUAL AND CONSTANT 1949 SPECIFICATION CARS

Model Year	Miles Per Gallon, New Actual Cars	Miles Per Gallon, New 1949 Specification Cars	Extra Cost of New Actual Cars Per 10,000 Miles* (Current Dollars)
1949....	16.4	....	....
1950....	16.4	16.7	3.1
1951....	15.7	16.9	12.5
1952....	16.0	17.1	11.4
1953....	16.1	17.2	11.7
1954....	15.6	17.3	18.4
1955....	15.1	17.4	26.8
1956....	14.8	17.7	34.6
1957....	14.5	17.9	42.4
1958....	14.4	17.9	43.2
1959....	14.3	18.0	44.3
1960....	15.3	18.0	30.6
1961....	15.2†	18.5	37.2‡

* Valued at prices in Table 7 (below).
† 1960 weights used.
‡ At 1960 prices.

To estimate the gasoline consumption that would have been incurred by cars with 1949 specifications, we took first each 1949 model's horsepower and used the results of Part C of this section to estimate what the model's displacement would have been in each successive year. From these estimates we selected as the displacement figure for each year the minimum of the displacements estimated for that model from 1950 to the year in question and the actual displacement for 1949. These displacements were then transformed into fuel economy factors using equation (1) from Part B and assuming that engine revolutions per mile in high gear would have been the same as in 1949. The resulting values of F were then transformed into gasoline consumption per 10,000 miles by use of the results of Part B of this section.

These estimated gasoline consumption figures were aggregated into brand-name figures using the 1949 weights. The results were then aggregated in turn into industry figures using registrations of 1949 cars as of July 1, 1950.[35] The resulting estimates of miles per gallon performance for both the actual and the constant 1949 specification cars are given in Table 6 for model years 1949 through 1960.

Table 6 shows that, while gasoline mileage was declining from 16.4 miles per gallon in 1949 to 14.3 miles per gallon in 1959, it could have been rising to 18.0 miles per gallon had 1949 specifications been continued. Even the rise to 15.3 miles per gallon that occurred with the introduction of the compacts in 1960 fell far short of the actual 1949 level, let alone the level that could have been achieved.

[34] The basic assumption in the latter case was that the *internal* distribution of each brand name over the various maker's models it included was the same for the calendar year as for the model year. This involved a host of minor problems of comparability between successive year's models too numerous to discuss in detail. The registration data are collected by R. L. Polk & Co., and reported in several trade journals.

[35] We assume here and below that the distribution of 1949 cars by brand names would have been preserved had 1949 specification been continued. Since brand market shares have not changed very much, this is not an important assumption.

In money terms, the average owner of a 1959 car (the most gasoline-consuming model year) was paying about $44 per 10,000 miles more for gasoline than would have been the case with 1949 specifications—about 20 per cent of his total gasoline expenditures. For high-price high-horsepower cars, the additional cost was even greater.

Unlike the costs discussed in the last two sections, the costs of extra gasoline consumption do not terminate with the building and sale of the car; they continue over the life of the automobile. We must therefore estimate the total gasoline consumption of that part of the car *stock* consisting of cars built after 1949 that would have been avoided in each year with constant 1949 specification.[36]

To construct estimates of gasoline consumption by actual post-1949 cars for each year, we took the average gasoline consumption by brand name and model year derived above and multiplied them by the registration figure for that brand name and model year as of July 1 of the year in question. The basic assumption used in the construction of estimates of the gasoline consumption of the constant 1949 specification car stock was that the history of these cars would have duplicated the actual history of the 1949 models, so far as the distribution in any year *t* of such cars over brand names is concerned.[37]

The resulting estimates of gasoline consumption by post-1950 cars for both the actual and the 1949 specifications car stock assume that cars were driven 10,000 miles per year, on the average. However, the Bureau of Public Roads and the American Petroleum Institute estimate the actual average mileage of passenger cars at somewhat less than this, their estimates ranging between about 9,000 and 9,500 miles per year.[38] There is no need for great precision here, and we took 9,250 miles as the relevant figure for every year.

We valued gasoline consumption at the current retail prices for regular gasoline, including tax,[39] adding one cent per gallon as an adjustment for the higher price of premium grade gasoline.

The resulting estimates are given in Table 7. However, they do not tell the whole story. As mentioned earlier, gasoline consumption costs of model changes last throughout the life of the car. Thus, even if the 1962 and all later model years were to see a return to 1949 specifications, the additional gasoline expenditures due to the 1950–61 model changes would continue for the next decade at least. Assuming an average car life of ten years, and discounting the future at 10 per cent (surely an ample rate), the present value in 1961 of such expenditures (at 1960 prices) is about $7,109.5 million.

V. TOTAL COSTS AND CONCLUSIONS

The various components of costs estimated in previous sections are brought

[36] We must make here some assumption about the change in gasoline consumption over the life of a car. Since we are primarily interested in the *difference* between the gasoline consumption of the actual car stock and of one made up of 1949 specification cars, we have only to assume that the effect of age on gasoline consumption is linear and the same in both cases, so that with the same age distribution of cars in the car stock, the difference in gasoline consumption will be unaffected.

[37] Other assumptions as to the composition of the car stock over brand names would have been more difficult to apply in practice and would make little difference to the totals. To assume that the total number of cars would have been less than actually was the case would have given a higher estimate of costs.

[38] American Petroleum Institute, *Petroleum Facts and Figures, 1959* (New York, 1960), pp. 252–53.

[39] We include taxes here as elsewhere as we are measuring expenditure by car owners. Taxes were about 7–10 cents per gallon during the period.

TABLE 7

GASOLINE CONSUMPTION COSTS OF MODEL CHANGES SINCE 1949

Year	Extra Gasoline Consumption by Post-1949 Cars (Million Gals.)	Average per Post-1949 Car (Gals.)	Per Cent of Actual Gasoline Consumption by Such Cars	Average Retail Price of Gas Including Tax (Current Dollars per Gal.)*	Gasoline Costs of Model Changes	
					Per Post-1949 Car (Current Dollars)	Millions of Total Current Dollars
1950	45.4	14.7	2.6	.2776	4.1	12.6
1951	126.1	15.1	2.7	.2815	4.3	35.5
1952	362.4	27.2	4.7	.2856	7.8	102.0
1953	542.7	29.8	5.2	.2969	8.8	161.1
1954	797.4	33.7	5.8	.3004	10.1	239.5
1955	1,237.7	42.1	7.2	.3007	12.7	372.2
1956	1,906.7	53.6	9.1	.3093	16.6	589.7
1957	2,523.6	62.7	10.5	.3196	20.0	806.5
1958	3,025.4	69.3	11.5	.3138	21.7	949.4
1959	3,642.0	77.0	12.7	.3149	24.2	1,146.9
1960	4,189.0	83.3	12.6	.3213	26.8	1,345.9
1956–60 average						967.7

* One cent per gallon added (see text) to figures for 1950–58 in American Petroleum Institute, *Petroleum Facts and Figures, 1959*, p. 379; 1959–60 *Platt's Oilgram Price Service*.

TABLE 8

TOTAL ESTIMATED COSTS OF MODEL CHANGES SINCE 1949

(Millions of Current Dollars)

Year*	Total Direct Costs (1)	Retooling Costs (2)	Gasoline Costs (3)	Total Costs† (4)
1950	−27	20	13	6
1951	267	45	36	348
1952	460	82	102	644
1953	436	246	161	844
1954	1,072	264	240	1,576
1955	2,425	469	372	3,266
1956	3,040	336	590	3,966
1957	4,048	772	806	5,626
1958	2,354	626	949	3,924
1959	3,675	532	1,147	5,354
1960	3,456	537	1,346	5,339
1956–60 average				4,843
Present value in 1961 of future gasoline costs already committed‡				7,110

* We have combined model-year and calendar-year figures. The actual timing of the various elements of the total is slighty different.

† Total may not equal sum of components due to rounding.

‡ Due to lack of data at time of writing, we do not present complete estimates for 1961. Preliminary estimates using 1961 figures presented in earlier sections indicate that costs in that year (including gasoline costs) continue well above $5 billion.

together in Table 8 and graphed in Figure 2.

What can we say about these figures? First, let us ask whether our estimates are likely to overstate or understate the costs to the economy of model changes since 1949. The answer seems to be that our estimates understate the cost. Aside from items previously discussed, we have not attempted to estimate such possibly important secondary costs as the added traffic and parking problems due to greater car length, or the costs in human life and property damage that may have resulted from higher horsepowers.[40] Further, newer model cars (especially as automatic transmissions became more and more widespread) tended to have higher repair costs than would presumably have

[40] Potentially at least, these costs could be estimated. Some parking garages charge a higher fee for longer cars, and insurance claims paid presumably could be analyzed for variation with specifications, other things being equal. This would be a full-scale undertaking, however.

been the case with 1949 specifications. None of these items has been included in our estimates.

Moreover, while we argued in Section III that the exclusion of design and research and development costs was in part an avoidance of double counting, it is clear that large elements of such design and research and development costs hardly contributed to the technological change involved in our estimates. One need only mention the expenditures that Ford must have incurred in the introduction of the short-lived Edsel to realize that we have failed to include some sizable items in our analysis.

Next, we have assumed throughout that the number of cars would have been unchanged had 1949 specifications been continued. This may or may not be a good assumption, but it is difficult to argue that *more* cars would have been sold. It follows that, if anything, our results fail to cost the extra cars that were in fact produced.

Finally, in choosing the 1949 model year as a standard for specifications, and in resting our analyses on the actual costs and gasoline consumption of domestically produced cars, we have not asked whether a more stringent standard could not be derived from the experience of various European car producers. Our cost estimates rest on the historical experience of the domestic industry. Had we chosen a European small-car standard, estimated costs clearly would have been higher.

For all these reasons, it seems to us that our estimates must err considerably on the low side, even after the greatest benefit of the doubt is given to the stochastic nature of our estimates. The order of magnitude of the cost of model changes is clearly greater than that indicated in our figures. On the other hand, we have not attempted to assess monetary benefits. For example, the increases in horsepower and in the use of power steering and automatic transmissions may have led to an increase in the average speed of automobile travel of about 10 per cent.[41] Assuming that in the base period the average speed was about 30 miles per hour, that approximately 9,000 miles were traveled by a car per year, and that on the average there were about

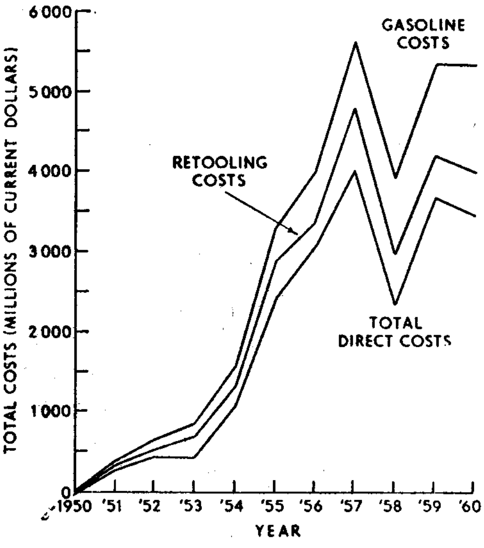

FIG. 2.—Total estimated costs of model changes since 1949.

1.5 passengers per car, we get an estimate of 45 man-hours saved per new car year. Valuing these hours at $1.00 per hour[42] leads us to a guess of $45 as the annual per car benefit from the time saving as-

[41] This and the following figures are purely illustrative. We have been unable to find a consistent set of national data on this topic. The following calculation is only intended to indicate the possible magnitude of such benefits. These estimates are probably on the high side.

[42] This relatively low figure is used, since a substantial fraction of these passengers are women and children who are not in the labor force.

pects of higher speeds. This is a large figure, of the same order of magnitude as our estimate of the costs of increased gasoline consumption per car, and would similarly persist throughout the life of the car. It is hard to think of many additional "benefits" of this sort. Their existence, however, is indicated by the apparent willingness of consumers to pay for at least some of these changes.

The costs of model changes since 1949 were thus a substantial part of expenditures on automobiles, especially in the last half of the 1950's, our estimates running about $5 billion a year.[43] Were such costs worthwhile? It is difficult to say. There is a presumption that consumer purchases are worth the money paid, yet one might argue that the fact that our figures for the late 1950's (about $700 in the purchase price per car, or more than 25 per cent, and $40 per year in gasoline expenses) will probably seem surprisingly high to consumers[44] is an indication that the costs in question were not fully understood by the consuming public.

On the other hand, one must not press such an argument too far. We have repeatedly stated that, in every model year considered, the *average* 1949 specifications lay inside the actual range of specifications encountered. The clear implication is that consumers could have bought such cars had they wished. Moreover, such items as automatic transmissions, power brakes, and power steering were separately available and had prices of their own. It is thus extremely hard to claim that at least some of the costs of model changes were not explicitly reflected in the prices set before consumers. Indeed, the only elements of such costs that were obviously not explicitly stated were the costs of retooling and advertising and (possibly) gasoline costs. Thus consumers knowingly purchased more costly cars than those with 1949 specifications, even in the presence of *some* explicit cost differential in favor of the latter.

All in all, save for the understatement of costs involved and the possibility that such costs were not fully understood by car-buyers, the model changes of the last decade seem to have been largely those desired by the consuming public, at least until the last years of the horsepower race. There are thus grounds for believing that car owners (at the time of purchase) thought model changes worth most of the cost. The general presumption of consumer sovereignty thus implies that these model changes *were* worth their cost.[45] How heavily that presumption is to be weighted in the presence of some cost understatement or in the presence of advertising directed at the formation or changing of tastes[46] is not a question that can be readily decided. Nor, indeed, is it obvious in retrospect that a referendum among the same car owners on the desirability of model changes would now reveal (or would have revealed in 1949) the same preferences for model change that seem to have been revealed in the historical market place.

It is thus not easy to decide whether the costs reported in this paper were worth incurring. Unlike some other ex-

[43] These figures include tax and are thus measures of expenditures by consumers. At factor costs they would still be over $4 billion a year.

[44] The Automobile Manufacturers Association clearly regards them as extremely high (see letter of Harry A. Williams [its managing director] in *The Nation*, February 17, 1962, p. 128).

[45] Indeed, one of the authors has used some of the same calculations to measure the improvement in the *quality* of automobiles since 1949 (see Griliches, "Hedonic Price Indexes . . . ," *op. cit.*).

[46] Or in the presence of external diseconomies of consumption in the case of some of the non-costed items mentioned earlier in this section.

amples of product change, the issue seems difficult enough to be worth raising. No one would deny that the shift from the horse and buggy to the automobile and the change from the kerosene lamp to the electric light were worth their respective costs.[47] Such improvements were so large and obvious that the issue is easy to decide. Whether this is true of some or all of the changes from the 1949 automobile specifications seems to us to be at least an open question.[48]

[47] Cf. Williams, *op. cit.*, and *Barron's Weekly*, January 11, 1962, p. 7.

[48] "The 1949 car . . . was pretty advanced transportation for its day" (Williams, *op. cit.*).