VERY GOOD!

STAFF PAPER 3

HEDONIC PRICE INDEXES FOR AUTOMOBILES: AN ECONOMETRIC ANALYSIS OF QUALITY CHANGE[1]

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1. Introduction and Summary

"If a poll were taken of professional economists and statisticians, in all probability they would designate (and by a wide majority) the failure of the price indexes to take full account of quality changes as the most important defect in these indexes."[2] In spite of its potential importance, there is almost no published empirical work devoted explicitly to this problem. The only available book that deals with problems raised by changes in quality reaches essentially defeatist conclusions.[3]

The main purpose of this paper is to investigate a relatively old, simple, and straightforward method of adjusting for quality change and find out whether (a) this method is feasible and operational, and (b) whether the results are promising and different enough to warrant the extra investment. It is standard practice in the price index industry to adjust for those quality changes to which a price can be attached. The appearance of automatic transmissions on the market at $200 extra will not raise the price of automobiles in the conventional indexes (except those of the USDA) even though eventually almost all cars are sold with it and the base price incorporates it as "standard equipment." However, only a few of the observed quality changes come in discrete lumps with an attached price tag. Most of the changes are gradual and are not priced separately. Nevertheless, many dimensions of quality change can be quantified (e.g., horsepower, weight, or length for automobiles); a variety of models with different specifications can be observed being sold at different prices at the same time; using multiple regression techniques on these data one can derive implicit prices per unit of the chosen additional dimension of the commodity; and armed with these "prices" one can proceed to adjust the observed price per "average item" for the changes that have occurred in its specification. There are many technical problems to be solved, but the main idea is quite simple: Derive implicit specificaton prices from cross-sectional data on the price of various "models" of the particular item and use these in pricing the time series change in specifications of the chosen (average or repre-

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[1] This paper is an outgrowth of my concern about the quality of the available capital measures and their use in productivity studies. It is a part of a larger study of technical change that is being supported by a National Science Foundation grant. I am indebted to Irma Adelman, George Stigler, and Lester Telser for valuable comments.

[2] Report of the Price Statistics Review Committee, III, 3.

[3] Erland von Hofsten, *Price Indexes and Quality Changes*, Stockholm, 1952.

sentative) item.[4] Alternatively, one can interpret the procedure as answering the question of what the price of a new combination of specifications (or qualities) of a particular commodity would have been in some base period in which that particular combination was not available, by interpolating or extrapolating the apparent relationship of price to these specifications for models or varieties of the "commodity" that were available in that period. This latter interpretation avoids some of the more metaphysical problems involved in the notion of "quality" and "quality change."

In this paper I investigate the relationship of automobile prices in the U.S. to the various dimensions of an "automobile" in 1937, 1950, and 1954 through 1960. A limited number of specifications or dimensions explain a very large fraction of the variance of car prices (as among different models) in any one of these years. Due to the high intercorrelation between some of these dimensions, there is some instability in the estimated "implicit prices" (the coefficients) of the dimensions. Also, there appears to have been a very substantial secular decline in the "price" of some of these dimensions (e.g., horsepower). Thus, estimates of the actual price change (after the quality change adjustments are made) differ markedly depending on whether they are based on beginning or end period weights. If we value the quality changes at their 1950 "implicit prices," we find that all the apparent increase in car prices between 1950 and 1960 can be explained by quality improvements, the hedonic price index actually falling during 1950–1960. Valued at 1960 implicit quality prices, these same quality changes account for a little over half of the apparent price increase over this period. Over the whole period since 1937, the CPI may be overestimating the rise in automobile prices by at least a third. Since the CPI is a Laspeyres index, the appropriate quality adjustment should also be based on "base" (beginning) period weights. If this is done, about three-fourths of the rise in automobile prices in the CPI since 1937 could be attributed to quality improvements.

Some limitations of this type of approach are explored in the last part of the paper and, in light of these, it is not yet recommended that such adjustments should be made routinely as part of the price index computations. Continuous studies of this sort, however, covering a wide range of commodities, would be of great value. They could provide us with estimates of the order of magnitude of the possible upward drift in the official price indexes due to their inability to cope adequately with the ever-present quality change problem. Moreover, they would spot for the price data collecting agencies what appear to be the more relevant dimensions or specifications of a commodity, providing them with a better basis for judging which specifications should be controlled in the pricing process.

2. Theoretical Considerations

It is impossible to deal here with all the index number problems raised by the changing quality of commodities.[5] Since we are in-

[4] As far as I know, this procedure was first suggested by A. T. Court in his paper "Hedonic Price Indexes With Automotive Examples", in *The Dynamics of Automobile Demand*, New York, 1939. A more recent exposition is given by R. Stone in *Quantity and Price Indexes in National Accounts*, OEEC, Paris, 1956, ch. IV.

[5] The reader is referred to the literature on this problem, and in particular to Hofsten and to Stone, op. cit.; see also Irma Adelman, "On an Index of Quality Change," paper given at the August 1960 meeting of the American Statistical Association, Stanford, California, which presents an approach very similar to the one outlined here.

terested in the effect of quality change on measured prices and price indexes, our first job is to find what relationship, if any, there is between the price of a particular commodity and its "quality."

Most commodities, particularly consumer and producer durables, are sold in many varieties or models. Thus at any one time we can observe a population of prices—p_{it}—where i is the index of varietal designation (e.g., No. 2 corn, or a Chevrolet Impala four-door hardtop with a V-8 engine) and t stands for the time period of observation. The reason why these different varieties or models sell at different prices must be due to some differences in their properties, dimensions, or other "qualities," real or imaginary. Thus we can write p_{it} as a function of a set of "qualities" X, and some additional small, and hopefully random, factors measured by the disturbance u.

$$p_{it}=f_t(x_{1it},\ x_{2it},\ \cdots\ x_{kit},\ u_{it}). \tag{1}$$

These qualities do not necessarily have to be numerical. Given a sufficient number of observations, we can use variables which take the value one if the item possesses the particular quality and zero if it does not and derive the average contribution of this "quality" to the price of the item. Nor do they have to be desired for their own sake. It will suffice if they are well correlated with some more basic dimension which may be more difficult to measure. For example, for many commodities, and at least over some range, "size" or "capacity" are very important qualities. They are, however, quite elusive and difficult to measure. On the other hand, they can often be approximated quite well by variables such as volume, weight, or length, even though none of these "proxy" dimensions may be desirable per se.

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The existence and usefulness of such a function is an empirical rather than theoretical question.[6] To estimate such a function we have to make additional assumptions about the number and kind of relevant qualities and the form in which they affect the price of the product. There is no a priori reason to expect price and quality to be related in any particular fixed fashion. This again is an empirical question. In this study, I have used the semilogarithmic form, relating the logarithm of the price to the absolute values (pounds, inches, etc.) of the qualities:

$$\text{Log}\ p_{it}=a_0+a_1x_{1it}+a_2x_{2it}+\ \cdot\ \cdot\ \cdot\ +u_{it}. \tag{2}$$

This choice was based on an inspection of the data and the convenience of this particular formulation.[7] Other forms, e.g., linear, or linear in the logarithms, may however be more appropriate in a study of other commodities and qualities.

Assuming that the equation can be estimated with enough precision it can be used to estimate the value of certain quality changes in the base period. Moreover, one can use it to estimate the price of a new bundle of qualities which may not have been available in this period, provided that the new bundle differs only quantitatively in its "quali-

[6] It can always be made into a tautology by specifying enough factors or qualities.

[7] If natural logarithms are used, an "a" coefficient will provide an estimate of the percentage increase in price due to a one unit change in the particular quality, holding the level of the other qualities constant.

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ties" from the previously available items and does not contain some new, previously unknown or unavailable qualities. Even if the new item possesses some previously unknown qualities, the equation can be used to estimate the change in price due to changes in the subset of quantifiable qualities, and half a loaf may be better than none.

An equation of this type can be computed for each period for which we have enough observations to do it. If the results are not the same in different periods, and they are unlikely to be so, we are faced with the general index number problem of changing weights. The implicit prices we obtain will depend on the particular period or periods chosen as "weight" or reference periods, and Laspeyres' and Paasche's indexes may diverge sharply. If the periods are not too far apart and the weight pattern not too different, we can estimate the average price change directly by assuming that the equation holds well enough in both periods except for the change in the additional variable "time."

(!)

$$\text{Log } p_{it} = a_0 + a_1 x_{1it} + a_2 x_{2it} + \cdots + a_d D + u_{it} \qquad (3)$$

where D is a variable that is zero in the first period and one in the second.[8] The coefficient a_d provides us with an estimate of the average percentage increase in price of these models or varieties between the two periods, holding the change in any of the measured quality dimensions constant. If we want to impose the same set of weights on more than two cross sections, this can be achieved by specifying additional "time" or "dummy" variables, taking the value one in their reference period and the value zero in all other periods. The necessary number of such variables is one less than the number of cross sections that are being estimated together. The resulting coefficients measure the percentage change in the average price, holding qualities constant, with the average price for the earliest cross section being the base of measurement.

Having estimated such equations, instead of adjusting the prices or price indexes directly, we can first define an index of quality change and use that to adjust the official indexes. Consider a particular variety of a commodity, say a Plymouth Savoy four-door sedan with a six-cylinder engine, whose qualities may have changed over some time period. Then the quality change measure g is defined as

(!)

$$g_{1i}^{0} = \frac{\hat{P}_{i1}}{\hat{P}_{i0}} \text{ where } \hat{P}_{i0} = f_0(x_{1i0}, \cdots),$$

and $P_{i1} = f_0(x_{1i1}, \ldots)$.[9] That is, the p's are each predicted prices for variety i on the basis of estimated equation f_0, one for the combination of qualities this variety had in period 0 and the other for the combination of qualities it has in period 1. More simply g_1^0 measures the percentage increase in price predicted by the function f_0 on the basis of the change in the level of different qualities (the x's) between the two periods. Of course, if we had used the estimated function for the second period, f_1, or a price quality function for some other period, we would have gotten a somewhat different measure.

[8] This was the procedure followed by Court, op. cit.
[9] The designation g is borrowed from Hofsten, op. cit.

For a larger number of varieties, or models, these g's can be aggregated into a quality change index, using the same weights that are used in aggregating their prices in the price index. To get at the adjusted "real" change in prices, we would "deflate" the observed price index by the estimated quality change index.[10]

$$\text{"true price index"} = \frac{\text{observed price index}}{\text{quality change index}} = \frac{P_1}{P_0} \Big/ \frac{\hat{P}_1}{\hat{P}_0} = \frac{P_1/\hat{P}_1}{P_0/\hat{P}_0}.$$

Note that this "quality change" index is based only on those "qualities" for which a price is being paid or exacted, and only to the extent of the price differential. If these price differentials are "phony" or "too high" or "too low" from some omniscient point of view, the index will not take this into account. In fact, it may not take into account some aspects of "quality" which may be important, and incorporate other "imaginary" qualities such as brand names whose "superiority" over unbranded items would be denied by many people. Thus, if we observe that garments bearing one union label sell on the average at a 5 percent higher price than comparable unlabeled items, and also that garments bearing the labels of three different unions sell for 15 percent more than comparable unlabeled items, we would predict that if a similar garment were available with two union labels, it would probably sell for about 10 percent more than the unlabeled items. And we would use this in calculating our price index (or price relative) for the two-label garment, even though we are morally certain (and supported in this by extensive test laboratory findings) that there is no "real" quality difference among all these items. We would do this since we are answering only a relatively modest question: What would the price have been if it were available? And not: Would consumers be "right" in paying this particular price, or for that matter the price of any other item? Once raised, the doubt whether the evidence of the marketplace reflects adequately, if at all, the "true" marginal utility of different items or qualities to the consumer can be turned against any other price or commodity. It is not a problem peculiar to the measurement of "quality."

While it is not necessary for our purposes, it would be nice, however, if these quality indexes represented something "real" and not just the mistakes and idiosyncracies of manufacturers' pricing policies. There are two possible sources of evidence on this point. The first, which will be explored to some extent at the end of the paper, is the evidence of second-hand markets. Do different qualities command approximately similar relative prices in the used market, a market which could be considered to be more competitive than the market for new items? If they do, this would indicate that consumers are still willing to pay these differentials even when they are not imposed by manufacturers. A second and more stringent test, which will not be pursued here, could have been made by investigating what happens to the sales of varieties or brands if their prices are too high or too low relative to their quality content. Given an estimated price-quality equation for a particular period, the estimated residual for a specific

[10] Compare this with Adelman, op. cit., where the quality change index is defined additively rather than multiplicatively. Ideally the varietal prices should be deflated individually before they are aggregated into an overall price index. Only for geometrically weighted indexes will the ratio of the two equal the "true" index exactly.

model or brand could be interpreted as a measure of over or under pricing relative to the quality content of this model. If, with the help of these residuals, we were able to predict reasonably well the market share experience of different models or brands, i.e., "over priced" items losing and "under priced" items gaining, this would provide strong support for the correctness of our price-quality equation and its interpretation.

3. The Sample and the Variables

The analysis of price-quality relationships reported below is based on data for U.S. passenger four-door sedans for the years 1937, 1950, and 1954 through 1960. In each of these years an attempt was made to collect price and specification data for all models and brands for which such data were easily available.[11] Since these calculations were viewed as being exploratory, no special attempts were made to assure completeness of coverage, nor were the model observations weighted by their relative importance in the market. The number of observations in each cross section varies from a low of 50 in 1937 to a high of 103 in 1958.

The new car prices used throughout this study are factory-delivered "suggested" (list) retail prices, at approximately the beginning of the model year.[12] Unfortunately, there are no published data on actual transaction prices for a wide range of models. Discounts from list prices may have varied over time, and this will make it somewhat difficult to compare our results with the CPI, since the CPI has tried to take discounts into account, at least since 1954. Only to the extent that relative discounting is correlated with some of our quality dimensions will the use of list prices lead to any special bias in the estimates of the quality coefficients. This same difficulty would not be present if an official government agency were doing such a study. The WPI actually collects the manufacturers' wholesale price to dealers for most automobile models. Similarly, it should not prove difficult to expand the CPI sample, at least once a year, to include a wider range of models.

No adjustment was made for any changes in minor equipment items that became standard equipment at some later point in time, such as directional signals or electric clocks.[13] Major items, such as automatic transmissions, power steering, and power brakes were treated by defining independent variables that took the value of one if the item was "standard equipment" on a particular model and zero if it was not.

[11] The 1937 price and specification data for new 1937 automobile models are taken from the *Red Book* (National Used Car Market Report), September-October 1937. The 1950 model data are from the *Red Book of Official Used Car Appraisal* (National Market Reports, Inc.: Chicago, Nov. 15, 1956.) For 1954 through 1960 the data are taken from various issues of the National Automobile Dealers Association, *Used Car Guide,* Washington. For 1955 through 1958 the data are from the February issue of the corresponding year. For 1954 models, the figures are taken from the July 1959 issue; for 1959 models from the January 1959 issue; and for 1960 models from the December 1959, issue. Data on power brakes come from various issues of *Ward's Automotive Reports.*

[12] Factory-advertised delivered price includes only standard equipment, Federal excise tax and dealer handling and preparation charges. Transportation, State, or local taxes are not included.

[13] The possible consequences of this omission are explored briefly in the Appendix of this paper.

The major numerical "quality" variables used in this study are horsepower (advertised brake horsepower), weight (shipping), and length (wheelbase for 1937 and 1950, and overall from 1950 on). In addition, "dummy" variables, i.e., variables that take the value of one if the particular model possesses this particular "quality" and zero if it does not, are defined for the following "qualities": V–8 engine or not, hardtop or not, automatic transmission as standard equipment or not, power steering as standard equipment or not, power brakes as standard equipment or not, and for 1960 models whether a car is a "compact" or not. Note that some of these variables do not measure the consequence of having a particular item of equipment as much as they stratify and control for the type of car on which such equipment is "standard" (included in its base price). Thus, for example, the variable for power steering effectively identifies most of the large luxury cars that differ from other cars in other ways besides sheer size or the presence of power steering as standard equipment.

A variety of variables for which no convenient data are available was not included in the calculations. Most important of these are the various "performance" variables: gasoline mileage, acceleration, handling ease, durability, and styling. Scattered data already exist on some of these qualities, and I am sure that it would not prove very difficult to collect more and include such variables explicitly in a similar price-quality analysis. Variables reflecting the level of "workmanship" associated with a particular car and variables accounting for small design changes, such as the substitution of an alternator for the generator were also omitted for lack of data. Nor were brand or manufacturer differentials taken into account. In fact, as far as the numerical qualities that are included in the analysis are concerned, they could probably all be interpreted as different aspects of one underlying quality "size" or "capacity."

The characteristics of the sample are summarized in Table 1. Note the sharp increase in horsepower per car since 1950, due to a large extent to the introduction of the V–8 engine, and the lengthening of cars which reached its peak in 1959. The drop in the average price and specification level of cars in 1960 is due mainly to the introduction of the "compacts" and the decline in the number of high- and medium-priced models on the market.

TABLE 1.—*Characteristics of the Cross Sections Used in This Study: U.S. Passenger Four-Door Sedans—1937, 1950, and 1954–1960*

Years	Number of models	Average (geometric) price	Average horsepower	Average shipping weight in pounds	Average length in inches	
					Wheelbase	Overall
1937	50	$1,183	109	3,506	122	
1950	72	2,113	115	3,533	122	205.7
1954	65	2,360	141	3,452		205.0
1955	55	2,281	166	3,429		205.4
1956	87	2,594	200	3,616		207.5
1957	95	2,785	226	3,696		208.9
1958	103	3,054	252	3,835		211.6
1959	87	3,180	251	3,907		213.7
1960	78	2,800	211	3,666		208.6

See footnote 11 for sources of data.

4. The Regression Results

It is impossible to reproduce here the very large number of multiple regressions that were computed for different years and different combinations of years and independent variables. Due to the very high multicollinearity between the three numerical "qualities" chosen for analysis (see Table 2) there was substantial instability in the coefficient estimates for some of the years. Usable estimates were obtained only for years in which there was some independent variation along the three numerical quality dimensions, and for combinations of years where the larger number of observations allowed us to determine the separate coefficients with greater precision.

Table 2.—*First-Order Correlation Coefficients: r*

Between	Year					
	1960	1959	1957	1954	1950	1937
H and log P	0.89	0.85	0.85	0.89	0.84	0.88
W and log P	.90	.92	.95	.88	.87	.92
L and log P	.77	.75	.84	.81	.91	.88
H and W	.85	.82	.90	.92	.76	.80
H and L	.72	.75	.79	.73	.74	.84
W and L	.92	.86	.85	.87	.83	.92

H = Horsepower.
W = Weight.
L = Length, overall, except wheelbase in 1937.
log P = logarithm of list price.

Regression estimates for selected years are summarized in Table 3. Table 4 summarizes a set of regressions utilizing two adjacent annual cross sections each and introducing an explicit variable to estimate the average price change holding quality change constant. It also presents the estimated coefficients of the overall regression for 1954–60, lumping all of the seven (1954 through 1960) cross sections together and allowing them to differ from each other in level but not in slope.

Since our dependent variable is the logarithm of price, the resulting regression coefficients can be interpreted as the estimated percentage change in price due to a unit change in a particular "quality," holding the other qualities constant. Thus, for example, the results for the 1960 cross section (column 1 in Table 3) imply that the following was true, on the average, for the 1960 model cars and their list prices. An increase of 10 units in horsepower, ceteris paribus, would result on the average in a 1.2 increase in the price of a car (with a standard error of 0.3 percent). An increase of 100 pounds in the weight of a car was associated with a 1.4-percent increase in price. An increase of 10 inches in the length of a car, holding the other qualities constant, was associated with a 1.5 increase in the price of the car (but was not significantly different from zero at conventional significance levels). A V–8 engine, holding horsepower, weight, etc., constant was associated with a 4-percent lower price than a six having comparable characteristics.[14] A "hard

[14] There was very little overlap in horsepower between the sixes and the V–8's in the sample. What the coefficient measures, actually, is the fact that higher horsepower levels could be achieved at a price that was about 4 percent cheaper than would be indicated by the extrapolation of the price-horsepower relationship for six-cylinder engine cars. For more on this, see the text below.

TABLE 3.—*Coefficients of Single Year Cross-Sectional Regressions Relating the Logarithm of New U.S. Passenger Car Prices to Various Specifications, Selected Years*

Coefficients of	Model year					
	1960	1959	1957	1950 (1)	1950 (2)	1937
H	0.119	0.118	0.117	0.365	0.585	0.867
	(.029)	(.029)	(.030)	(.110)	(.133)	(.181)
W	.136	.238	.135	.111	.145	.388
	(.046)	(.034)	(.010)	(.066)	(.096)	(.078)
L	.015	−.016	.039	.192	.147	−.009
	(.017)	(.015)	(.013)	(.026)	(.045)	(.078)
V	−.039	−.070	−.025	−.054	−.091	−.023
	(.025)	(.039)	(.023)	(.032)	(.040)	(.060)
T	.058	.027	.028	—	—	—
	(.016)	(.019)	(.012)	—	—	—
A	.003	.063	.114	—	—	—
	(.040)	(.038)	(.025)	—	—	—
P	.225	.188	.078	—	—	—
	(.037)	(.041)	(.030)	—	—	—
B	—	—	.159	—	—	—
			(.026)	—	—	—
C	.048	—	—	—	—	—
	(.039)	—	—	—	—	—
R^2	.951	.934	.966	.892	.835	.904

NOTES.—While the original computations were all done with logarithms to the base 10, the results in this Table are converted to natural logarithms (to the base e) as an aid to interpretation. The resulting coefficients, if multiplied by a hundred, measure the percentage impact on price of a unit change in a particular specification or "quality," holding the other qualities constant. The numbers in parentheses are the calculated standard errors of the coefficients. For 1950 regression (2) and 1937: length of wheelbase rather than overall length.

H = Advertised brake horse power in 100's.
W = Shipping weight in thousand pounds.
L = Overall length, in tens of inches.
V = 1 if the car has a V-8 engine; = 0 if it has a 6-cylinder engine.
T = 1 if the car is a hardtop; = 0 if it is not.
A = 1 if automatic transmission is "standard" equipment (included in the 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.

top" was on the average 6 percent more expensive than other comparable ("soft top"?) models. Holding other "qualities" constant, the inclusion of an automatic transmission as "standard equipment" was not associated with any significant price increase. The presence of power steering as "standard equipment" led to a 22-percent higher price over comparable models.[15] The cars designated as "compacts" were selling for about 5 percent more than other cars, holding other "quality" differences constant, but again, this premium was not significantly different from zero.

If we look now across the rows of Tables 3 and 4, several things are worth noting. The fit of these equations is quite good. With the help of a few numerical and shift variables, we manage to explain most of the time 90 or more percent of the variance of the logarithm of car prices in a particular year or set of years, even though the range of our sample extends from Ramblers to Cadillacs.[16] The coefficient of "weight" is almost always significantly different from zero, at conventional levels, and its magnitude remains rela-

[15] This is more related to the "luxuriousness" of these models than to the presence of power steering per se.

[16] This does not mean, necessarily, that we are able to predict the price of any one particular car very well. The average standard error of regression for these equations is around 8 per cent.

TABLE 4.—*Coefficients of Regressions of the Logarithms of Price on Various "Qualities": U.S. Passenger Cars, 2 Years Taken Together, and All the 7 Years, 1954 Through 1960*

Coefficients of	Model years							
	1954 through 1960	1959–60	1958–59	1957–58	1956–57	1955–56	1954–55	1937–50
H	0.056	0.114	0.062	0.040	0.095	0.091	0.241	0.538
	(.013)	(.018)	(.025)	(.026)	(.028)	(.055)	(.059)	(.108)
W	.249	.212	.285	.271	.211	.241	.009	.328
	(.021)	(.029)	(.034)	(.038)	(.039)	(.056)	(.060)	(.053)
L	.023	−.006	−.018	.007	.045	.053	.082	.108
	(.007)	(.011)	(.013)	(.013)	(.011)	(.015)	(.016)	(.039)
V	.010	−.059	−.026	.005	−.037	−.043	−.031	−.093
	(.013)	(.023)	(.031)	(.026)	(.020)	(.031)	(.024)	(.035)
T	.023	.040	.030	.024	.022	.018		
	(.009)	(.013)	(.012)	(.013)	(.010)	(.018)		
A	.090	.034	.070	.075	.058	.079	.236	
	(.016)	(.027)	(.030)	(.026)	(.021)	(.028)	(.037)	
P	.088	.206	.125	.113	.089	.062	.035	
	(.017)	(.028)	(.040)	(.030)	(.023)	(.029)	(.038)	
B	.109		.115	.162	.138	.098	−.045	
	(.016)		(.038)	(.028)	(.019)	(.029)	(.045)	
C	.157	.052						
	(.031)	(.031)						
D		−.023	.005	.027	.027	.020	−.093	.527
		(.011)	(.014)	(.012)	(.011)	(.018)	(.020)	(.027)
D_1	−.044							
	(.015)							
D_2	−.015							
	(.0.4)							
D_3	.019							
	(.015)							
D_4	.044							
	(.016)							
D_5	.044							
	(.016)							
D_6	.023							
	(.016)							
R^2	.922	.943	.915	.929	.945	.924	.904	.916

NOTE.—See notes to Table 3 for the definition of most of the variables.

D=1 in the second of two periods being estimated together; =0 in the first. The coefficient of D can be interpreted as the percentage change (if it is multiplied by 100) in the average price of cars between the two periods, holding all the qualities constant. Thus, e.g., for 1937–50, the estimated "true" price change is approximately 53 percent.

D_1=1 in 1955; =0 in other years.
D_2=1 in 1956; =0 in other years.
D_3=1 in 1957; =0 in other years.
D_4=1 in 1958; =0 in other years.
D_5=1 in 1959; =0 in other years.
D_6=1 in 1960; =0 in other years.

The coefficients of these variables measure the average percentage change in price holding quality constant as of 1954. Thus for 1960, it indicates that since 1954 the average price holding quality constant increased only by about 2 percent and that, moreover, this increase is not significantly different from zero. To get the estimated percentage change between two adjacent years, one has, in this case, to take the difference between the two coefficients. Thus, e.g., the 1954 through 1960 equation estimates the average percentage change in price between 1957 and 1958 as 1.5 (4.4—1.9), against a 2.7 estimate given by the equation for 1957–58 alone.

tively stable from cross section to cross section. The coefficient of horsepower is also statistically significant in a large fraction of cases, but varies somewhat more in magnitude around a downward trend. The coefficient of length is perhaps the most unstable of all the estimated coefficients, being very large and significant in 1950, declining rapidly in the middle fifties, and becoming insignificant and sometimes negative by 1958 and in subsequent years. This is partly the result of the generally very low variability of "length" in the sample (its coefficient of variation was only about 4 percent, on the average) and the very marked increase in the length of the lower priced cars since 1957.

Looking at the coefficients of the shift or "dummy" variables representing the presence or absence of certain "qualities," perhaps the most interesting result is the consistently negative sign attached to the coefficient of the V–8 versus six-cylinder engine variable. It is true, that most of the time this coefficient is not significantly different from zero, but the consistency in sign from period to period is both surprising and instructive. While we know that a V–8 engine costs about $100 more than a six on a "comparable" car, this is not what is meant by "comparable" in the context of our equations. What the coefficient says is that if we hold horsepower and the other variables constant, a V–8 is cheaper by about 4 percent. Since the "comparable" cars are likely to differ much only in horsepower, and since there is very little overlap in the sample between the horsepower levels achieved by six-cylinder engines and the horsepower generated by the V–8's, what this coefficient is really saying is that higher horsepower levels can be achieved more cheaply if one shifts to V–8 engines than would be estimated by extrapolating the price-horsepower relationship for the six-cylinder engines alone. It is a measure of the decline in the "price" per horsepower as one shifts to V–8's, even though the total expenditure on horsepower goes up.

The coefficient of the "hard top" variable is reasonably stable over time, indicating a premium of around 3 to 4 percent for this type of car. The coefficient of the "automatic transmission included in the price" variable is always positive, but varies substantially from time to time. The coefficients of the "power steering" and " power brakes standard equipment" variables are usually very significant and relatively large in size.[17] It is quite apparent that what they measure is not so much the presence or absence of these particular equipment items, as the presence of many other "luxuriousness" attributes associated with cars on which these items are "standard equipment." In a sense, these shift variables take care of some of the nonlinearity in the relationship of the logarithm of price to numerical qualities such as weight or horsepower. Usually the high-medium and high-priced cars are priced somewhat higher than would be predicted just by extrapolating the price-horsepower (or length or weight) relationship from the lower price range. Allowing the cars having power steering, power brakes, or automatic transmission as standard equipment, to have separate constant terms, brings these cars "into line" and reduces the possible bias in the estimated price-quality relationship for the numerical qualities.

5. Price and Quality Indexes for U.S. Automobiles

A. HEDONIC PRICE INDEXES FOR THE SAMPLE AS A WHOLE

As we have noted already in our discussion of Table 4, the results presented there provide us with an estimate of the average price change that occurred between two periods in the list prices of automobiles, holding all the specified qualities constant. This is comparable to the deflation of the change in the price of the average car in the sample by a quality index with "average" rather than base or end period weights. These "average" weights are derived from the coefficients of the regression that provides the best fit simultaneously

[17] The power brakes variable is not included in the years when all (or almost all) the models on which power steering is "standard equipment" have also power brakes included in their price. Note that in those years the estimated coefficient of power steering alone equals approximately the sum of the two coefficients in the other years.

to data for two years, a regression that imposes the same price-quality relationship (slope) on both years, but allows them to differ in level. The weights are used then to adjust for the change in the specifications of the average car in the sample that has occurred between the two periods.

The resulting price indexes are summarized in Table 5 and compared to the Wholesale Price Index "Passenger Cars" component. The comparison with the WPI is more appropriate for two reasons. First, it is the only one of the official indexes that covers all passenger cars rather than just a few selected makes and models, and second, it is based on manufacturer prices to dealers whose relationship to the list prices used in this study has remained approximately constant over time. Unfortunately, the comparison is imperfect in the sense that the WPI is a weighted index of car prices, with weights based on the market shares of various makes (in some base period?), while our list price index is an unweighted average of all makes and models.[18] Relative to the WPI, our index gives too much weight to the high and medium priced cars.

TABLE 5.—*U.S. Cars: Percentage Change in Various Price Indexes, Selected Years*

Model Year	List Prices			WPI[3]
	Average car in sample[1]	Hedonic price index based on[2]		
		Estimated adjacent two-period weights	Estimated average 1954 through 1960 weights	
1937–50	79.0	52.7		83.0
1954–55	−8.3	−9.3	−4.4	2.7
1955–56	13.7	2.0	2.9	4.1
1956–57	7.7	2.7	3.4	4.7
1957–58	9.6	2.7	2.5	0.6
1958–59	3.6	0.5	0.0	5.1
1959–60	−11.9	−2.3	−2.1	0.1
1954–60	18.7	[4]−4.2	2.3	19.7

[1] Percentage change in the geometric average of all list prices in the sample.
[2] Computed from Table 4.
[3] From various BLS releases. For 1937 and 1950 models, price as of December of the previous year. For 1954 models, price as of January 1954. For all subsequent model years, price as of November of the preceding calendar year.
[4] Computed by multiplying all the estimated two-year price relatives.

If we disregard these reservations, or limit the implications to our sample only, the results presented in Table 5 attest strongly to the importance of "quality" change. About one-third of the price change between 1937 and 1950 and almost all of the price increase between 1954 and 1960 is attributable to changes in a few selected specifications. If we use a chain-link index for the 1954–60 period, adjusting the 1954–55 price change by a quality index with average 1954–55 weights, adjusting the 1955–56 price change by a quality index with 1956–57 weights, and so on, we actually come to the conclusion that the average 1960 car in our sample was cheaper than the 1954 average

[18] Different makes are weighted, in a sense, by the number of models of each make included in the sample. This mitigates the problem somewhat, since the more popular makes are likely to have a larger number of models on the market, but does not solve it.

car, once some of the appropriate quality adjustments are made. If we use average 1954–60 weights derived from the joint multiple regression equation for all seven cross sections, we do indicate a small price rise for the 1954–60 period (2.3 percent) but we cannot reject the hypothesis that actually there was no real change in price over the period as a whole.

B. QUALITY AND PRICE INDEXES FOR THE "LOWER PRICED THREE."

Since two of the most important automobile price indexes (the automobile components of the CPI and of the Prices Paid by Farmers Index of the USDA) are based on prices for the "low priced three" makes—Chevrolet, Ford, and Plymouth—it is of some interest to develop quality and quality-adjusted price indexes that are restricted to this particular group of cars.[19] An attempt will be made to approximate a quality index appropriate to the group of cars priced by the CPI. Since it is impossible, from the published material alone, to discover all the details of the pricing and specification procedure used by the CPI, we cannot reproduce it exactly, adding only our quality adjustments.[20] In principle, however, our methods can be applied directly to the CPI data by the BLS, allowing a more firm estimate of the possible "quality bias" in the index.

The specification and list price history of the "average" Chevrolet, Ford, and Plymouth in the sample is presented in Table 6. Some attempt is made at weighting the different makes by including only two Plymouth models in this sample versus three models each for

TABLE 6.—*Specifications and List Prices of the Average*[1] *"Low Priced Three" Car*

Year	Horsepower	Weight, (pounds)	Length: Wheelbase	Length: Overall	Price[2]
SIX-CYLINDER ENGINES					
1937	81	2,756	112	196.0	$703
1950	94	3,099	116	196.1	1,521
1954	111	3,149		195.8	1,795
1955	120	3,129		198.7	1,839
1956	135	3,172		199.7	1,938
1957	139	3,255		203.6	2,140
1958	142	3,349		206.6	2,275
1959	138	3,448		209.6	2,415
1960	141	3,539		211.5	2,425
V-8 ENGINES					
1955	163	3,185		198.7	1,939
1956	176	3,246		199.7	2,039
1957	184	3,354		203.6	2,240
1958	210	3,440		206.6	2,390
1959	202	3,525		209.6	2,533
1960	190	3,615		211.5	2,537

[1] Average for 3 Chevrolets, 3 Fords, and 2 (the 2 lower priced series) Plymouth models, except in 1937 and 1950. The 1937 sample consists of 2 Chevrolets, 2 Plymouths, and 3 8-cylinder Fords. The 1950 sample consists of 4 Chevrolets, 2 Fords and 2 Plymouths. The 8-cylinder Fords in 1937 were included to raise the sample size to approximately the same levels as in the subsequent years. Since these 8's (not V-8's) had a lower list price than comparable 6's in 1937, their inclusion, if anything, will bias the quality indexes downward.

[2] Arithmetic average.

[19] The USDA index also includes one Buick model. The CPI will probably introduce "compact" cars into its calculations in the Fall of 1960.

[20] It is not clear which models within a make are being priced; what weights, if any, are attached to each model and make; whether the index averages price relatives for each model or make, or takes the relative of the average price of these models, and so forth. See also the Appendix for additional discussion of the CPI.

Chevrolet and Ford cars. Also, the specification and price history of six-cylinder engine cars and V–8 engine cars is recorded separately. Since the CPI switched over in 1956 from pricing six-cylinder cars to pricing the V–8 models of these same cars, we shall follow suit by computing separate indexes for each type of car and linking them at 1956.[21]

Table 7 presents some of the weights used in aggregating these "qualities." It is immediately apparent that the computed quality indexes will differ substantially depending on which set of weights is used. To provide historical perspective, this table also records weights derived by Court in his earlier study of the same problem. The weights reproduced in this table and additional weights taken from Table 4 are used in construcing the set of quality indexes summarized in Table 8.

TABLE 7.—*Estimated Quality Weights or "Prices": Percentage Change in the Price of Cars as the Result of a Unit Change in Selected "Qualities," in Selected Years*

Years	Percentage change in price per—		
	10-unit change in horsepower	100-pound change in weight	One-inch change in length [1]
1930 to 1935 [2]	5.5	5.7	0.31
1935 to 1937 [2]	5.3	5.8	.01
1937 to 1939 [2]	7.1	3.0	.15
1937 [3]	8.7	3.9	−.09
1950 (2)[3]	5.8	1.5	1.47
1950 (1)[3]	3.6	1.1	1.92
1957 [3]	1.2	1.4	.39
1959 [3]	1.2	2.4	−.18
1960 [3]	1.2	1.4	.15
1954 through 1960 [4]	.6	2.5	.23

[1] Wheelbase length, 1935 through 1950 (2), overall length thereafter.
[2] From Court, op. cit., p. 111.
[3] From Table 3.
[4] From Table 4.

TABLE 8.—*Quality Indexes for the "Low Priced Three" (6-cylinder engines to 1956, V–8's thereafter)*

Period	Percentage change			
	Beginning period weights [1]	Adjacent year weights [2]	1954 through 1960 weights [3]	End period weights [4]
1937 to 1950	24.3	22.7	----------	18.7
1950 to 1960	61.0	----------	18.7	15.1
1937 to 1960 [5]	100.1	----------	----------	36.6
1950 to 1954	6.1	----------	2.2	2.3
1954 to 1955	9.3	5.7	.7	----------
1955 to 1956	8.1	2.9	2.2	----------
1956 to 1957	12.4	4.8	4.1	----------
1957 to 1958	16.9	3.4	4.4	----------
1958 to 1959	4.3	1.4	2.3	----------
1959 to 1960	.6	.3	2.0	----------
1954 to 1960	51.7	20.0	16.1	12.4

[1] 1937 weights for the 1937–50 comparison and 1950(1) weights for all the subsequent comparisons. For example, the 1937–50 figure is arrived at by multiplying the change in the average specifications given in Table 6, by the 1937 weights given in Table 7 and adding them together ($8.7\times1.3+3.9\times3.43-0.1\times4.0=24.3$).
[2] Weights from Table 4, i.e., the 1954–55 comparison uses average 1954–55 weights, and so on. The figure for 1954–60 is the product of all the paired year comparisons.
[3] Weights from Table 4.
[4] 1950(2) weights for the 1937–50 comparisons and 1960 weights for the 1950–60 and 1954–60 comparisons.
[5] Derived by adding 100 each to the first 2 rows, multiplying, and subtracting 100.

[21] Alternatives to this linking procedure are discussed below.

The quality indexes measure how much higher the price of the particular car (or the average price of a particular class of cars) would have been, in the weight period, if its specifications had changed by the same amount as they did between the two periods that are being compared. Using beginning period weights, we find that "quality per car" practically doubled since 1937, with most of the increase occurring since 1950. Using end period weights, the indicated increase is only about 37 percent, which is still quite substantial. Using chain-link weights, or average 1954–60 weights, produces intermediate results. Since the CPI is a Laspeyres based fixed weight index, with the latest set of weights being based on the 1950 Consumer Expenditure Survey, the "beginning period" weighted quality index is the most appropriate deflator for it. From a theoretical point of view, the chain-link index with its frequently changing weights is probably the best single measure of quality change.

Before proceeding to "deflate" the CPI by our quality indexes we have to convince ourselves that it is legitimate to do so. Since our indexes were derived from list prices, we have first to compare the CPI to an unadjusted list price index for the same makes and models. Such a comparison is presented in the first two columns of Table 9. It is apparent that the list prices and the CPI moved fairly closely together until 1954. Since 1954 the CPI has risen much less than the list prices of comparable cars (or the comparable WPI index, see Table 5). It is not exactly clear how and why this happened, and the problem is explored in greater detail in the Appendix. In part this may be due to the BLS beginning to ask for discounts in 1954; in part to absolute or relative declines in transportation costs and the cost of various attachments which were not included in the list prices. Be this as it may, unless the recent divergence between list prices and the CPI index is somehow associated with one or the other of our quality dimensions, these indexes are still appropriate deflators for the CPI. They would be inappropriate if either relative discounting were associated with some of the quality dimensions, e.g., higher

TABLE 9.—*The "Low Priced Three" (Sixes to the 1956 Model Year, V–8's Thereafter): Percentage Changes in Price—List Prices, the CPI, and the CPI Adjusted for Quality Change*

Years	List prices unadjusted [1]	CPI unadjusted [2]	CPI adjusted for quality change using [3]			
			Beginning period weights	Adjacent year weights	1954 through 1960 weights	End period weights
1937–50	116.0	101.3	61.2	64.1		69.2
1950–60	58.5	31.3	−18.4		10.6	14.1
1937–60	242.4	161.3	30.6			91.3
1950–54	18.0	18.0	11.2		15.5	15.3
1954–55	2.5	−1.7	−10.0	−8.0	−2.4	
1955–56	5.4	−.9	−8.3	−3.7	−3.0	
1956–57	9.9	5.1	−6.5	.3	1.0	
1957–58	6.7	4.2	−10.9	.8	−.2	
1959–60	.2	.1	−.2	−.2	−1.9	
1954–60	34.4	11.3	−26.6	−7.8	−4.1	−1.0

[1] Computed from Table 7.
[2] From BLS Bulletin No. 1256 and various CPI releases. For 1937 and 1950 as of March of the same year; for 1954 as of January 1954; for subsequent years as of November of the preceding year.
[3] Computed by dividing the figures in the second column by the appropriate entry from Table 8 (adding first 100 to each and subtracting 100 from the result).

horsepower cars being discounted disproportionately, or if the CPI had, in collecting its prices, linked out the particular horsepower, weight, and length increases we have used in constructing the quality indexes. Since we have no reason to believe that either is true, deflation of the CPI by these indexes appears to be warranted.

The results of deflating the changes in the CPI by the appropriate entries from Table 8 are presented in Table 9. For the 1937–50 period about a third of the price rise can be attributed to quality change no matter which set of weights we use.[23] In the 1950–54 period the role of quality change appears to have been minor, unless we weight it by 1950 weights. All weights point to the conclusion that "real" automobile prices fell rather than rose during 1954–60.[24] Using beginning period (1950) weights, the fall was around one-quarter. Using end period (1960) weights, the fall was very small, indicating roughly no change in "real" automobile prices. For the 1937–60 period as a whole, quality change accounted for about one-third (using end period weights) to about three-fourths (using beginning period weights) of the recorded price change in the CPI. These results are quite tentative and subject to various limitations to be discussed below. Nevertheless, if we realize that we have only scratched the surface as far as quality adjustments are concerned, considering only a very limited and narrow class of "qualities," the conclusion is inescapable that the lack of adequate quality adjustments has resulted in a very serious upward bias in the official automobile price indexes.[25]

6. Additional Tests, Limitations and Conclusions

A. THE EVIDENCE OF THE USED CAR MARKET

One of the problems associated with the use of list prices in this study is the extent to which they may just represent pricing mistakes by manufacturers at some point in time. A manufacturer may overprice or underprice a particular innovation and there is nothing in our method that would catch it. Of course, if we had sales data broken down by makes, models, and attachments, an appropriate weighting of the original data would go a long way toward the solution of this problem. In the meantime, however, we may want to investigate the prices of these cars. The prices of used cars are not

[23] Loosely speaking. Since the quality index is defined multiplicatively, there is no unique way of decomposing a given price change into additive "quality" and "pure" price change components. With 1937=100, the CPI stood at 201 in 1950, the beginning period weighted quality index at 124, and the "adjusted" CPI at 161. $1.25 \times 1.61 \approx 2.01$. The "role" of quality in change could be measured as

$$\frac{24}{101}, \text{ or } \frac{101-61}{101}=\frac{40}{101}, \text{ or as } \frac{1/2(24+40)}{101}.$$

The last procedure leads to the "one-third" statement in the text. On this problem see the note by H. S. Levine. "A Small Problem in the Analysis of Growth" in *Review of Economics and Statistics*, May 1960, pp. 225–228.

[24] If we had deflated the list price index instead of the CPI, we would have shown some price rise for the 1954–60 period with all but the 1950 set of weights.

[25] And in the CPI as a whole. Adjusting the overall CPI for quality change in only *one* commodity—automobiles (applying 1950 quality weights to the 1950–60 changes in specifications and using the 1950 weight of automobiles in the index —3.7 percent), results in a reduction of the index from 125.6 (in November 1959) to 123.7 (1947–49=100). Over 7 percent of the increase in the CPI since 1947–49 may be due just to the changing quality *of one* commodity.

tied any more to the manufacturers' list prices and are set, presumably, more directly by the "market."

Since a used and a new car are not exactly the same commodity, we should not expect a perfect agreement between estimates of "quality prices" from these two different sets of data. In particular, as cars age, one might expect that some of the "qualities" depreciate much faster than others. Nevertheless, relatively "new" used cars should be reasonably good substitutes for new cars and their prices should reflect similar quality differentials.

Table 10 compares the results of using used prices instead of list prices for selected cross sections. For the 1960 models the used prices are for approximately 6-month-old cars. For the other cross sections they are for a little over one-year-old cars. As can be seen by comparing the coefficients of the "new" and "used" regressions respectively, the difference between the two are relatively minor and usually well within the range of their respective standard errors. Thus, the quality weights that could be derived from the regressions using the prices of 1-year-old cars are roughly similar to those that we obtain using new car (list) prices.[26]

TABLE 10.—*A Comparison of Price-Quality Regression Coefficients of New and Used Cars*[1]

Coefficients of	Model year									
	1960		1959		1957		1954			
	New	Used in 1960	New	Used in 1960	New	Used in 1958	New	Used in		
								1955	1956	1957
H	0.052	0.040	0.058	0.029	0.051	0.042	0.149	0.067	0.057	0.052
	(.009)	(.011)	(.011)	(.015)	(.013)	(.015)	(.038)	(.038)	(.038)	(.050)
W	.063	.069	.090	.112	.059	.053	.084	.126	.122	.118
	(.009)	(.011)	(.013)	(.017)	(.017)	(.020)	(.032)	(.032)	(.032)	(.042)
L	--------	--------	--------	--------	.017	.024	--------	--------	--------	--------
	--------	--------	--------	--------	(.006)	(.007)	--------	--------	--------	--------
V	−.017	−.011	−.035	−.030	−.011	−.011	−.022	.024	.035	.049
	(.010)	(.021)	(.015)	(.020)	(.010)	(.012)	(.015)	(.015)	(.015)	(.020)
T	.026	.039	.011	.028	.012	.047	--------	--------	--------	--------
	(.007)	(.008)	(.008)	(.011)	(.005)	(.006)	--------	--------	--------	--------
A	--------	--------	--------	--------	.050	.026	--------	--------	--------	--------
	--------	--------	--------	--------	(.011)	(.013)	--------	--------	--------	--------
P	.102	.094	.104	.077	.034	.001	.037	.091	.123	.145
	(.011)	(.013)	(.014)	(.018)	(.013)	(.015)	(.030)	(.029)	(.030)	(.038)
B	--------	--------	--------	--------	.069	.095	--------	--------	--------	--------
	--------	--------	--------	--------	(.011)	(.014)	--------	--------	--------	--------
R^2	.950	.919	.934	.872	.966	.948	.828	.854	.854	.793

1 The results differ from those presented in Table 3 in two ways. First, they exclude variables which turned out to be insignificant in the particular years such as length or "automatic transmissions." Second, they are presented as computed, using logarithms to the base 10. To make them comparable to the results in Tables 3 and 4, all the coefficients and standard errors should be divided by 0.4343 ($\log_{10} e$).

The used prices in 1960 are taken from the July issue of the N.A.D.A. *Used Car Guide*. For all other years they are taken from the February issues of the *Guide*.

26 There are some minor differences that foreshadow the results that would be found if we were to use prices of 3-, 4-, 5-, and 6-year-old cars in our analysis. The relative price of horsepower falls somewhat with age, while the coefficient of weight remains stable or rises somewhat. The discount on V–8's turns to a premium with age. The premium on "hardtops" rises. The "automatic transmission" premium depreciates very rapidly. In general the results for 5-, 6-year-old used cars look quite different from those reported here. They will be described elsewhere.

B. RELIABILITY

One of the advantages of the approach outlined above is the possibility of computing confidence intervals for the quality indexes or the quality adjusted price indexes. For each new combination of specifications we can compute not only its predicted price in some base period but also the "prediction interval," the probable range of the error of prediction based on the goodness of the fit of the equation and the distance of the new specifications from their mean values. Since this computation is somewhat laborious and since time was limited, no such calculations were actually performed.[27] Some insight, however, into the possible magnitude of such an interval can be obtained by examining the standard error of regression (the standard deviation of the residuals from the equation). The average error of "prediction" for any *one* particular car is quite large. It varies from about 5 percent in 1957 to about 8 percent in 1950 for single year cross sections, from about 6 percent for the 1956–57 combined regression to about 9 percent in the 1958–59 regression, and is about 8 percent for the overall 1954 through 1960 regression. This figure is applicable if we want to predict the price of a particular make and model. We are interested, however, in predicting the *average* price for the three "low-priced" makes. In our case this is an average of eight models and the error of predicting an average goes down, approximately and under suitable conditions, as the square root of the number of items. Thus, the average residual for this group of cars as a whole is only about a third ($\sqrt{8}=2.8$) of the individual errors quoted above. It would be even smaller if we had computed a weighted regression, since the three "low-priced" makes would probably account for about 60 percent of the weights.

C. SHIFTING SUPPLY CONDITIONS AND TASTES

To the extent that shifting supply conditions or changing tastes change the relative "price" of a particular quality we are back to the classical index number problem of changing weights. Not much can be done about this in practice except to shorten the timespan of comparison, compute base and end period weighted indexes, and hope that they are not too far apart. In our case, the more striking examples of such changes are the rapid decline in the "price" of horsepower with the introduction of the V–8's and the fall in the "price" of length.

The CPI in switching to the pricing of V–8's in 1956 linked them to the previously priced six-cylinder engine cars without allowing the index to rise or fall as the result of this substitution, and we have followed suit in the calculation of our indexes. If we use contemporary weights (e.g., for 1955–56) this is about right. Our estimates of the horsepower coefficients are based on a sample that includes V–8's and thus it is not surprising that the increase in horsepower weighted by its coefficient comes close to the difference in price.[28] For the "low-priced three," if we use the horsepower and weight difference between the sixes and the V–8's in 1956 and weight them with 1955–56

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[27] But they present no problem, in principle. See A. Mood, *Introduction to the Theory of Statistics*, 1950, pp. 304–305, and G. C. Chow, "Tests of Equality Between Sets of Coefficients in Two Linear Regressions," *Econometrica*, July 1960, pp. 591–605.

[28] A V–8 engine has usually 50 more horsepower units than a comparable "six" and costs about $100 more. Since our horsepower coefficient during this period is around 1 percent per 10 horsepower units, we would predict a 5-percent higher price. But 5 percent on a $2,000 car is $100.

quality prices, we predict that comparable V-8's should cost about 6 percent more. Actually, they were only 5.5 percent more expensive. Using the 1959 horsepower differences between these cars and 1959-60 weights we predict a 9-percent price differential against the observed 5 percent.[29] This agrees with our finding for the sample as a whole that the V-8's were about 3 or more percent cheaper than would be predicted from an extrapolation of the price-horsepower relationship for six-cylinder engine cars.

The introduction of the V-8's represented a decline of a few percentage points in the "real" price of cars that is not caught by the linking procedure. But this is only an "economies of scale" effect along a given relationship, and does not represent the total possible contribution of the V-8 engine. In fact, the appearance of the V-8 on the market in substantial quantities brought the whole level of horsepower "prices" down. Thus, if we were to value the V-8 at 1950 horsepower "prices," when there were only a few V-8 engine cars in the sample, we would estimate it to be a 15-percent "more car" (to have a 15-percent higher "quality" index) as against only a 5-percent increase in its price. The very fact of the rapid rise of the V-8 to market dominance would indicate that it was somewhat "underpriced" relative to the sixes. This is also supported by the used car price-quality regressions. In a large number of cases, the negative coefficient (discount) of the V-8 variable observed for new car prices turns into a positive coefficient (premium) once these cars get to the used car market.

Another problem is created by our use of proxy variables, of dimensions that may not be desirable per se, but which are correlated with other, more difficult to measure, but basically more desired dimensions. Weight, for example, is unlikely to be desired very much for its own sake. Rather, it is a proxy for "size." The relationship between price and weight may involve, however, other things besides "size," and the relationship between weight and the underlying desired characteristics may change over time. Our weight coefficients are derived on the basis of the difference in price between the cheap and the expensive cars, but the "large" cars may be expensive for reasons other than just "size." We have tried to control this by introducing a variety of dummy variables such as power steering and automatic transmissions which are standard equipment on the more expensive cars.[30] This prevents these cars from exerting an undue influence on the price-weight relationship for the sample as a whole. Alternatively, we could have computed separate estimates for different groups of cars; for example, the "low," "medium," and "high" priced cars. Still another approach would have been to estimate "compar-

[29] This brings out an additional problem associated with the linking procedure. The additional cost of a V-8 engine has remained approximately constant at $100 while the absolute price of cars increased. Thus a price index based on six-cylinder engine cars would rise somewhat faster than the V-8 based index. The inclusion of attachments in the pricing procedure may lead to an underestimate of the price rise of the attachmentless car if, as appears to have happened recently, attachment prices do not rise as much as the price of the "basic" unit or at all. To the extent that a substantial fraction of cars is bought without them, this could bias the index.

[30] This is one reason why these estimated coefficients should not be used directly in estimating the "value" of a particular attachment. We know that power steering and brakes come to about $130, which is far from the 20-percent or so increase in price indicated by their coefficients. The main purpose of these variables is not to estimate the price of these attachments, which we know, but to reduce the possible bias in our slope estimates for the numerical qualities by allowing different groups of cars to differ in the position or intercept of these slopes.

able" prices for different models by subtracting from the more expensive cars the estimated "value" of most of the attachments and features not available on the lower priced cars. Since many of these are listed as "extras" for other cars, one could probably go some distance in "standardizing" prices.

The basic method would of course be seriously compromised if the relationship between any one of the measured dimensions and the more basic "real" qualities were to change from one period to the next. For example, suppose all cars were, after a given date, made of an aluminum alloy which halved their weight, but absolute and relative prices did not change. This change in weight would increase the apparent price of weight and reduce its level per car while in fact nothing may have happened except for a change in units of measurement. If we did not know what had happened, we would have mistaken this weight change for a quality change. But in practice this should not present an insuperable problem. We usually know enough about what is happening in a particular market and to a particular product to be able to make some adjustments for it. More important, such changes are unlikely to be sudden and all inclusive. Aluminum cars will probably sell for several years together with more "old-fashioned" cars, and we shall be able, by the use of dummy variables or other techniques, to detect the difference between these cars and build it into our equations.[31]

D. SUGGESTIONS FOR FURTHER RESEARCH AND CONCLUSIONS

It is obvious that our investigation is only illustrative of a promising line of attack on the quality change problem. There are more than just a half-dozen dimensions to an automobile and they may not interact in any simple linear fashion.[32] Further work along these lines would include the introduction and testing of a number of additional "qualities"; an examination of the residuals from the various price-quality regressions which could reveal overlooked variables or nonlinearities; use of weighted regressions, where different cars would be weighted according to their importance in the market; division of the sample into separate subgroups to test hypotheses about the linearity of the various price-quality relationships; use of actual transaction prices instead of list prices in the analysis; and the extension of this type of analysis to a variety of other commodities such as trucks, refrigerators, and cameras.[33]

Continuous studies of the present type by the price collecting agencies, should prove of great value. First, they would eventually perfect the method enough so that it could be used routinely in the computation of the official indexes. Second, they would provide them with much more information on the various dimensions of a commodity, allow the use of a more sophisticated linking procedure, and isolate the qualities or dimensions which appear to be most important. Third, the availability of such information is also likely to lead to a more useful specification of commodities for price collection purposes.

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[31] The next few years will provide a good test of this assertion. One of the 1961 model year cars is already using an aluminum block engine.

[32] For evidence on how complicated a machine an automobile really is and for the many changes that actually occurred in it since the 1930's, see the history of the Plymouth and its specifications summarized in *Administered Prices*. Hearings before the Subcommittee on Anti-Trust and Monopoly, U.S. Senate, 85th Congress, 2nd session, Part 7: Appendix, 3655–65 and 3734–49.

[33] A study of wheel tractor prices along these same lines is in progress.

And finally, such studies, if done for a wide enough range of commodities, could provide an estimate of the probable upward drift of the price indexes due to their inability to control adequately for many of the constantly occurring quality changes.

APPENDIX

The Official Automobile Price Indexes

There are three official automobile price indexes: The "new automobiles" component of the CPI, the "passenger cars" component of the WPI, and the automobile component of the Prices Paid Index of the U.S. Department of Agriculture. The CPI new automobile price index is a retail price index for Chevrolet, Ford, and Plymouth sedans with V–8 engines (sixes before 1956 except Ford), automatic transmissions (since 1956), and other minor items such as extra trim, radio and heater, gasoline and antifreeze. The WPI is a wholesale (manufacturer to dealer) index of car prices, presumably covering all or most makes and models weighted by some base period production. The Agricultural Marketing Service index, which is not published separately, is based on a mail survey of prices paid by farmers for six-cylinder Chevrolets, Fords, and Plymouths, and for V–8 Chevrolets, Fords, Plymouths, and Buicks. Average prices paid for six-cylinder cars and for V–8's are published separately each quarter in *Agricultural Prices*. Again, it is not clear how the different makes and models are weighted, and what weights are used in aggregating state data into national averages.

Of the three indexes, the AMS stands alone in not specifying exactly what attachments are included in the model being priced. The CPI explicitly deals with the items that are being priced with the car, and adjusts for changes in "extras." The WPI presumably prices the "standard equipment" car and adjusts for major changes in what is being considered as standard. The AMS, however, has collected prices paid by farmers for specified models and makes "together with the usual equipment bought by farmers." It has tried to control for some aspects of size by comparing similar "price lines" of each make in different years, and has priced V–8's and sixes separately, but its failure to specify other attachments allows the index to drift upward as the result of farmers shifting to the purchase of more heavily equipped cars, cars that include radios and heaters, automatic transmissions, power steering and brakes, and other extras. That this drift is serious is indicated by the fact that the difference between the average six- and eight-cylinder car priced by the AMS which stood at $200 in 1947–49 increased to $660 by November 1959. Since, the price of V–8's and Buicks probably did not increase as much, percentagewise, as the price of the "low-priced-three" sixes, most of this increase must be due to the increasing number of attachments bought with the more expensive cars.

Percentage changes in these indexes are tabulated in Table 11 for selected periods and are compared to changes in a list price index of the "low-priced-three" makes. Note that in almost all of the comparisons, the AMS prices rise more than all the other indexes, including the list price one. This is another indication of the upward drift

TABLE 11.—*A Comparison of Official Indexes and List Prices for U.S. Cars: Percentage Change, Selected Periods*

Period	WPI [1]	CPI [2]	AMS [3]	List prices	
				Unadjusted [4]	Adjusted for minor equipment changes [5]
1937-50	83.0	101.0	129.0	116.0	
1947-49 to January 1954	20.6	29.7	32.7	[6] 18.0	16.9
January 1954 to November 1954	2.7	−1.7	[7] 2.2	2.5	
November 1954 to November 1955	4.1	−.9	[8] 3.8	5.4	
November 1955 to November 1956	5.7	5.1	5.4	9.9	
November 1956 to November 1957	.6	4.2	3.8	6.7	
November 1957 to November 1958	5.1	4.2	11.8	6.0	
November 1958 to November 1959	.1	.1	3.0	2.0	
January 1954 to November 1959	19.7	11.3	33.6	34.4	
1947-49 to November 1959 (1960 models)	44.3	44.3	68.4	[9] 58.6	
January 1954 to November 1957	13.8	6.7	29.8	[9] 26.7	21.6

[1] See Table 6.
[2] See Table 7.
[3] Sixes before November 1955, V-8's thereafter; the V-8's include Buick Special in addition to the "low priced three." From various issues of *Agricultural Prices*. The 1937-50 comparison is based on an unpublished index used to deflate farmers' expenditures on automobiles.
[4] From Table 7: The "low priced three." The model year is assumed to start in November of the previous calendar year.
[5] Adjusting list prices for differences in minor equipment items included in the price, such as directional signals and electric clocks, based on data from *Administered Prices, op. cit.*, pp. 3548-9, 3622-6, and 3730-3. Also, including automatic transmissions in the list prices as of 1956.
[7] January 1954 to January 1955.
[8] January 1955 to November 1955.
[9] Beginning with 1950 models.

in the AMS index as the result of its relatively loose specification policy. Looking at the other indexes, we note that the movements to 1954 are roughly similar, with the WPI rising somewhat less than the CPI and the list price index. The main divergence between these indexes comes in the 1954–58 model year period, with the CPI rising substantially less than either the WPI or list prices. It is not too surprising that the WPI rose less than the list price index for the lower priced makes. About half of its weight is given to medium and higher priced cars which have risen less percentagewise than the lower priced makes.[34] The sharp divergence between the CPI and list prices during 1954–58 is, however, surprising and requires explanation.

A reconciliation of the two series is seriously hampered by the lack of a detailed description of how the CPI is actually computed. There is no published information on whether the index is a ratio of the average price for these makes or an average of their price relatives; what weights, if any, are used in averaging the price data for different makes and models; which models of a given make are being priced in a particular year and to what models they are being compared in the previous year; and what quality changes were "linked-in" or "out," and when and how.[35] The list price index was constructed in such a way as to approximate the CPI closely.[36] It differs from the

[34] Between 1954 and 1958 the prices of Buicks, Pontiacs, Mercurys, and Dodges advanced relatively less (about 15 percent) than the prices of Chevrolets, Fords, and Plymouths (which rose 23 percent). Compare also with Table 5.
[35] Many of these problems could have been settled by a consultation with BLS personnel and an examination of their records. Unfortunately, previous commitments, deadlines, and distance prevented this from being accomplished in time.
[36] It differs from the CPI in that before 1956 it prices only six-cylinder engine cars (except in 1937) whereas the CPI priced eight-cylinder Fords throughout, and in not including automatic transmissions in its price which the CPI has done since 1956.

CPI in that it does not adjust for changes in minor equipment items, it does not include transportation costs, state and local taxes, and minor accessories sold with the car, and it does not allow for changes in the discount from list prices.

It is possible to adjust the list prices for some of the minor equipment changes using more detailed price data presented in the Kefauver Hearings.[37] This will reduce the rise in list prices somewhat (see the last column of Table 10), but it still leaves a very substantial difference between the CPI and list prices (or the WPI) unexplained. Some of this difference could be due to the inclusion in the CPI of various "trim" items, transportation costs, and taxes, which may have remained constant or risen less than the price of the "basic" (stripped) car. Still it could not explain it all—the actual difference is too large for that.

Another source of this difference could lie in the fact that the CPI started in 1954 to collect data on discounts offered by retailers. But even this is unlikely to explain much of the difference between the two series. Assume that before 1954 the CPI did not include discounts, that it does so since 1954, and that no linking was done to account for this. We know that list prices went up by about a third during 1954–60, that the spread between the price to the dealer and the list price remained at approximately the same percentage level (24 per cent) throughout the period, and that during the same period the CPI rose only 11 per cent. Consider the following arithmetic example: A representative car cost $1,350 wholesale in 1954, listed for $1,800 at retail, with the dealer's margin being $450. No discount was given in 1954. The same type of car lists for $2,400 in 1960 (a rise of 33 per cent) and costs the dealer $1,800. If the actual retail price had risen only 11 per cent, to $1,998, the dealer's return would have dropped from $450 to $198 per car, or from a 25 to an 8 per cent margin. This seems to be too big a drop in the return to dealers in a period of rising prices to be plausible.

An additional explanation for this divergence has been suggested by John M. Blair, who was also puzzled by it.[38] He has argued that since the BLS agent first asks for the list price and then separately for the magnitude of the discount the difference between the two may not equal the actual price charged. It is said to have been common practice during 1955–58 for dealers to "pack the price," i.e., to quote a discount that was not calculated from the list price but from some higher figure. Subtracting this "unrealistic" discount figure from the list price would lead to a downward bias in the estimated price actually paid by consumers. But this should be a transitory phenomenon. Once eliminated, as it apparently has been in the most recent years, it should have led to a comparably higher rise in the CPI. This has not happened.

The final possibility is that the CPI has been much more thorough in its quality adjustments than is reflected in the published literature. That is, it could have been argued in some year, for example, that "this year's cheapest Ford model is equivalent in size, trim, and horsepower to last year's medium-priced Ford." The only detailed de-

[37] *Administered Prices.*
[38] *Administered Prices*, pp. 4000–4002.

scription of automobile prices in the CPI suggests this possibility by saying:

> . . . the automobile retail price indexes have been designed to measure solely the trend of prices paid by city workers for automobiles of as nearly fixed quality as possible . . . Therefore, prices are collected for automobiles which are regarded as most nearly equivalent to the cars priced in the preceding year.[39]

But then the next sentence reduces the probability of this by stating:

> Equivalent quality of new cars has been assured to a great extent by specifying as a basis of pricing the same make and body style, the *same or equivalent price series*, and the same number of cylinders as the car which was priced in the preceding year. [Emphasis supplied.]

Thus, it appears quite unlikely that the CPI has linked out the type of horsepower, weight, and length changes used in constructing our quality indexes. If this is true, then it is quite probable that for some unknown reason, the CPI underestimated the rise in new car prices (given its own definition) between 1954 and 1958.

[39] "Automobile Prices in the Consumer Price Index," *Monthly Labor Review*, November 1955, p. 5.