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Hedonic Price Indexes of U.S. Domestic Passenger Cars for 1970-83: Traditional and New-Fashioned Indexes

by

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Abstract

Traditional hedonic price index (T-index) is estimated usually by an adjacent two-year hedonic regression that assumes the constancy of all the parameters over time. But the gasoline cost parameters changed significantly in the two oil shocks. New-fashioned index (N-index) is devised to take this change into account. We consider two types of N-indexes, the difference being in the consumer expectation about gasoline price. After obtaining the theoretical relationship between T-index and N-index and discussing their uses, we estimate them for U.S. passenger cars and compare them.

Key Words: Traditional hedonic price index; New-fasioned hedonic price index; Consumer Price Index; Weighted index; Oil shock; Consumer expectation;

1. INTRODUCTION

Hedonic price index is the quality-adjusted price index obtained by hedonic approach. Hedonic approach regresses the price of a good on its characteristics to estimate their imputed prices and considers the product sum of the imputed prices and the levels of characteristics as the estimated quality of the good. Taking cars as an example, the characteristics are their weights, lengths, engine sizes, etc. We can find several studies about the hedonic price indexes of the U.S. domestic passenger cars before 1970 (Griliches 1961, Triplett 1969, Ramm 1971, Ohta and Griliches 1976), but there does not seem to be an extensive study of them after 1970 except for Blanciforti and Gabin (1984) about new cars for 1978-81. This paper will present the annual percentage changes in the estimated hedonic price indexes of used cars for 1970-83.

Traditionally when we estimate the changes in hedonic indexes, we hold the coefficients of the characteristics of a semi-logarithmic hedonic regression equation to be the same between the two adjacent years, allowing only the year dummy coefficient to change over time. But as Ohta and Griliches (1983) found, the coefficients of the gasoline cost part of the hedonic regession equation changed significantly in the two oil shock periods in 1973 and 1979. We will allow these coefficients to change over time, when we estimate our "new-fashioned" hedonic price index (that will be explained in the next section) in these shock periods in this paper.

Thus this paper will present the annual changes in hedonic indexes measured both in a traditional way and in a new-fashioned way. We will estimate the weighted indexes by sales (actually by production level) to represent the passenger car market better as well as the unweighted indexes. We will estimate our new-fasioned indexes only for the oil shock periods because of the reason stated later in section 2, although we will present the annual changes in the traditional indexes for the whole period 1970-83.

The rest of the paper is organized as follows: First (section 2) we will discuss theoretical issues and explain the estimation procedure. Next we will describe the data (section 3) and will present our empirical results (section 4). Summary of our findings (section 5) will close the paper.

2. THEORETICAL ISSUES AND ESTIMATION METHOD

Let $x=(x_1,x_2,\cdots,x_n)$ be a vector of physical characteristics of a passenger car such as weight, displacement of engine, etc., excluding fuel economy. Fuel economy is measured by mileage driven per gallon (MPG). Both x and MPG are measured when the car is new. A car deteriorates with age s. Then the hedonic hypothesis says that the price of a car is a function of x, MPG and s at a given point of time.

The above function is called a hedonic price function and can be written generally as P(x,MPG,s,t). Then P(x,MPG,s,t) is the price of a car of age s at time t with characteristics x and MPG when new. Its functional form is determined by demand and supply forces at time t in the market, as was shown in Rosen (1974).

Hedonic price index is traditionally defined as the ratio of the price of a car of a given age s and a given level of characteristics x and MPG at the comparison time t_1 to the price at the base time t_0. Mathematically "traditional" hedonic price index of time t_1 with time t_0 as base is defined as $P(x,MPG,s,t_1)/P(x,MPG,s,t_0)$. We will write the traditional index as T-index for brevity. The percentage change in the T-index, π_T, is defined as $\dot{P}(x,MPG,s,t)/P(x,MPG,s,t)$, where $\dot{P}$ is dP/dt.

Generally T-index (and π_T) takes different values for different values of x, MPG and s. But usually we do not estimate these different values in the empirical studies. Instead we usually assume the separability that P(x,MPG,s,t) can be written as $f(t)\cdot h(x,MPG,s)$. Then T-index is $f(t_1)/f(t_0)$ and π_T is $\dot{f}(t)/f(t)$ and so both of them do not depend on x,MPG and s.

Specifically the following semi-log form of adjacent-time regression was used usually to estimate π_T (Griliches 1961, Ohta and Griliches 1976), excluding MPG variable.

$$\log P(x,MPG,s,t)=Const.+\sum_t \pi_{Tt}\cdot T_t+\sum_s \delta_s D_s+\sum_i \alpha_i\cdot x_i+u \qquad (1)$$

Here π_{Tt} is the proportional rate of change in the T-index between the base time and time t, T_t is a dummy for time t, D_s is a dummy for age s and u is a disturbance. We do not include dummies for the base time and for the youngest age. We can obtain not only the estimate of π_T but also its standard error by this adjacent-time hedonic regression. This standard error serves as the measure of the unreliability of the estimate of π_t.

Following Ohta and Griliches (1983), we include the expected present value of gasoline cost over the remaining life of the car, g, in the hedonic equation as follows.

$$\log P(x,MPG,s,t)=Const.+\sum_t \pi_{Tt}\cdot T_t+\sum_s \delta_s\cdot D_s+\sum_i \alpha_i\cdot x_i-g/P(x,MPG,s,t)+u \qquad (2)$$

Here g/P in the right hand side may be interpreted as "real" expected gasoline cost, where the car price P serves as a deflator.

In order to treat g as data, we have to calculate it before regression. To do so, we have to know the expected length of the life of each car, its expected miles driven, expected gasoline price in each future year, expected deterioration of MPG and expected furture interest rate. We have not good data on these expectations.[1] So, following Ohta and Griliches (1983), we will parameterize g as follows to estimate instead of imposing some arbitrary value for it.

$$g\simeq \beta/MPG+\gamma\cdot s+\varepsilon\cdot s/MPG \qquad (3)$$

It will be obvious that MPG enters g in the above approximation. Age s affects g in two ways. First s affects the length of the remaining life of the car. Second fuel economy deteriorates with s. Generally parameters β, γ and ε change their values over time, because they depend on many factors that change over time, especially, gasoline price.

Substituting (3) into (2) yields the following equation.

$$\log P(x,MPG,s,t)=\text{Const.}+\sum_t \pi_{Tt}\cdot T_t+\sum_s \delta_s\cdot D_s+\sum_i \alpha_i\cdot X_i$$

$$-(\beta/MPG+\gamma\cdot s+\varepsilon\cdot s/MPG)/P(x,MPG,s,t)+u \qquad (4)$$

This is the basic regression equation to estimate the hedonic price index. We constrain all the coefficients (including, especially, β, γ and ε) to be constant over time to estimate the percentage change in the T-index π_T. That is, the functional form of the hedonic price equation (4) must be stable over time to estimate π_T in this traditional way.

According to the finding of Ohta and Griliches (1983), we can treat both the characteristics' coefficients α's and the gasoline cost parameters β, γ and ε to be constant over the periods 1970-73, 1974-79 and 1980-81. But in the two oil shocks in 1973 and 1979, the hypothesis of the constancy of both the characteristics' coefficients and the gasoline cost parameters over time is rejected. Even in these shocks, however, we can still treat α's to be constant over time if we allow the gasoline cost parameters to change. The change in the gasoline cost parameters can be explained well by the change in the gasoline price alone in these shocks.

We applied the testing method in our 1983 paper to the period 1981-83. We used equation (1) to test the null hypothesis of the constancy of α's over time. Even in equation (1) that does not take the gasoline price change into account, the null hypothesis is not rejected practically, as we will explain below.

We use ΔSER criterion as a practical test criterion. That is to reject the null hypothesis if and only if the difference in the standard error of regression between the constrained and the unconstrained regressions, ΔSER, is larger than .01. Since the left hand variable of our regression equation is the logarithm of price, ΔSER of .01 implies that the imposition of the null hypothesis decreases the fit to the price by one percent. The standard error of regression (SER) is about .15 in our study and so the ΔSER of .01 is about 6.7 percent increase of SER by the imposition of the null hypothesis.

The ΔSER is .000 and .002, respectively, in the periods 1981-82 and 1982-83 (We used April used car prices in each year). So the null hypothesis of the constancy of α's is not rejected practically by our ΔSER criterion, even if we do not take gasoline price change into account.[2] One may feel uneasy about this test result, because the gasoline price decreased much (12.5 percent) from 1981 to 1982. But the gasoline cost g in equation (2) is its "expected" present value and so the car price will not be affected much by the gasoline price decrease if consumers expect the decrease properly in advance.

Summing up the above test results, we may treat all the coefficients of equation (4) to be constant over time in each of the periods 1970-73, 1974-79 and 1980-83. So it is quite adequate to estimate T-index in the traditional way that constrains all the coefficients to be constant in each of these periods.

But in the two oil shocks in 1973 and 1979, we have to allow the gasoline cost parameters β, γ and ε to change over time in the direction of the gasoline price change, while we can treat all the other parameters to be constant over time. That is, the functional form of the hedonic price function changed over time in the oil shocks in this way. The traditional estimation of T-index commits a specification error in these shocks, because it assumes the constancy of the functional form including the gasoline cost parameters. We will, however, present the T-index estimated in the traditional way later for these shock years to compare it with our "new-fashioned" index.

In order to avoid the above specification error, we have to estimate the hedonic price equation cross-sectionally for each year and to calculate $\Delta P(x,MPG,s,t)/P(x,MPG,s,t)$. Generally the index estimated in this way takes different values for different levels of characteristics x and MPG and for different ages s. We do not estimate the change in the T-index in this way, because we can not get its standard error which the traditional adjacent-year regression yields.

Another way to adjust for the change in the form of the hedonic price equation (4) in the oil shocks is to use the finding of Ohta and Griliches (1983) explained before. Namely we increase the gasoline cost parameters β, γ and ε by the same rate as the increase of the expected present value of gasoline cost g in the oil shock, while keeping all the other parameters constant over time. The time dummy coefficient estimated in this way is the estimated proportional rate of change in our "new-fashioned" hedonic price index (N-index). We denote this proportional rate of change in the N-index by π_N. We will estimate π_N only for the two oil shock periods, because the gasoline cost parameters (together with all the other parameters) are statistically stable for other periods.

The essential difference between the T-index estimated in the traditional way and the N-index is as follows. The T-index attaches the same value of g to the same values of MPG and s before and after the oil shock, while the N-index attaches a larger value of g to the same values of MPG and s after the oil shock. N-index do so more to a lower MPG car. We will explain the N-index more formally and will obtain the relationship between the T-index and the N-index below.

We use the semi-log form of hedonic price equation (2) for simplicity of exposition. Then the quality Q of a car of age s with characteristics x and MPG is as follows.

$$Q=EXP(\sum_s \delta_s \cdot D_s + \sum_i \alpha_i \cdot x_i - g/P(x,MPG,s,t)) \tag{5}$$

Here g is allowed to change over time, while the other parameters δ's and α's are constrained to be constant. So the quality evaluation Q changes for fixed characteristics x and MPG and fixed age s when the gasoline cost g changes. The "new-fashioned" index (N-index) is the ratio of P/Q of the comparison year to that of the base year. It is verified easily from equations (2) and (5) that π_N explained before is the proportional rate of change over time in N-index.

We have the following relationship between π_T and π_N from equation (5), because they are defined as $\dot{P}/P$ and $d(P/Q)/dt/(P/Q)$, respectively.

$$\pi_N=\pi_T+(\dot{g}/g-\dot{P}/P)\cdot(g/P) \tag{6}$$

So π_N is greater than π_T if and only if $\dot{g}/g$ is greater than $\dot{P}/P$ (that is, π_T). That is, π_N is greater than π_T when and only when the "real" expected present value of gasoline cost g/P increases, where the automobile price P serves as the deflator. π_N coincides with π_T if and only if g/P is constant over time.

Conceptually we can consider another type of automobile price index that takes gasoline price change into account, as follows.[3] The "full" price of operating a car is the sum of the car price P and the gasoline cost g, ignoring other operating costs such as insurances, taxes and repair cost. Then the "full" price index (F-index) of the automobile is the ratio of its full price P+g at the comparison year to that at the base year. Obviously, the proportional rate of change in the F-index, π_F, is the weighted sum of the proportional rates of changes of P and g as follows.

$$\pi_F=(\dot{P}/P)\cdot P/(P+g)+(\dot{g}/g)\cdot g/(P+g) \tag{7}$$

We have the following relationships from (6), (7) and the definition of π_T as $\dot{P}/P$.

$$\begin{aligned} \pi_F-\pi_T &= (\dot{g}/g-\dot{P}/P)\cdot g/(P+g) \\ \pi_N-\pi_F &= (\dot{g}/g-\dot{P}/P)\cdot(g/P-g/(P+g)) \end{aligned} \tag{8}$$

So the relationship $\pi_N>\pi_F>\pi_T$ holds if and only if the "real" expected present value of gasoline cost g/P increases over time. π_N, π_F and π_T are all equal if and only if g/P is constant over time.

We do not measure π_F in this paper because of the following reason. We regress the log of P+g on characteristics x, age dummies, time dummies and a constant to estimate π_F, where the time dummmy coefficients are π_F's. We have to treat g as data in this regression. But it is not reliable to calculate g extraneously as was explained before.

What is the use of π_T and π_N? Generally hedonic price index of capital goods can be used as a "constant-quality" deflator of capital goods. Then which is the better deflator, π_T or π_N? The answer depends upon the case as below.

Take a taxi industry as an example. Let Y=A(L,G,K) be its true short-run production function, where Y is the output measured by man-mile, L is the number of drivers, G is the gasoline used and K is the number of cars that is fixed in the short-run.

Suppose that we want to estimate this production function. Suppose further that we do not have data on K but have data on the value of K denoted by VK as well as the data on Y, L and G. Then we have to replace K by its real value RVK that is obtained by deviding VK by some deflator. The appropriate deflator is not $1+\pi_N$ but $1+\pi_T$ in this case. The reason is as follows. Suppose that the gasoline price increases, while all the other prices are held constant. Then it decreases G and so K will be under-utilized. But the under-utilization of K is taken care of by the decrease of G and so the appropriate deflator of VK is $1+\pi_T$. If we use $1+\pi_N$ as the deflator, then the under-utilization of K is double-counted; by the use of π_N as the deflator and by the decrease in G.[4] π_N takes care of the devaluation of K due to the gasoline price increase and the devaluation of K reflects the under-utilization of K.

Suppose that we do not have data on G so that we have to estimate the production function Y=B(L,RVK) instead of the true function Y=A(L,G,K). The appropriate deflator for RVK is not $1+\pi_T$ but $1+\pi_N$. The reason is as follows. Suppose again that the gasoline price increases, while all the other prices are held constant. Then it decreases G and so K will be under-utilized. The under-utilization of K is taken care of by using $1+\pi_N$ as the deflator, because π_N takes care of the devaluation of cars by users due to the gasoline price increase. π_T does not take care of this devaluation.

Now we will explain several issues for estimation. First the left hand variable P appears also on the right hand side of equation (4). Following Ohta and Griliches (1983), we solve this problem by using a three-stage procedure: First the log P equation is estimated based on the x's (characteristics) alone, yielding a $\hat{P}$ to be used in stage 2 to estimate equation (4). This yields a new $\hat{P}$, which is used in the final third stage to reestimate (4).

Second we allow the gasoline cost parameters β, γ and ε to change over time in the two oil shock periods to estimate π_N. We do this adjustment in such a way that all these parameters increase proportionally by the same rate σ after the oil shock. Then the expected present value of gasoline cost g increases by σ after the oil shock than before it.

The above treatment constrains the relative values of the three gasoline cost parameters after the oil shock to be the same as before it. We impose this constraint, because otherwise it is difficult to estimate π_N and also because Ohta and Griliches (1983) found that these parameter changes can be constrained to be so.[5]

A priori the expected present value of gasoline cost g is expected to increase in the oil shocks. Ohta and Griliches (1983) found that this holds true empirically.[6] So σ, the proportional rate of increase in g, should be positive in the shocks. We consider two treatments for σ, depending upon the effect of the shock on the consumer expectation about future gasoline price increase.

One treatment is to set σ to be equal to the rate of increase of the Consumer Price Index (CPI) of gasoline between the base and the comparison year. This will be relevant when consumers have static expectation about future gasoline prices. The other is to estimate σ in the hedonic regression. This will allow consumers to have non-static expectation about future gasoline prices so that they extrapolate some of the present gasoline price increase into the future. In this treatment, the estimate of σ can be larger than the rate of increase of the CPI of gasoline.

We have two new-fashioned hedonic price indexes, according to the two different treatments of σ stated above. When we constrain σ to be equal to the rate of the increase of the CPI of gasoline, we will call the N-index the "N1-index". We will call the N-index the "N2-index", when we estimate σ in the hedonic regression so that consumers are allowed to extrapolate the present gasoline price increase into the future.

We will call the corresponding hedonic regressions the N1-regression and the N2-regression, respectively. These regressions allow the gasoline cost parameters β, γ and ε to increase by the same rate σ in the way explained above in the oil shock period, but they constrain all the other parameters to be constant over time. Also we will call the hedonic regression the T-regression, when we set σ to be equal to one. That is, the T-regression constrains all the parameters of equation (4) including gasoline cost parameters to be constant over time.

Third we do adjacent several-year regressions to obtain better estimates of characteristics' coefficients α's by pooling more years and using more data instead of doing the usual adjacent two-year regressions.

We can adopt the several-year regression because α's are stable over time except for the two oil shocks. We can not do so in the first few years because of our sample structure.

We choose the vintages of cars to be used in the regression in such a way that the age structure is the same in each year. Whenever possible, we use sample cars of ages two, three and four years, because the cars of these ages appear most in the used car market: They represent the market well and also the used price data of them are most reliable since the used price data are the average of the actual transaction prices.

Finally we will present the estimates obtained by the weighted regression with the sales volume (actually production level) as weight in order to represent the market well, together with the estimates obtained by the unweighted regression.

3. DATA

N.A.D.A. <u>Official Used Car Guide</u> is our data source on U.S. domestic passenger car prices and characteristics. We collected the characteristics of 1966 to 1982 vintage cars and their used prices in April from 1970 to 1983. Six years is the oldest age that we observe in these data. Whenever sample structure allows, we use the cars of ages two to four years as sample because of the reason stated in the previous section. Our sample distribution is shown in Table 1.

The information on the 1970-82 vintage cars was taken from the New England Edition of the N.A.D.A. <u>Guide</u>. Data on the 1966-69 vintages were taken from the earlier Ohta and Griliches (1976) study which used the Central Edition of the same <u>Guide</u>. We will not confuse Central Edition used car prices with those of the New England Edition in the regression. The 1970 and 1971 used car prices of 1966-69 vintages are Central Edition prices and all other prices are New England Edition prices, as shown in Table 1.

The earlier Ohta and Griliches data set contained only sedans and hardtops with four or two doors. The new data collected for the 1970-82 vintages include also station wagons and coupes with four, two, three and five doors, encompassing all segments of the passenger car market.

The following physical characteristics were used by us: (1) number of cylinders, (2) shipping weight (in pounds), (3) number of doors, (4) wheelbase (in inches), (5) length (inches), (6) width (inches), (7) CID (cubic inch displacement of engine), (8) brake horsepower, (9) AT (dummy for automatic transmission, 1 if standard, 0 otherwise), (10) PS (dummy for power steering, 1 if standard, 0 otherwise), (11) AC (dummy for airconditioning, 1 if standard, 0 otherwise).

MPG data are taken from E.P.A. publications, but these are available only for 1974 and later vintages. Furthermore, they are for city driving in some years and for highway or for combined city and highway driving in other years: City MPG is available for 1974-78 vintage cars, highway MPG available for 1975-78 vintages and combined MPG is available for 1976-82 vintages. We can match our sample cars perfectly with the cars in E.P.A. publications after 1975. In 1974, the match is imperfect and we use occasionally the MPG data for the nearest available similar car (nearest in CID and weight within the same make).

We used Facts and Figures of Consumer Reports to get the MPG data for 1966-73 vintage cars. For 1966 vintage cars, we use traffic gas mileage data, which involve acceleration, 35 mph maximum, idling, and an average speed for the course of about 21 mph. For 1967-73 vintage cars, we use the arithmetic average of the lower and upper extremes of the range of gas mileage to be expected in normal use. The lower extreme is for short-range stop-and-go traffic and the upper extreme is for open-road, constant-speed trips. Thus the Consumer Reports MPG data correspond roughly to city MPG data of E.P.A., although we do not use both data simultaneously. The number of models for which Consumer Reports MPG data are available is rather small (about 20 per vintage). We use this small sample, when we use Consumer Reports MPG data in the regression for 1967-73 vintage cars.

We obtained the production data by body style and by cylinder type for each car model of each vintage from Ward's Automotive Yearbook. We use the CPI of gasoline for urban wage earners and clerical workers as gasoline price index till 1978 and use the CPI of gasoline for all urban consumers from 1978.

4. EMPIRICAL RESULTS

We considered three variational regressions for our basic equation (4). They are the T-, the N1- and the N2-regression. These regressions are designed to estimate the proportional rate of change in the T-, N1- and N2-index, respectively. As stated in section 2, we do the N-regressions only for the two oil shock periods in 1973 and 1979, while we do the T-regression for all the periods 1970-83.

Following Ohta and Griliches (1983), the physical characteristics used in these regresssions (in addition to time and age dummies) are as follows: (1) CID, (2) number of cylinders (NOC), (3) weight (WT, in pounds), (4) wheelbase times width (WBW, in squared inches), (5) dummy for number of doors less than four (NOD2), (6) dummy for number of doors greater than four (NOD5), (7) AT, (8) PS and (9) AC. (1) and (2) contribute to speed, (3) and (4) mainly to roominess of a car, (5), (6) and (9) to the quality of the ride, and (7) and (8) to the ease of driving and maneuvering.

As an example, we will present the four-year unweighted regression results for the period of 1977, 1978, 1980 and 1981 in Table 2 and the weighted regressions by sales (actually production) for the same period in Table 3. This period includes the second oil shock in 1979 in the interim. We chose the second oil shock period rather than the first one as an example, because Ohta and Griliches (1983) found that the second shock affected the hedonic price function more strongly. We omit 1979 in this regression because of the reason explained later.

Sample cars of this regression are two, three and four years old. The actual vintages used in the regression are shown in Table 5. The gasoline cost parameters β, γ and ε are constrained to be constant in each of the pre-second-oil-shock period 1977-78 and the after-shock period 1980-81. But they are allowed to be different between the 1977-78 and the 1980-81 periods. The rate of increase of the gasoline cost parameters σ between these two periods is set equal to the rate of increase of the CPI of gasoline between 1978 and 1980 (that is, .979) in the N1-regression and is estimated in the N2-regression.

R^2 is higher and SER is lower in the weighted regression (Table 3) than in the unweighted regression (Table 2), as should be the case. This holds for all the periods 1970-83. The results of the weighted regression by sales represent the market better. The estimated time dummy coefficients are the proportional rates of changes in the hedonic indexes with 1978 as the base year. These estimates are re-arranged in Tables 5 and 6.

By similar regressions we estimate the percentage changes in the hedonic indexes for the other years (Tables 5, 5A and 6). The percentage changes in the relevant components of CPI are shown in Table 4 for comparison.

Table 5 lists the percentage changes in the T-index (that is, π_T in percent) estimated from the regressions based on equation (4) which includes the gasoline cost variables. Since the number of cars whose MPG data are availabe in the Consumer Reports is small, we report the estimates obtained by using all the sample cars but by using equation (1) which excludes the gasoline cost variables in Table 5A. We also list the estimates based on equation (1) by using only the Consumer Reports sample cars for comparison.

In these estimations, we use the estimated inverses of City MPG of the 1973 and 1979 vintage cars that are esimated in the following way. First, following Wilcox (1984), we regress the inverted City MPG of the 1974-78 vintage cars on their physical characteristics, constant and vintage dummies

(R^2 is .857). Then we estimate the inverted City MPG of these two vintage cars by using their physical characteristics and the estimated coefficients of the characteristics and vintage dummies in the above regression, on the assumption that the 1973 vintage (the 1979 vintage) has the same technology level in transforming the physical characteristics to MPG as the 1974 vintage (the 1978 vintage).

We list two estimates for 1974-75 in Table 5. One is based on the regression for 1972-75 and the other is based on the one for 1974-77. The latter estimate is more reliable, because the age structure of its sample is more desirable. Actually the two estimates are not significantly different from each other judging from their standard errors.

Similarly we list two estimates for 1980-81 in these tables. One estimation pools the years 1977, 1978, 1980 and 1981. The other pools 1978, 1979, 1980 and 1981. We will call the former pool of the years the pool B and the latter the pool C. We consider the pool B because of the following reason. The year 1979 was in the midst of the second oil shock, as is seen in the CPI of gasoline in Table 4, and the 1979 car market might not be adusted well enough to the shock. So the pool B omits the 1979 car market that might be in diequilibrium, because that market will not provide us with the estimated parameters of hedonic equations that can apply to the other years. We use the pool C only to fill in the annual percentage changes from 1978 to 1979 and from 1979 to 1980.

We list the estimates based both on the unweighted and the weighted regression with sales (actually production level) as weight. We will call the corresponding hedonic indexes the "unweighted index" and the "weighted index." The weighted index represents the market price movement better, as was stated before.

Judging from the standard errors of the estimates, there are no significant differences between the estimated percentage changes of the unweighted indexes and those of the weighted indexes, except for the 1973-74 difference of the estimates based on all the sample (that is, not restricted to Consumer Reports MPG availability) in Table 5A. Even for this, the difference (4.4 percent) is just significant (the sum of the standard errors of the estimated indexes is 4.4 percent). The difference is also large (6.6 percent) for this 1973-74 period between the unweighted and the weighted percentage changes of N2-index (Table 6), but this difference is not significant. On the whole, we may conclude that the estimated percentage changes are not significantly different between the unweighted and the weighted indexes.

Comparing Tables 5 and 5A, we note that the omission of the gasoline cost variables does not affect the estimated percentage changes in the T-index significantly for the periods examined 1970-77, except for 1974-75. The omission affects them significantly for 1974-75, if we use the sample cars of ages one and two years. But even for this period, the omission does not affect them if we use the sample cars of ages two to four years. As was stated before in section 2, the estimates using the latter sample cars are more reliable. On the whole, we may say that the omission of the gasoline cost variables does not affect the estimated percentage changes in the T-index for the periods examined.

Table 5A gives us an example about the effect of changing the sample size and structure on the estimated percentage change in the hedonic indexes. By comparing the estimates obtained by using the Consumer Reports sample cars with those by all the sample cars, we note that they are significantly different in the following three periods, judging from their standard errors. They are 1973-74 (weighted index), 1974-75 (both weighted and unweighted, using the sample cars of ages one and two years) and 1975-76(weighted). The difference is the largest for 1973-74 (10 percent, with the sum of the standard errors of 4.8 percent).

Thus the sample size and structure affects the estimates rather strongly. This is reasonable because the Consumer Reports sample and all the sample represent different segments of the car market. The Consumer Reports sample are inexpensive cars that sell well. All the sample encompasses wide market segments, as was stated in section 3. But also note that the direction of the hedonic index movement is the same, on the whole, between the two samples.

Let us compare the estimated percentage changes of the weighted T-index (Table 5) with those of the CPI of used cars (Table 4). Our used car price data are taken from the April issue of the N.A.D.A. Guide. They will be the averages of the reported transaction prices a little before April. So we will list the average January-March annual percentage changes of the CPI as well as the April ones.

Roughly speaking, our T-index moves in line with the CPI. But the size of the movement itself is often significantly different between the two from the viewpoint of the standard error of our estimated percentage changes in the T-index. T-index increases significantly while the CPI decreases from 1971 to 1972 and then CPI increases significantly more than T-index from 1972 to 1973. Again T-index increases significantly while the CPI decreases from 1973 to 1974 and then the CPI increases significantly more than T-index from 1974 to 1975. The CPI increases significantly more than T-index from 1976 to 1977 and then it decreases significantly more from 1977 to 1978. CPI increases significantly more from 1978 to 1979 and in all the annual comparisons from 1980 to 1983.

Thus the cases where the CPI increases significantly more than our T-index are more in number than the opposite cases, and the CPI increases more than T-index by 26.0 percent in total from 1970 to 1983. Also the examination of their annual percentage changes reveal that the magnitudes of fluctuation are larger in the CPI than in T-index.

Now we will look at the estimated changes in the N-index in Table 6. The estimates are obtained only for the two oil shock periods, as was explained in section 2. For the first oil shock in 1973, we pool the years 1972, 1973, 1974 and 1975 in one regression. The physical characteristics coefficients are constrained to be constant over these four years, but the gasoline cost parameters β, γ and ε are treated to change between the former two years (1972, 1973) and the latter two years (1974, 1975). In the N1-regression, the gasoline cost parameters are treated to increase in absolute value between the two subperiods (1972-73 and 1974-75) by the same rate of increase of the CPI of gasoline between 1973 and 1974 (.418).

In the N2-regression, the proportional rate of increase of the gasoline cost parameters, σ, are estimated. The estimate of $1+\sigma$ is 6.797 (7.067) in the unweighted N2-regression and is 1.202 (.122) in the weighted N2-regression (standard errors of the estimates in the parentheses). The difference between the two estimates of $1+\sigma$ is very large but is not significant from the viewpoint of their standard errors. Especially the unweighted estimate of $1+\sigma$ is very unreliable. The weighted regression yields its better estimate. The weighted estimate of $1+\sigma$ is smaller than the corresponding rate of the CPI of gasoline (1.418), although the difference is barely insignificant. This implies that consumers did not extrapolate the gasoline price increase of the first oil shock into the future: Rather they expected its small decline in the future, although the expectation was not significant.

Reflecting the above difference in the estimates of σ, the weighted N2-index increases less than the unweighted N2-index from 1973 to 1974. The difference in the estimated percentage increases is large, but is not significant because of the large standard error of the latter estimate. Also reflecting the above relation between the weighted estimate of σ and the CPI of gasoline, the weighted N2-index increases less than the weighted N1-index from 1973 to 1974, although the difference is insignificant.

As for the second oil shock period, we consider two pools of years, B and C, that we explained before. We devide the pool B of years into the pre-shock subperiod 1977-78 and the post-shock subperiod 1980-81. The rate of increase of the gasoline cost parameters between the two subperiods, σ, is set equal to the rate of increase of the CPI of gasoline from 1978 to 1980 (.979) in the N1-regression. The estimate of $1+\sigma$ is 3.828 (.808) in the unweighted N2-regression and is 5.020 (1.266) in the weighted N2-regression. These estimates of $1+\sigma$ are not significantly different from each other, but is significantly larger than the corresponding rate of the CPI of gasoline (1.979). The latter finding will reflect the consumers' extrapolation of the gasoline price rise in the second oil shock into the future.

Owing to this extrapolation, the N2-index increases significantly more than the N1-index from 1978 to 1980. This is one of our main findings. The percentage increases of N2-index and those of N1-index are not significantly different from each other from 1977 to 1978 and from 1980 to 1981.

We did the pool C just to fill in the estimated annual increases of the indexes from 1978 to 1979 and from 1979 to 1980. We devide the years of the pool C into the 1978-79 and 1980-81 subperiods. The big increase of N-indexes from 1978 to 1980 occurred mostly in a year from 1979 to 1980. The difference in the estimated percentage changes between the N1-index and N2-index is not evident between 1979 and 1980 but is significant between 1978 and 1979 and between 1980 and 1981. This would be because the 1979 car market will not provide us with the estimated parameters of hedonic equations that can apply to the adjacent years as was explained before. In other words, we should not pool 1979 with other years, but we had better omit it as in the pool B. Therefore we rely on the results of the pool B rather than those of the pool C.

Finally we compare the percentage changes of the T-index (Table 5) with those of the N-indexes (Table 6). The N-indexes increase significantly much higher than T-indexes in the two oil shock years 1973-74 and 1978-80 (or, more narrowly, 1979-80), as is expected theoretically in section 2. This is our major finding. The difference between the two indexes are more evident in the second oil shock years than in the first. That is, the second shock affected the car market more strongly. Apart from these two shock years, the percentage changes of N-indexes are not significantly different from those of T-indexes, on the whole, for the periods examined, with only a few exceptions. Even these exceptions are only barely significant.

5. CONCLUSION

We conclude the paper by summarizing the empirical results. Our main findings are as follows. (a) N-index increases significantly much higher than T-index in both of the two oil shock periods 1973-74 and 1978-80 (or, more narrowly, 1979-80). The difference between the two indexes is larger in the second shock. (b) Consumers did not extrapolate the gasoline price rise into the future in the first oil shock, but they did it significantly in the second shock. So the percentage increase of N2-index is not significantly different from that of N1-index in the first oil shock, but it is significantly larger than that in the second shock. These findings (including the latter half of (a) above) imply that the second shock affected the used car market more strongly than the first one. This is consistent with the finding of Ohta and Griliches (1983).

Other findings are as follows. (a) T-index moves roughly in line with the CPI of used cars. But the CPI fluctuated more in magnitude and increased more from 1970 to 1983 by 26 percent in total than T-index. (b) The estimated percentage changes in T-indexes are not affected significantly by the omission of the gasoline cost variables. These variables become important in the construction of N-indexes. (c) The unweighted index and the weighted index are not significantly different from each other. This is true both for T-index and for N-index. (d) Sample size and its structure affect the estimates of the indexes somewhat strongly.

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Footnotes

1. Kahn (1984) assumed that the length of the car life is 10 years, that the mileage driven is 10,000 per year and that the annual interest rate is .05 for all his sample cars to calculate g. This might be relevant for his sample, because he limits the sample to a relatively homogenous class of passenger cars. But it is not so for our sample which encompasses very wide segments of the passenger car market.

2. We used the 1977-79 vintage cars as sample for the 1981-82 period and the 1978-80 vintages for 1982-83. We computed the F-statistic in the seemingly unrelated regression (SUR) as a formal test, since the sample cars are fixed in each test and the omitted characteristics cause the large covariance of the disturbance between the regression equations of the two adjacent years in each test. The SUR's F-value is 7.12 with 9 and 776 degrees of freedom for 1981-82 and is 40.98 with 9 and 820 degrees of freedom for 1982-83. These values are much larger than the conventional critical value at the one percent level. But as sample becomes large in the large sample, the F-value becomes large so that the null hypothesis becomes almost always rejected (Arrow 1960, Zellner 1971, Leamer 1978). To avoid this situation, Leamer (1978) proposed a Bayesian critical value which increases the significance level as sample becomes large. This critical value is about 7 with the present degrees of freedom. So the null hypothesis is rejected slightly in the 1981-82 and rather strongly in the 1982-83 period. But as Leamer himself pointed out, the derivation of his critical value is based on strong assumptions such as sample dominance, we rely more on our informal ΔSER criterion as a practical test than the Bayesian F-test of Leamer.

3. Still another type of price index that takes fuel costs into account is proposed and applied to commercial aircraft by Gordon (1983). This is the input price index of aircraft to obtain the same real net revenue both at the base period and at the comparison period.

4. This is pointed out also by Triplett (1983).

5, 6. See the empirical results of their prediction method and the omitted variable approach.

Table 1. The Sample

Vintage	No. of Obs.	Years When Used Car Prices Available
1966	64	1970*, 71*
67	63	70*, 71*
68	62	70*, 71*,74
69	60	70*, 71*,74,75
1970	126	1971-76
71	124	72-77
72	119	73-78
73	113	74-79
74	111	75-80
1975	117	1976-81
76	123	77-82
77	122	78-83
78	136	79-83
79	144	80-83
80	143	81-83
81	114	82-83
82	106	83

NOTE: * denotes Central Edition used car prices and those without * are taken from New England Edition of N.A.D.A.

Table 2. Unweighted Regression for 1977, 1978, 1980 and 1981

Estimated Coefficient of	T-regression	N1-regression	N2-regression
Constant	8.558	8.193	8.174
	(.065)	(.067)	(.065)
T_{1977}	.030	.012	.003
	(.014)	(.013)	(.013)
T_{1980}	.030	.264	.361
	(.016)	(.021)	(.044)
T_{1981}	.172	.435	.513
	(.022)	(.018)	(.035)
D_3	-.156	-.188	-.199
	(.021)	(.020)	(.016)
D_4	-.342	-.359	-.391
	(.047)	(.042)	(.029)
CID[a]	.112	.205	.195
	(.019)	(.019)	(.017)
NOC	-.001	-.015	-.014
	(.008)	(.008)	(.007)
WT[b]	.011	.025	.023
	(.014)	(.014)	(.014)
WBW[c]	-.056	-.089	-.083
	(.012)	(.011)	(.011)
NOD2	.030	.048	.049
	(.012)	(.012)	(.012)

(Table 2-Continued)

NOD5	.009	.012	.008
	(.016)	(.015)	(.015)
AT	-.031	-.041	-.043
	(.019)	(.019)	(.019)
PS	.137	.194	.182
	(.022)	(.023)	(.022)
AC	.349	.379	.368
	(.027)	(.028)	(.028)
$1/(MPG \cdot \hat{P})$	-26201	-6393	-5835
	(3296)	(1194)	(1205)
$Age/\hat{P}$	-218	97	38
	(45)	(37)	(19)
$Age/(MPG \cdot \hat{P})$	5618	-720	-21
	(835)	(239)	(176)
Est. of $1+\sigma$[d]	1	1.979	3.828
	(—)	(—)	(.808)
R^2	.788	.797	.798
SER[e]	.173	.170	.169

[a]In 100 cubic inches. [b]In 1000 pounds. [c]In 1000 square inches. [d]$1+\sigma$ is estimated only for N2-regression. These values are extrapolated for the other regressions. [e]Standard error of regression.

(Table 2-Continued)

NOTE: Dependent variable is log of used car price P. Standard errors of estimates are shown in the parentheses. 1978 is the base of the year dummies. Age 2 is the base of the age dummies. City MPG is used as the MPG data. Sample vintages are 1973-75 for 1977, 1974-76 for 1978, 1976-78 for 1980 and 1977-79 for 1981 so that the ages of sample cars are 2, 3 and 4 in each year. Number of observations is 1470 for each regression.

Table 3. Weighted Regression for 1977,1978,1980 and 1981

Estimated Coefficient of	T-regression	N1-regression	N2-regression
Constant	8.263	7.896	7.898
	(.065)	(.067)	(.065)
T_{1977}	.004	-.008	-.021
	(.013)	(.012)	(.012)
T_{1980}	.024	.235	.318
	(.015)	(.019)	(.043)
T_{1981}	.183	.438	.508
	(.022)	(.017)	(.033)
D_3	-.152	-.220	-.235
	(.020)	(.019)	(.013)
D_4	-.310	-.421	-.463
	(.045)	(.039)	(.021)
CID[a]	.096	.210	.197
	(.018)	(.017)	(.015)
NOC	.021	.005	.006
	(.007)	(.007)	(.007)
WT[b]	.009	.023	.023
	(.014)	(.013)	(.013)
WBW[c]	-.032	-.070	-.069
	(.013)	(.012)	(.012)
NOD2	.056	.075	.082
	(.011)	(.011)	(.011)

NOD5	-.005	.009	.002
	(.018)	(.017)	(.017)
AT	-.016	-.031	-.030
	(.016)	(.015)	(.015)
PS	.058	.132	.128
	(.020)	(.020)	(.019)
AC	.339	.366	.374
	(.027)	(.028)	(.029)
$1/(MPG \cdot \hat{P})$	-23105	-6214	-4146
	(3216)	(1119)	(1114)
$Age/\hat{P}$	-260	126	51
	(43)	(35)	(19)
$Age/(MPG \cdot \hat{P})$	5156	-791	-121
	(793)	(224)	(142)
Est. of $1+\sigma$[d]	1	1.979	5.020
	(—)	(—)	(1.266)
R^2	.814	.821	.824
SER	.159	.156	.154

NOTE: See the footenotes a, b, c and d, and NOTE of Table 2.

Table 4. Percentage Increases in the CPI

(%)

Years Compared	Percentage Increases in the CPI of				
	All Items April	Gasoline April	New Car April	Used Car April	Used car Jan.-March Average
1970-71	4.3	-2.7	3.8	10.6	8.9
71-72	3.4	1.3	-1.8	-3.1	-2.2
72-73	5.1	8.4	-.5	10.2	8.6
73-74	10.2	41.8	2.0	-5.6	-7.9
74-75	10.1	.9	12.5	24.8	29.4
75-76	6.1	5.2	5.4	15.4	9.1
76-77	6.8	9.2	4.6	17.8	22.5
77-78	6.6	1.7	7.5	-5.6	-5.1
78-80	26.6	97.9	17.1	10.9	14.8
78-79	10.4	23.8	8.7	12.8	13.7
79-80	14.7	59.9	7.7	-1.7	.9
80-81	10.0	11.9	5.1	21.6	19.7
81-82	6.6	-12.5	5.3	19.2	19.5
82-83	3.9	.2	2.6	9.7	10.5

NOTE: Seasonally unadjusted. CPI for all urban wage earners and clerical workers till 1978. CPI for all urban consumers after 1978.

Source: U.S. Bureau of Labor Statistics, The Consumer Price Index.

Table 5. Percentage Increases in the T-index: Based on Regression Including the Gasoline Cost Variables

Years Compared	Vintages Used	No. of Obs.	Type of MPG Used	Percentage Increases in T-index (%) Unweighted	Weighted
1970-71	70(67-69)	127	Consumer	16.6	10.9
	71(66-68)		Reports	(4.6)	(4.5)
71-72	71(70)	250	Without	8.0	7.8
	72(71)		MPG[a]	(1.6)	(1.4)
72-73			Consumer	5.6	3.8
	72(70-71)		Reports	(2.4)	(2.6)
73-74	73(71-72)	168		4.3	5.6
	74(72-73)			(2.5)	(2.4)
74-75	75(73-74)			9.3	10.4
				(3.0)	(2.9)
74-75			Consumer	16.0	12.7
	74(70-72)		Reports	(4.2)	(4.0)
75-76	75(71-73)	244		13.1	13.0
	76(72-74)			(4.0)	(3.6)
76-77	77(73-75)			1.5	.6
				(3.0)	(2.7)
77-78			City[b]	-3.0	-.4
	77(73-75)			(1.4)	(1.3)
78-80	78(74-76)	1470		3.0	2.4
	80(76-78)			(1.6)	(1.5)
80-81	81(77-79)			14.1	15.9
				(1.7)	(1.5)

78-79			City[c]	2.4	3.5
	78(74-76)			(1.5)	(1.4)
79-80	79(75-77)	1491		-.7	-3.0
	80(76-78)			(1.3)	(1.2)
80-81	81(77-79)			14.3	15.3
				(1.7)	(1.6)
81-82	81(77-79)		Combined	13.5	15.8
	82(78-80)	1223		(1.5)	(1.4)
82-83	83(79-81)			4.6	4.1
				(1.2)	(1.1)

[a]Regression based on text equation (1) that excludes the gasoline cost variables, because otherwise the sample is too small. [b,c]The inverses of the City MPG of the 1973 and 1979 vintage cars are estimated by using the estimates obtained from regressing the inverted City MPG of the 1974-78 vintage cars on their physical characteristics, constant and vintage dummies, and assuming that the 1973 vintage (the 1979 vintage) has the same technology level in transforming the physical characteristics to MPG as the 1974 vintage (the 1978 vintage).

NOTE: Regression based on text equation (4) which includes the gasoline cost variables, except for 1971-72 (see footnote a above). The vintages of the sample cars used in the regression are shown in the form YY(VT1-VT2). This means that the vintages from VT1 to VT2 are used as sample cars for the year YY in the regression. For example, 74(70-72) means that the cars of the

(Table 5-Continued)

1970-72 vintages are used as sample for 1974. The table shows which years are pooled in one regression by the horizontal lines between the columns "Vintages Used" and "Type of MPG Used". For example, 1974, 1975, 1976 and 1977 are pooled in one regression. Standard errors of the estimates are shown in the parentheses.

Table 5A. Percentage Increases in the T-index: Based on Regression Excluding the Gasoline Cost Variables

Years Compared	Vintages Used	No. of Obs.	Sample Range[a]	Percentage Increases in T-index (%) Unweighted	Weighted
1970-71	70(67-69)	127	Consumer	11.5	10.9
	71(66-68)		Reports	(2.0)	(1.7)
72-73			Consumer	6.5	6.0
	72(70-71)		Reports	(2.4)	(2.5)
73-74	73(71-72)	168		7.7	8.8
	74(72-73)			(2.4)	(2.3)
74-75	75(73-74)			15.9	17.5
				(2.3)	(2.0)
74-75			Consumer	16.9	18.2
	74(70-72)		Reports	(2.8)	(2.6)
75-76	75(71-73)	244		13.6	17.1
	76(72-74)			(2.9)	(2.5)
76-77	77(73-75)			1.5	.5
				(3.0)	(2.7)
70-71	70(67-69)	374	All	10.8	10.8
	71(66-68)			(1.3)	(1.2)
71-72	71(70)	250	All	8.0	7.8
	72(71)			(1.6)	(1.4)
72-73			All	6.1	6.1
	72(70-71)			(1.8)	(2.6)
73-74	73(71-72)	947		4.2	-.2
	74(72-73)			(1.9)	(2.5)

74-75	75(73-74)			10.9	10.8
				(1.9)	(2.4)
74-75			All	18.9	18.5
	74(70-72)			(1.5)	(1.9)
75-76	75(71-73)	1409		12.3	11.4
	76(72-74)			(1.6)	(1.8)
76-77	77(73-75)			2.9	2.6
				(1.6)	(1.8)

[a]"Consumer Reports" in this column indicates that the regression uses only those sample cars whose MPG data are available in Consumer Reports. "All" indicates that the regression uses all the sample cars of the vintages shown in the "Vintages Used" column.

NOTE: Regression based on text equation (1) which excludes the gasoline cost variables. See NOTE of Table 5 for the explanation of the table format.

Table 6. Percentage Increases in the N-index

Years Compared	Range of Pool[a]	Percentage Increases in N1-index (%) Unweighted	Weighted	N2-index (%) Unweighted	Weighted
1972-73	A	4.7	3.6	6.3	3.4
		(2.4)	(2.6)	(2.3)	(2.6)
73-74		17.5	20.5	20.2	13.6
		(4.2)	(4.3)	(13.2)	(5.8)
74-75		9.5	9.6	13.6	8.6
		(3.3)	(3.2)	(3.2)	(3.2)
77-78	B	-1.2	.8	-.3	2.1
		(1.3)	(1.2)	(1.3)	(1.2)
78-80		26.4	23.5	36.1	31.8
		(2.1)	(1.9)	(4.4)	(4.3)
80-81		17.1	20.3	15.2	18.9
		(1.7)	(1.6)	(1.7)	(1.6)
78-79	C	4.1	5.5	8.6	10.7
		(1.4)	(1.3)	(1.4)	(1.3)
79-80		16.7	14.5	18.9	12.9
		(2.5)	(2.4)	(4.4)	(4.4)
80-81		13.4	15.1	17.2	20.2
		(1.7)	(1.6)	(1.7)	(1.5)

[a]This column shows the range of years that are pooled in one regression. For example, the pool A shows that 1972, 1973, 1974 and 1975 are pooled in one regression.

(Table 6–Continued)

NOTE: Regression based on text equation (4) which includes the gasoline cost variables. Vintages used in the regression are as follows, using the notation in Table 5. For the pool A, 72(70-71), 73(71-72), 74(72-73) and 75(73-74). For B, 77(73-75), 78(74-76), 80(76-78) and 81(77-79). For C, 78(74-76), 79(75-77), 80(76-78) and 81(77-79). Type of MPG used in the regression is Consumer Reports MPG for the pool A and is City MPG for B and C. The Inverted City MPG of the 1973 and 1979 vintage cars are estimated in the same way as explained in the footenote b of Table 5. The number of observations is 168 for the pool A, 1470 for B and is 1491 for C. The estimate of $1+\sigma$ is 6.797 (7.067) in the unweighted N2-regression and is 1.202 (.122) in the weighted N2-regression for the pool A. They are 3.828 (.808) and 5.020 (1.266), respectively, for B. They are 4.501 (.988) and 6.276 (1.775), respectively, for C. The CPI of gasoline is 1.418 times as high in 1974 as in 1973, 1.979 times as high in 1980 as in 1978 and is 1.599 times as high in 1980 as in 1979. Standard errors of the estimates are shown in the parentheses.