European Economic Review forthcoming

# Asset Prices and Public Information: An Empirical Investigation in the Market for Automobiles*

by

Winand Emons
University of Basel
CH 4003 Basel, Switzerland**

and

Jürgen von Hagen
Graduate School of Business
Indiana University
Bloomington, IN 47405, USA

revised, August 1990

*We thank Helmut Bester, Richard Carlson, Vincent Crawford, Martin F. Hellwig and an anonymous referee for valuable comments.

**Financial support by the Deutsche Forschungsgemeinschaft through SFB 303 and Research Grant Em 39/1-1 and the hospitality of the Department of Economics at the University of California San Diego are gratefully acknowledged.

Asset Prices and Public Information:
An Empirical Investigation in the Market for Automobiles

by

Winand Emons

and

Jürgen von Hagen

Abstract

This paper examines the impact of public quality information on the structure of equilibrium prices in a consumer durables market. We model the link between prices and an observable quality index on the basis of the user cost approach. Using cross section data of the West German automobile market we show that the hypothesis of information efficiency cannot be rejected.

Keywords: Information efficiency, user cost, seemingly unrelated regressions

Journal of Economic Literature Classification Numbers: 026, 227, 611, 631

Correspondence:

Jürgen von Hagen
Graduate School of Business
Indiana University
Bloomington, IN 47405

Winand Emons
Institut für Volkswirtschaft
Universität Basel
Petersgraben 51
CH-4003 Basel

## I. Introduction

A number of studies (e.g., Bulow (1982), Parks (1979), Rust (1985), Stokey (1981)) have recently pointed out the close relationship between consumer durables prices and financial asset prices implied by the user cost approach to the pricing of durables. Standard models of financial asset markets hold that financial asset prices depend on investors' expectations of future income streams. Similarly, the user cost approach implies that durables prices depend on expected future service flows and expected maintenance cost. In the financial markets literature, the central role of expectations in price formation has led economists to analyze the problem of market efficiency, i.e., the question whether equilibrium prices correctly reflect all relevant information about future income streams available in the market. With a similar role of expectations in the pricing of durables, a similar question can be asked: Here, the efficient markets hypothesis implies that equilibrium prices reflect all available information about future service flows and maintenance cost. As in the case of financial asset markets, this yields a potentially testable hypothesis.

The purpose of this paper is to present such a test. We consider an automobile market where new and used cars are traded and where public information about the average reliability of all cars of the same vintage class and make is available. Our analysis is similar in spirit to Bresnahan and Yao (1985). If cost-of-maintenance expectations are rationally based on published quality information, the user cost approach implies that the structure of observed quality data induces a distribution of the equilibrium prices in the market. This basic conjecture about the equilibrium distribution of prices is tested empirically using West German cross-section data for 1984 and 1985. We find that the distribution of published quality data contributes significantly to explaining the empirical distribution of prices in the German automobile market.

To avoid misunderstandings, let us stress at the outset that we neither present an empirical representation of a complete pricing model, nor do we merely infer a relationship between quality data and car prices. Instead, we apply the user cost approach to derive a relationship between expected price changes of durables over time and maintenance cost that owners should expect on the basis of observable quality information.

The paper is organized as follows. Section II presents a user cost model of automobile prices. Section III describes the data used in the test. Section IV reports the empirical results. The main conclusions are summarized in the final section.

## II. The Model

Consider an automobile market where new and used cars of different types are available. For each type j, $j=1,\ldots,J$, we consider $t = 0,2,\ldots,T_j$ vintage classes, where the index t refers to the age of a car and $t = 0$ denotes new cars. In view of the empirical analysis below, we consider only two-year vintage classes. Call the set of vehicles of type j and vintage class t group jt of cars. Within each group, $n_{jt}$ cars are traded, indexed by $i = 1,\ldots,n_{jt}$. Subsequently, we drop the index j where possible to simplify the notation.

We assume the automobile market to be in equilibrium such that prices equate demand and supply within all groups.[1] Prices in the market are determined according to the user cost approach to consumer durables, which holds that consumers derive utility from the flow of transportation services provided by a car rather than from the car itself. A consumer's demand for transportation services, therefore, depends on the user cost or rental price of such services.[2] The equilibrium price of a car is determined by the condition that the expected cost of owning it for a given period of time be equal to the equilibrium rental price of the services it provides during that period. Since transportation services identically valued by all consumers cannot have different rental prices in equilibrium, the prices of cars providing identical transportation services must give rise to the same rental price. This reasoning allows us to base our analysis on a simple model of equilibrium prices rather than model demand and supply within each group explicitly.[3]

In this section, we will derive the cost of holding a car for a period of two years, chosen in view of the empirical data used below. A consumer purchases a vehicle i at a price $p_{it}$ today and expects to sell it in two years time at the expected price $Ep_{it+2}$. We define $Ep_{it+2}$ such that the expected price has been adjusted for the expected increase in the overall automobile price level, and assume that inflation expectations are the same for all consumers. During the two years of owning it, the consumer incurs a cost of maintenance to keep the car well functioning. The expected cost is denoted by $EC_{it}$ and is again defined in real terms. We normalize $C_{it}$ so as to accrue at the end of the holding period. Finally, let r be the relevant real rate of interest, i.e., the nominal rate corrected for expected inflation in automobile prices, and let $\delta = (1+r)^{-2}$ be the discount factor for the two year holding period. The expected cost of holding a vehicle i is the sum of the expected capital loss and the expected cost of maintenance during that period, i.e., $p_{it} - \delta Ep_{it+2} + \delta EC_{it}$.

We assume that all consumers consider the flow of services provided by cars of the same group as equivalent. Consumers comparing cars of the same group need not take into account transaction cost, cost for gasoline, insurance, etc., because these expenses accrue regardless of which car they buy out of this group. Accordingly, only the cost of holding a car is relevant for deciding which specific vehicle to buy out of a group. Let $\gamma_t$ denote the implicit rental price of the service flow for a group of vehicles. Given an expected resale price after two years and an expected cost of maintenance, the price $p_{it}$ must equalize the expected cost of holding the car with that group's implicit rental price:

$$\gamma_t = p_{it} - \delta E p_{it+2} + \delta E C_{it} \qquad \text{for all i.} \tag{1}$$

For each type of automobiles, implicit rental prices across different vintage classes are connected through economic depreciation, which includes both the physical decay of a car and the loss of novelty effects that might lead consumers to value services of new cars higher than similar services by used cars. This yields

$$\gamma_t = \rho_t \gamma_{t-2} \qquad t=2,4,\ldots,T, \tag{2}$$

where $\rho_t$ is the economic depreciation factor.[4] Equations (1) and (2) together imply that automobile prices of different vintage classes of the same type are related through the depreciation factors.

Let us now turn to the formation of consumer expectations. Each consumer bases his expectations on two different kinds of information, namely general information observable by all agents and individual information. Each consumer observes the current average price $p_{t+2}$ of all vehicles of the same type which are two years older than the car he considers to buy. Assuming that consumers do not expect shifts in relative prices over the next holding period, his expected average resale price adjusted for inflation then is $p_{t+2}$, i.e., the same as the current price of cars of the same type in the next vintage class. Furthermore, a consumer knows how he will handle his car during the next two years, i.e., how much he expects to drive it, under what conditions, etc. This gives rise to an expected individual deviation $\epsilon_{it}$ from the expected average price in two years time. A consumer's resale price expectation is, therefore,

$$E_i p_{t+2} = p_{t+2} + \epsilon_{it}. \quad (3)$$

Individual rationality on behalf of all consumers requires

$$n_t^{-1} \sum_{i=1}^{n_t} \epsilon_{it} = 0 \qquad \text{for all } t=2,4,\ldots,T-2, \quad (4)$$

i.e., expected individual deviations must be zero on average.

Similarly, consumers have both public and private information to forecast the cost of maintenance for a vehicle. Public information in the market consists of two elements. The first is the general reputation of the various brands in the market. Formally, brands are a partition $J_l$, $l=1,\ldots,L$, of the index set $\{1,\ldots,J\}$ of vehicle types, where each subset $J_l$ is the collection of all types belonging to one brand. The brand effect on cost expectations captures the notion that different brands in the market can have the reputation of high or low reliability in general, which leads consumers to expect lower or higher than average maintenance cost. It will be represented by indicator variables $D_l$ in the consumers' expectation function, with $D_{lj} = 1$ if $j \in J_l$, and $D_{lj} = 0$ otherwise.

The second piece of public information is the more interesting one in our analysis. We assume that all consumers observe a regularly published index of the technical quality and condition of the entire current fleet of vehicles in the market. Specifically, let $q_{t+2}$ be a quality index of all vehicles currently in group (t+2), such that $q_{t+2} \in [0,1]$ denotes the fraction of cars within that group that did not meet a well-defined technical standard in the previous holding period and therefore needed some costly repair in order to be maintained.[5] If market conditions are stationary, the buyer of a vehicle in a group today can translate this index into the probability that his vehicle will suffer a corresponding technical problem during the holding period to come and will therefore require a costly repair. Given the (expected) cost of a future repair of a vehicle, the expected cost of maintenance then increases with an increase in the observed index $q_{t+2}$. Consequently, if consumers in the market use the published information in a rational way, average expected maintenance cost expectations are positively related to the observed quality index.[6]

As a simple approximation we assume that the expectations function is additive in the brand effect, the quality index effect, and the impact of individual information on cost expectations. We normalize expected average maintenance cost of a vehicle in a group by the implicit rental price of a new car of the same type, $\gamma_0$, to account for the common observation that the repair cost and the value of new cars are positively correlated. This gives rise to the following expectations function

$$E_i C_{it} = \gamma_0 (H_t(q_{t+2}) + G_{lt}(D_l)) + \xi_{it} \qquad (5)$$

where $\xi_{it}$ is buyer i's deviation from the average expectation arising from, e.g., his knowledge of individual handling of his car, or some individual information about its past performance. As before, individual rationality of all consumers requires $\xi_{it}$ to be zero on average within each group. The first term of the expected cost function has a positive derivative

$H_t^{'} > 0$, which is assumed to be constant across types, but not necessarily across vintages. Finally, $G_{lt}^{'} \geq 0$ (<0) represents a brand reputation that is worse (better) than average.

Using (1) - (5) and taking averages for each group, we can now state the implicit rental price of vehicles in a group in terms of average prices and expectations

$$\gamma_t(1 - \pi_t\delta(H_t(q_{t+2}) + G_{lt}(D_l))) = p_t - \delta p_{t+2} \qquad (6)$$

with $\pi_0 = 1$ and $\pi_t = \pi_{t-2}\rho_t^{-1}$ for t=2,4,...,T. Equation (6) states the equilibrium relation between published quality information and expected capital losses. It may be interpreted as follows: Let two types of cars, say j and j', be perfect substitutes so that their rental prices are the same within each vintage class. Suppose, further, that from the second holding period on both types are of exactly the same quality. Then buyers of two year old cars of both types expect the same maintenance cost and thus have to pay the same price. Finally, suppose that $q_{j2} < q_{j'2}$, i.e., the published information signals better quality for type j than for j' for the first holding period. This means higher expected maintenance cost for type j' during the next holding period. Equation (6) then says that $p_{j0} > p_{j'0}$. Since consumers are indifferent between the services provided by both types, cars of type j' have to incur lower expected capital losses to compensate the buyers for the higher expected maintenance cost.

From (6) we obtain the following relation between equilibrium prices and expectations across vintages of cars of the same type:

$$\frac{p_t - \delta p_{t+2}}{p_{t+2} - \delta p_{t+4}} = \frac{1 - \pi_t\delta(H_t(q_{t+2}) + G_{lt}(D_l))}{\rho_{t+2}[1 - \pi_{t+2}\delta(H_{t+2}(q_{t+4}) + G_{lt+2}(D_l))]}. \qquad (7)$$

Equation (7) highlights the basic empirical contention of this paper: the user cost approach, together with the assumption of rational use of public information by all consumers, implies that the structure of observed quality indices induces a distribution of equilibrium prices in the market. Given the economic rate of depreciation and the general reputation effect of a brand, the ratio of expected average equilibrium capital losses from holding cars of two vintages t and t+2 is determined by the quality indices observed by all consumers in the market. The empirical distribution of published quality indices should therefore contribute significantly to explain the distribution of equilibrium capital losses and, thereby equilibrium prices in the market. This hypothesis will be tested empirically in the remainder of the paper.

## III. The Data

All passenger cars registered in West Germany have to be presented every second year at a technical surveillance agency called "Technischer Uberwachungsverein" (TÜV). The TÜV checks more than 100 parts of each car which are related to the safety condition of an automobile. The purpose of the examination is to assure that the car will meet a number of well defined safety and technical standards over the next two years. Only when the TÜV testifies that the car is in a technically good shape, is one allowed to drive it for another two years. Formally, this is documented by a TÜV sticker fixed on the license plate which expires after two years. If the TÜV refuses to confirm good technical condition, the owner is provided with a list of complaints which enumerates the required repairs and the car must be presented again.

The results of the technical checks are collected by the TÜV and are published annually for the main vehicle types.[7] For each type j, j = 1,...J,
k

the TÜV reports a collection of quality indices grouped by vintages, $q_t$. The most important indices are:

$q_t^1$ - fraction of automobiles of group jt (f.o.a.) which had a broken or corroded running gear

$q_t^2$ - f.o.a. with defects in the wheel suspension,

$q_t^3$ - f.o.a. with defects in the main braking system,

$q_t^4$ - f.o.a. with defects in the hand braking system,

$q_t^5$ - f.o.a. with corroded brake lines,

$q_t^6$ - f.o.a. with defective headlights, and

$q_t^7$ - f.o.a. which did not meet emission standards.

An overall index $q_t^0$ summarizes the information by giving the f.o.a. with at least one of the possible defects.[8]

The TÜV data are published in spring or early summer. They are sold in the form of a booklet at a (negligible) price of DM 6 that is available in bookstores and at newspaper stands. When the new data comes out, it is reviewed and advertised in major popular journals and other media. Accordingly, it is safe to assume that potential buyers and sellers in the West German automobile market are aware of the latest TÜV data. Note that the data correspond to knowledge of the default ratio in the entire existing population of cars of each group .[9]

Most of the used cars in West Germany are traded when they have just passed the TÜV check. Therefore, the two year holding period considered above is a good approximation of West German market conditions.

Automobile prices are reported by make, model, technical equipment, and age in a monthly publication, "Schwacke-Liste", which, similarly to the TÜV data, can be considered to be available and known to buyers and sellers.[10]

The published prices are average sale and resale prices collected from professional car dealers across Germany. A survey we undertook among 50 randomly chosen dealers of various brands across the country suggests that the published average prices are well-known among dealers and clients and represent a reliable image of the German market.

By using dealer prices, we circumvent to some extent the 'lemons problem', first studied in a seminal paper by Akerlof (1970). Akerlof analyzes the situation where sellers know the quality of their cars, whereas buyers only know the average quality of all cars but not the quality of an individual vehicle. This asymmetric information causes the average quality of those cars which are actually traded to be lower than the average quality of all cars in the economy. It is reasonable to assume that car dealers are able to discern the individual quality level of the car they intend to buy. Furthermore, reputation effects, warranties on used cars, etc., make the risk of buying a 'lemon' from a dealer smaller than from a private party. Therefore, we expect that the average quality of the cars traded via dealers is not much lower than the average quality of the cars in the whole economy.[11] Finally, the downward bias in average market prices due to the 'lemons problem' would not distort our empirical results since we deal with expected relative capital losses across the market rather than absolute market prices. Note that car dealers act as intermediaries which buy from and sell to nonprofessional consumers. Accordingly, cars are not traded between professionals as is typically the case for financial asset markets.[12]

Our empirical analysis uses TÜV data for 73 types of 23 brands for 1984 and 1985. We consider three consecutive vintage classes t=0,2,4 of these types. The relevant quality indices are therefore $q_2^k$, $q_4^k$ and $q_6^k$. All indices are transformed into logits. The TÜV also reports the size of each group $N_{jt}$ in the economy. All data is weighted with the ratio of group size to total size of the automobile population of a given vintage class, $w_{jt} = N_{jt} / \Sigma_j N_{jt}$. Weights range from .004% to 3.2% with a mean of .5% in 1984 and from .01% to 3.3% with a mean of .5% in 1985.

Since the indices $q_t^k$, k=0,...,7, show a high degree of correlation among each other within each vintage class, we first consider the usefulness of the overall index $q_t^0$ as a summarizing statistic aggregating the information contained in the collection of all eight indices. For this purpose, factor analysis is applied to each set of indices of the same vintage class. For all three sets, and both years, the results are very similar. The first factor explains over 80%, the first and the second factors together over 90% of the total variation in the data. This indicates that the probabilities of a vehicle having faults of types k=0,...,7 are not independent. Most of the information contained in the set of indices can therefore be expressed by the two factors. Next, we estimate the correlation of the overall indices $q_t^0$, t=2,4,6, with the two factors of their respective index sets. The correlation coefficient was around .9 with the first and between -.3 and -.4 with the second factors and highly statistically significant in all cases. This means that $q_t^0$ conveys most of the information carried by the two factors. We therefore focus on the use of the overall indices, below. For notational convenience, we suppress the subscript k = 0 from now on.

For each type j=1,...,73, prices of different versions are reported in the Schwacke-Liste. Versions of one type differ in equipment and outfit but not in technical standards, so that the $q_t$ indices apply to all versions of a type. The detailed definition of alternative versions in the Liste, however, allows us to make sure that price differences over time and between vintages are not due to changes in equipment or outfit which would distort our results. We select prices of three different versions for each type. Prices in 1984 are corrected for inflation in automobile prices to achieve compatibility with 1985 prices using the automobile price index of the Federal Statistical Office. All price data are taken from the October issues of the Schwacke-Liste, to make sure that the prices reported are based on transactions that took place after the publication of the 1984 and 1985 TÜV reports.

Finally, assuming static inflationary expectations, the real interest rate r is computed from a nominal rate on government bonds with maturity of two years by subtracting the 1984 and 1985 automobile inflation rates. This results in a real rate of 2.2% for both years. Table 1 presents an overview of the price and quality data.

## IV. Empirical Results

To transform equation (7) into a regression model, we take logs on both sides and a linear approximation of the right hand side.[13] This yields

$$R_{jt} = a_{0t} + \sum_{l=1}^{L} a_{lt}D_l + a_{L+1,t}q_{jt+2} + a_{L+2,t}q_{jt+4} + u_{jt} \qquad (8)$$

where $R_{jt} = \ln(p_{jt} - \delta p_{j,t+2}) - \ln(p_{j,t+2} - \delta p_{j,t+4})$, $a_{0t} = -\ln\rho_{t+2}$, $a_{lt} = \delta(\pi_{t+2}g_{lt+2} - \pi_t g_{lt})$, $a_{L+1,t} = -\pi_t\delta h_t$, and $a_{L+2,t} = \pi_{t+2}\delta h_{t+2}$. $u_{jt}$ is the regression error and $h_t$ and $g_{lt}$ are coefficients of the linearized cost expectations function. The parameter $a_{0t}$ yields an estimate of the depreciation factor $\rho_{t+2}$. Given our assumption on $\delta$, if (8) is estimated for different vintages t, we can use the estimated depreciation factors to compute the $\pi_t$ coefficients and solve for the main parameters of interest, $h_t$.

We estimate a system of two equations, $R_{j0}$ and $R_{j2}$, involving prices of vintage classes 0, 2, 4, and 6 for each type of vehicle in our data set. Since $R_{j0}$ and $R_{j2}$ have the expected capital loss $p_{j2} - \delta p_{j4}$ in common, it is natural to expect that $u_{j0}$ and $u_{j2}$ be (negatively) correlated. Accordingly, we treat the system as a model of seemingly unrelated regressions and use Zellner's SUR estimator. Furthermore, consistency of the system requires that $\rho_2 a_{L+2,0} = - a_{L+1,2}$, since both parameters relate to the impact of the quality index $q_{j4}$ on the expected capital loss $p_2 - \delta p_4$. Note that our cross-section estimation now assumes that the depreciation factors are the same for all groups of cars of the same type. Although this assumption may seem theoretically unsatisfactory, the specification tests below would indicate if it is significantly violated empirically. Our model gives rise to the following a priori expectations about the signs of the coefficients: $a_{0t} \geq 0$, i.e., depreciation factors between zero and unity, and $a_{L+2,t} < 0 < a_{L+1,t}$, for $t = 0, 2$.

In view of the latter condition, equation (8) clearly does not simply say 'high quality cars cost more' for two reasons. First, the dependent variable is the ratio of expected capital losses, not prices themselves. In fact, equation (8) has no direct implications for the level of equilibrium prices or price differences between types of cars. Second, under the simple high-quality-high -prices hypothesis, all quality signals would enter the equation with the same sign. In contrast, our user cost cum efficient markets model has the very specific implication that $\text{sign}(a_{L+1,t}) = -\text{sign}(a_{L+2,t})$.

The empirical results are presented in Table 2. We report both single equation and SUR estimates to demonstrate the impact of the cross equation residual correlation. The results shown in the table relate to estimates using the total sample of 1984 and 1985 observations, relying on the assumption of structural stability between 1984 and 1985 which is tested in a second step. Furthermore, the estimates are from weighted regressions, the weights being $w_{j2}$ and $w_{j4}$ as explained above. Table 2 shows that all coefficients in the system take their expected signs. In particular, the switching sign pattern on the quality indexes implied by the model is found in the data. The F-test on overall significance of the model is highly significant. The published quality indices indeed account for a substantial part of the variation of relative expected capital losses.

It is interesting to note, first, that the intercept is statistically different from zero only in the case of $R_{j0}$. The estimated intercept yields a depreciation factor $\hat{\rho}_2 = 0.64$. Economic depreciation amounts to about one third of a vehicle's value over the first two years of its life. This indicates that consumers value the services provided by a new car considerably higher than those of a used car. Thus, similarly to Wykoff's (1973) result for the U.S. automobile market, we find that the services rendered by new and used cars are only imperfect substitutes. On the other hand, the estimated depreciation factor $\rho_4$ is 1.0, indicating that economic depreciation between the ages of two and four years is negligible. Novelty effects apparently are completely exhausted after two years and the services of cars of these vintages are regarded as perfect substitutes.

The coefficients on brand dummies $D_l$ turn out to be statistically insignificant in most cases. This may be due to the fact that the regression models only capture the differences of brand effects over two vintage classes that are likely to cancel out if the brand effects are similar for both vintages. Table 2 only reports coefficients that meet at least a 10%

significance level of the t-statistic. Note that the retained effects relate to brands with higher than average market shares.

All coefficients on the quality indices are found to be of the anticipated sign and are highly significant. Table 2 reports the estimates solved for the parameters $h_t$ of interest, while the t-values pertain to the estimates $a_{L+1,t}$ and $a_{L+2,t}$. The F-test for consistency of the system, namely, $0.64\ a_{L+2,0} = -\ a_{L+1,2}$, takes the value $F_1 = 0.1$, not rejecting consistency.

In short, the empirical findings support our empirical conjecture. They indicate that the relative expected capital losses respond to published quality data in a way as suggested by our model. Since the expected capital losses are imputed from market prices, this means that market prices reflect the information conveyed by published quality data.

Finally, Table 2 reports the results of a number of specification tests performed on the model. The first test is on the heteroskedasticity of the residuals between the subsamples of 1984 and 1985 for each equation. White's (1980) heteroskedasticity test is applied for this purpose. The test statistics are denoted $L_1$ and are $\chi^2(1)$ distributed under the Null of equal variances. The result shows no indication of heteroskedasticity. The second test is for parameter stability between the same subsamples. The alternative in this case is a shift in the parameters of interest, $a_{L+1,t}$ and $a_{L+2,t}$. The relevant statistics are denoted by $L_2$. In addition, the stability test is also performed on the whole system at a time. The overall statistic is F-distributed under the Null of stability with (226,4) degrees of freedom. The estimated value of 1.87 indicates no instability. The final test is an IM test on autocorrelation of the residuals of each equation between 1984 and

1985. Again, the test statistics, $L_3$, are $\chi^2(1)$ under the Null, and there is no indication of autocorrelation. Overall, then, there is no evidence of serious misspecification of the model.

## V. Summary and Conclusions

This paper presents a simple user cost oriented model of how published quality information plays an important role in the determination of prices of consumer durables. The main focus is on testing the proposition that equilibrium prices reflect market information. Using data of the West German automobile market, we find that the hypothesis that consumers rationally use public information cannot be rejected empirically.

Our results provide empirical support for the hypothesis that durables markets are informationally efficient. They corroborate related findings by Daly and Mayor (1983), Hartman (1987), and Kahn (1986), who demonstrated that used car prices in the U.S. reflect market information about increasing energy and fuel cost and product recalls. This sheds doubt on the popular conjecture that, since consumers are myopic and trade only occasionally on such markets, durables markets fail to make use of available information efficiently. An important policy implication from these results is that the mere prevalence of quality uncertainty in durables markets does not yield sufficient justification for direct public intervention in durables markets.

References

Akerlof, G. (1970): "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism", Quarterly Journal of Economics, 84, 488-500.

Berkovec, J. (1985): "New Car Sales and Used Car Stocks: A Model of the Automobile Market", Rand Journal of Economics, 16, 195-214.

Bond, E. W. (1982): "A Direct Test of the Lemons Model: The Market for Used Pickup Trucks", American Economic Review 72, 836-840.

Bresnahan, T. F. and D. A. Yao (1985): "The Nonpecuniary Costs of Automobile Emissions Standards", The Rand Journal of Economics 16, 437-455

Bulow, J. L. (1982): "Durable-Goods Monopolists", Journal of Political Economy, 90, 314-322.

Daly, G. D. and T. H. Mayor (1983): "Reason and Rationality during Energy Crises", Journal of Political Economy, 91, 168-181.

Hartman, R. S. (1987): "Product Quality and Market Efficiency: The Effect of Product Recalls on Resale Prices and Firm Valuation", Review of Economics and Statistics 69, 367-372.

Kahn, J. A. (1986): "Gasoline Prices and the Used Automobile Market: A Rational Expectations Asset Price Approach", Quarterly Journal of Economics, 101, 323-339.

Parks, R. W. (1979): "Durability, Maintenance, and the Price of Used Assets", Economic Inquiry 17, 197-217.

Rust, J. (1985): "Stationary Equilibrium in a Market for Durable Assets", Econometrica, 53, 783-805.

Stokey, N. L. (1981): "Rational Expectations and Durable Goods Pricing", Bell Journal of Economics, 12, 112-128.

White, H. (1980): "A Heteroskedasticity Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity", Econometrica, 48, 817-838.

Wykoff, F. C. (1973): "A User Cost Approach to New Automobile Purchases", Review of Economic Studies, 40, 377-390.

## Notes

1. Note that prices within a group need not equalize, allowing for, e.g., different mileage of used cars.

2. As Daly and Mayor (1986, p. 196) put it, the purchase of a car can be understood as the purchase of an option for the provision of transportation services over the holding period.

3. See, e.g., Berkovec (1985), Rust (1985), or Stokey (1981) for explicit demand and supply models based on the user cost approach. Parks (1979) derives a relationship between prices and maintenance cost of durables in a model that is similar to ours.

4. Wykoff (1973) found that there is a strong novelty effect for new cars on the U.S. market. Recall that we drop the index j for notational convenience. That is, equation (2), for example, reads $\gamma_{jt} = \rho_{jt}\gamma_{jt-2}$ , t=2,4,...,T, and the economic depreciation factor is generally different across types of cars.

5. Recall that we suppress the index j to simplify notation. That is, consumers observe the indices $q_{jt+2}$, j = 1, ..., J.

6. Alternatively, $q_{t+2}$ can be a vector of indices each related to a well-defined technical failure of cars in group t+2. $q_{t+2}$ can then be translated into a vector of probabilities that cars in t suffer from each of these failures, with the same consequences for expected cost as above.

7. "TÜV Auto-Report", ed: Vereinigung der Technischen Überwachungsvereine e.V., Essen.

8. One might argue that the quality indices are downward biased for expensive cars if owners of expensive cars tend to take them first to the shop to avoid delays at the TÜV check. While such behavior seems plausible for, say, business men, it runs counter the common experience that shops will rip customers off if told to fix everything that might cause a TÜV complaint. Note that even with a bias for expensive cars our empirical tests are not affected, since they focus on the differences in the indices among the vintage classes of cars of the same type.

9. The U.K. has a compulsory annual safety check, called MOT test. For the U.S., reliability data can be found in 'Consumer Reports, Buying Guide Issues', ed.: Consumer Union of U.S., Mount Vernon, N.Y. Accordingly, similar exercises can be performed using data for these countries.

10. "Eurotax--Schwacke-Liste", ed. Eurotax AG, Pfäffikon.

11. See Bond (1982) for empirical evidence that the 'lemons problem' can be solved by market institutions.

12. Unfortunately, our data do not allow to infer the importance of the lemons problem in the used car market, as we have no way to discern the average quality of cars traded from the average quality of the cars in the population.

13. We choose a linearized form of the model because it readily permits the imposition and testing of a cross-equation restriction derived from the theoretical specification. Note that the specification tests conducted below give no indication that the linear form is a serious misspecification.

Table 1: Average Prices (DM) and Quality Indices

| | 1984 Mean | 1984 Standard Deviation | 1985 Mean | 1985 Standard Deviation |
|---|---|---|---|---|
| $p_0$ | 17,630 | 1,660 | 18,140 | 1,690 |
| $p_2$ | 9,940 | 1,040 | 9,390 | 990 |
| $p_4$ | 8,530 | 760 | 7,820 | 820 |
| $p_6$ | 5,800 | 410 | 6,170 | 510 |
| $q_2$ | 4.58% | .4% | 3.70% | .30% |
| $q_4$ | 9.32% | .7% | 9.10% | .69% |
| $q_6$ | 15.40% | 1.2% | 15.74% | 1.16% |

Table 2: Regression Estimates[a)]

| Dep. | Int. | $\rho_2$ | $\rho_4$ | D4 | D7 | D11 | D14 | $q^0_{j2}$ | $q^0_{j4}$ | $q^0_{j6}$ | $R^2$ | F | DFE | SE | $F_1$ | $L_1$ | $L_2$ | $L_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | OLS - Estimates | | | | | | | | | | |
| R0 | .405 | .67 | -- | -.08 | .24 | -- | .19 | -.28 | .29 | -- | .41 | 16.5** | 120 | .014 | -- | -- | -- | -- |
| | (10.2**) | | | (-1.6) | (5.2**) | | (2.2*) | (-4.1**) | (2.7**) | | | | | | | | | |
| R2 | .06 | -- | 1 | -- | -- | .08 | .13 | -- | -.20 | .25 | .10 | 3.4* | 121 | .011 | -- | -- | -- | -- |
| | (1.0) | | | | | (2.8**) | (1.9) | | (-2.3*) | (3.0**) | | | | | | | | |
| | | | | | | | | GLS - Estimates[b)] | | | | | | | | | | |
| R0 | .44 | .64 | -- | -.08 | .23 | -- | .19 | -.25 | .28 | -- | -- | -- | -- | .012 | -- | .6 | 2.4 | .4 |
| | (4.6**) | | | (-1.7) | (5.4**) | | (2.1*) | (-4.1**) | (2.7**) | | | | | | | | | |
| | | | | | | | | | | | | 11.7** | 241 | | .1 | | 1.87[c)] | |
| R2 | .03 | -- | 1 | -- | -- | .11 | .20 | -- | -.27 | .33 | -- | -- | -- | .01 | -- | .5 | 6.5 | .02 |
| | (.6) | | | | | (2.6*) | (1.8) | | (-3.3**) | (4.0**) | | | | | | | | |

Notes to Table 2:

a) $\rho_2$ and $\rho_4$ are estimated economic depreciation factors. All coefficient estimates for $D_l$ and $q_{jt}$ have been adjusted for discounting and depreciation factors, see equation (9). Numbers in brackets are t-statistics. F is the F-statistic for overall significance. DFE is the number of degrees of freedom of regression errors. SE is the standard error of regression. $F_1$ is the F statistic of a test for equal coefficients on $q_{j4}$ in the two equations, with (241,1) d.o.f.. $L_1$ - $L_3$ are the LaGrange - multiplier test statistics pertaining to the test of heteroskedasticity ($L_1$), parameter stability for $q_{jt}$ ($L_2$) and correlation of residuals of each equation between 1984 and 1985. All three have $\chi^2$ - distributions under the Null with one, two and one d.o.f., respectively.

b) The Zellner - estimates are based on a cross-equation residual correlation of -.43.

c) F-test version of the LaGrange - multiplier test of parameter stability between 1984 and 1985, with (226,4) d.o.f..