USING HEDONIC PRICES TO ESTIMATE QUALITY CHANGES IN AMERICAN AND JAPANESE CARS

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Introduction

The goal of this research is to analyze the increases in the price of American and Japanese mid size automobiles during the period 1989-1998 and estimate how much of this price increase may be attributed to improvements in quality. This quality adjusted price increase would then be compared with the Consumer Price Index (CPI) to estimate the quality bias of the CPI for this segment of prices.

Underlying Economic Theory

The underlying economic theory for this analysis is the approach based on "hedonic prices". The theoretical foundation for the use of hedonic price models is based on the theory of consumer behavior of Lancaster (1971). Lancaster proposed that characteristics inherent in a product are the source of its demand. Hence it is these characteristics that relate to the source for the generation of consumer utility. Each characteristic therefore has a price attached to it, which is defined as the implicit price. Hedonic pricing models thus advocate that the price of a product is the sum of the implicit prices of the different characteristics of that product.

Lancaster's theory thus differs from the traditional approach that goods are direct objects of utility. Instead he claims that it is the properties or characteristics of the good from which utility is derived. Lancaster thus summarizes that his theory represents a break with traditional approaches on the following issues:

(1) The good, per se, does not give utility to the consumer; it processes characteristics, and these characteristics give rise to the utility.

(2) In general, a good will possess more than one characteristic, and many characteristics will be shared by more than one good.

(3) A Good in combination may possess characteristics different from those pertaining to the good separately.

The hedonic price function takes the general form of

$$P(Z) = p(Z_1, Z_2, Z_3, \ldots\ldots\ldots Z_n)$$

where P is the observed market price for a particular commodity and $Z = (Z_1, Z_2, Z_3, \ldots\ldots\ldots Z_n)$ is a vector of characteristics associated with that commodity. Observed product prices and the specific number of characteristics associated with each good define a set of implicit or "hedonic" prices. Hedonic price functions have been widely used in empirical studies of durable goods that are differentiated by characteristics.

Triplet (1986) proposed that "characteristics" may be defined by the following principles. First, characteristics are homogenous economic variables that are building blocks from which heterogeneous goods are, figuratively speaking at least, assembled. Hence the characteristics are being "packaged" or "bundled" into a specific product. Secondly, characteristics are valued by both buyers and sellers. We may conclude that this issue definitely leads towards considering characteristics as an economic variable. Albeit characteristics are not priced separately, the price of the whole product represents the valuation of all the characteristics that are bundled together in that good. Once the characteristics in a bundle have been identified and measured, the hedonic function is interpreted as a function or equation that serves as the role of "desegregator" and desegregates the price of the good into the implicit prices and quantities of the characteristics. Because the prices must be estimated rather than simply observed, they are called "implicit prices". These implicit prices are the most important empirical results from a hedonic function.

As with ordinary prices, an implicit price also measures what the seller receives for a characteristic when it is sold and what the buyer receives for it. As with ordinary prices, implicit prices for characteristics are proportional to the marginal valuation for users and they are also proportional to the marginal costs for the producers.

Characteristic prices also differ in certain aspects from ordinary prices. First, because of the bundling, the characteristic prices must be estimated with a hedonic function, they can seldom be observed like ordinary prices. Secondly, because characteristics are purchased as part of a tied sale, in bundled form, relations among the characteristic prices are more complex that what is usually assumed for prices of goods.

Literature Review

The primary basis of this research is on the work done by Feenstra (1987) in which he estimates a quality index for automobiles based on the hedonic pricing approach. Using this approach, Feenstra estimates how much of the increase in prices can be attributed to increases in quality for Japanese and American automobiles for their corresponding price rises from 1979 to 1985. Feenstra uses the following car characteristics to determine hedonic prices: length, width, horse power, transmission, power steering and air conditioning. Feenstra's research concluded that for the above time period studied, two third or 66% of the increase in car prices of Japanese imports can be explained by the upgrading and thus of increased quality of individual models. During this same period, however, for the American small automobiles, only one third, or 33% of the increase in car prices could be attributed to improvements in quality.

The research of Feenstra (1987) is significantly derived on the econometric techniques of hedonic pricing models as formulated by Griliches (1971). Griliches is cited as one of the pioneering architects on the development of hedonic prices for automobiles. His analysis of the price-quality relationships was based on data for U. S. passenger four door sedans for the year 1937, 1950 and 1954 through 1960. For all these years, he used the data on price and specifications for all models and brands for which data was available. Among his findings was that the coefficient for the "hardtop" variable was reasonably stable over time. This indicated a premium of 3 to 4 percent for that type of car. The overall conclusion of Griliches was that there was an upward quality bias during the years 1954-1960. Further research in this area was conducted by Triplet (1969) in which he used the same techniques of Griliches and applied it to later years. He used specifications on the variables used by Griliches, for a four door sedan body of each automobile model (for year in which a four door sedan was available) produced in the United States for the years 1960-1965 and his analysis concluded that the Griliches conclusion for an upward mobility bias during 1954-1960 could not be exterpolated to other periods or to other components of the CPI.

One of the earliest found research in this area is by Court (1939) of the Automobile Manufacturer's Association. He used car data for the years 1925 to 1935 and used the following characteristics: weight of the car, length of the wheel base in inches and the advertised horse power. He thus attempted to quantify the issues of quality as defined by these characteristics and used the hedonic approach. His analysis suggested that the importance of the wheel base was decreasing over the years.

Arguea and Hsiao (1993) used the hedonic approach to estimate the demand function for automobiles and used a technique that estimated the equilibrium shad prices for characteristics. To analyze the price-quality relations of automobiles, Hogarty (1975) uses data to study American produced cars for the period 1957-1971. He devised his analysis on the premise that the principal attributes desired by car buyers are comfort, durability, economy, maneuverability, performance, safety and style. He devised an index of each of these by using different characteristics of the automobile. For example comfort was measured as headroom, plus legroom and multiplied by seat width. His findings supported the earlier research that the bulk of observed price increase in automobiles could be traced to improvements in quality. Hogarty (1975) primarily refers to Pickering et. Al. (1973) attempting to apply the analytical approach of characteristics for survey data. These authors were able to identify five groups of commodities, namely, utilities, luxuries, leisure goods, central heating and automobiles that were distinct in terms of the characteristics that could be attributed to them. The results obtained by Pickering et. al. suggested that the principal attributes desired by car buyers are comfort, durability, economy, maneuverability, performance, safety and style. The results of Pickering et. al. is also complemented by Cowling and Cubbin (1972) who showed that virtually all the variation in prices among different models of cars could be explained by observable physical characteristics. They derived this conclusion from their study done with data for the period 1956 to 1968 for cars in the United Kingdom.

Rosen (1974) provided additional theory to the methods of Court (1939) and Griliches (1971). Rosen proposed that if a market is in short-run equilibrium, and if the statistical model is properly specified, then the hedonic price regression indicates the markets' valuation of each of the components of the good jointly purchased by the buyer and supplied by the seller. The buyer's decision is formulated through the family of "bid" functions that generally reflect the decreasing marginal utility provided by successive increments of the component. The seller's decision is formulated through a family of "offer" functions that reflect the increasing marginal costs of the additional units of the component. The hedonic price function, then, reflects the set of points at which the marginal bids and marginal offers are equal. Several papers have been written on the basis of Rosen's ideas.

In one of them, Agarwal and Ratchford (1980) in their illustrative application of the Rosen model developed estimates of the demand functions for automobile attributes from cross-section data on consumer choices and characteristics. For their analysis, they used the data on car purchased, transaction price and buyer characteristics from 225 recent new car buyers in Eire County, New York in the Fall of 1976. These 255 useable responses were obtained from a mailing of 1462 questionnaires, giving a response rate of 17.5%. Agarwal and Ratchford found that their result provided evidence that the demand for automobile characteristics was price sensitive. Also, whether or not the car is used for long distance trips was an important determinant of willingness to pay for increased size. Also, foreign manufacturers were willing to supply interior room and luggage space at a price lower than domestic producers. Their results also indicated that the willingness to pay for car attributes was inversely related to education.

In another study on the theories of Rosen (1974), Goodman (1983) used the hedonic pricing analysis on automobile market activity with special emphasis on the implicit valuation (hedonic price) of increased automobile efficiency as measured through Miles per Gallon. He tested four sets of hypothesis on data for two year old cars sold in 1977 and 1979. The first hypothesis considered and rejected coefficient equality over the two years. The second hypothesis examines the flexible forms of the hedonic regressions because the often used linear and log linear functions were used and found to be somewhat lacking. The third hypothesis examined the values of the hedonic coefficients, with special emphasis on Miles per Gallon. And the fourth hypothesis examined the elasticity of willingness to pay to more Miles per Gallon. For the 1977 market, this was found to be positive but rapidly decreasing. His conclusions this include that Miles per Gallon performed well for the two old 1975 models put did poorly for two year 1977 models.

Atkinson and Halvorsen (1990) used the hedonic regression techniques in the market data for automobiles to estimate a consumer's valuation for life. In other words, an estimate was made of the willingness to pay for changes in the risk of dying as found in the value put on different characteristics in a car that directly related to safety and reliability. They used the hedonic approach to estimate the marginal willingness to pay reduce the risk of a fatal accident. Their study thus obtained estimates of the value of a statistical life using data on automobile purchase decisions. The estimated value of a statistical life varies inversely with the level of risk. They concluded that an approximate estimate of the value of a statistical life would be $3.357 million 1986 dollars.

Asher (1992) did a test to check whether the prices of new automobiles reflected their different degrees of safety and reliability after one controls for other characteristics. She used a semi logarithmic functional form such that the coefficients on each variable could be used to derive the price elasticity for each characteristic. Most of the data used for this analysis was from the 1983 Consumer Satisfaction With Dealer survey conducted by J. D. Power and Associates. The data set consisted of 7,109 observations on individuals who purchased new cars in the Spring of 1982. Out of this total data set, 2,637 were used in the study. Her study concludes that a one percent reduction in safety, which is reflected as an increase in the safety index, results in a decrease in the price of a new car. The results for reliability also support this hypothesis.

The hedonic approach was used by Couton, Gardes and Thepaut (1996) to deal with the environmental and safety characteristics of cars for the French car market (catalytic converter and airbag) and showed that they are positively valued by the market. The hedonic price, evaluated on individual panel data for three periods of time and eighty models is proved to be highly correlated to the market price. Thus the computation of hedonic prices for the French car market in 1991 and 1992 showed that there was a positive influence of environmental and safety characteristics of cars. Moreover, the Akerlof effect of a perception of quality through unexplained prices is directly proved by the statistics on the car's quality perceived by consumers. They define the Akerlof effect as "all things being equal, (i.e. for quality adjusted prices) and in the case of asymmetric information between buyers and dealers, higher prices are an indicator of the quality of goods for the consumer".

In using the hedonic approach to analyze the grey market for automobiles, Giannias (1996) finds that the quality and price of a grey market luxury car like Mercedes, decreases faster as mileage increases as compared to that of a similar (same mode, year and mileage) non grey market Mercedes. His research is instructive in showing the use of the hedonic approach and demonstrating the incorporation of the multiple product characteristics. This kind of analysis is very useful in the marketing decisions of a firm and especially in the context of product positioning and comparative product evaluation and target marketing.

<u>Quality Bias in the Consumer Price Index</u>

One aspect of this research is to compute the quality adjusted price indexes for the automobile segment (mid size, i.e. four door sedans, excluding luxury models) being analyzed. This would enable us to determine how much of the increases in the prices can be attributed to increase in quality. The next part of this research is to compare the relevant data from the Consumer Price Index (CPI) and note the extent of the "quality bias" that exists in the CPI and compare them with results from the theis.

Michael Cox and Richard Alm (1999), in their book, "Myths of the Rich and Poor" note the significant misrepresentation of not adequately accepting America's increases in its standard of living over the last several decades. They believe that this is greatly attributed to the Consumer Price Index (CPI) failing to adequately capture the constant introduction of new products and the improvement in product quality. When prices rise, its sometimes means that when consumers pay extra for the same goods and services they may sometimes be worse off. However, well being does not fall as much when higher prices reflect better quality and "new bells and whistles". The authors also mention that 9 out of 10 households now own passenger vehicles. Nearly two thirds have two or more. Among those sixteen years or older, vehicles per 100 people rose from 53 to 93 in just 26 years. Within a few years the country may become the first in history to have more passenger vehicles than people. Dozens of automotive innovations have improved performance, safety and comfort. These include antilock brakes, air bags, turbochargers, cruise control, automated air conditioning and heating, sun roofs, adjustable steering wheels and windshield wiper delays. So the authors feel that "today's cars are loaded with power". However, these improvements in quality are not completely captured by the Consumer Price Index.

Thus, at the most basic level, the problems of quality changes arise because conventional price indexes measure the price of the commodities that the consumers buy rather than the cost of attaining a given level of economic well being or utility. Since it is quite impossible to measure utility directly, the next best approach is to measure the fundamental characteristics of the product that consumers value. This has been advocated by Nordhus (1998). Nordhus (1998) also points out that the Boskin Commission (1996) reviews for the Consumer Price Index (CPI) estimated that the CPI has an upward bias of 1.1 percentage point per year. Of this amount, the bias for underestimating quality change is 0.7 percentage points per year, which is more that half of the total bias.

Boskin et. al. (1997) point out that the Consumer Price Index overstating the change in the cost of living by 1.1 percentage point per year is especially signifiacant because when compounded over time the implications are enormous. The Boskin Commission, in its 1996 report to the United States Senate, points out that when economists try to define the change in the cost of living, it is to answer the question, "how much more will consumers need to be just as well off with the new set of prices as that of the old." This makes it necessary to measure quality adjusted prices. In its recommendations, the Boskin Commission also advocated for the greater use of hedonic statistical methods to adjust for quality change.

Gordon and Griliches (1997) point out that an important criterion for the assessment of quality changes is the evolution of market shares for particular models and products. When a new, more expensive model is introduced and gains market share, we can conclude that it was superior in quality to the other models by more than the differential in price between them. Gordon and Griliches (1997) also point out that not all change is positive and not all change is positive for everyone. For example, an existing service or good may even deteriorate in quality.

Moulton and Moses (1997) of the Bureau of Labor Statistics acknowledge the Boskin Commission estimate of the overall bias in the Consumer Price Index as 1.1 percentage point per year. Of this amount, 0.4 percent is attributed to the failure of fixed weight index to account for consumer substitution as relative price changes; 0.1 percent is attributed to inadequate measurements of improvements in quality and of new goods. They also point out that a noteworthy accomplishment of the Boskin Commission was the classification of the Consumer Price Index (CPI) into twenty seven major categories of items and then providing a separate estimate of quality bias for each category. This is the first systematic analysis, category by category, of quality bias is in the Consumer Price Index (CPI). It is to be also noted that of the twenty seven categories, the commission assigned eight a quality bias of zero. These categories are, fuels, housekeeping supplies, housekeeping services, other private transportation, public transportation, health insurance, entertainment services and tobacco. The commission assigned each of the remaining categories an estimated bias that was positive. Thus, the Boskin Commission concluded that the price change is overstated because the quality change is understated. So the price rise indicated by the CPI is not accurate nor complete if we are to factor in the improvements in quality.

As mentioned earlier, the Boskin Commission estimated a total quality bias of 0.6 percentage points for all the twenty seven categories. But in the category of new vehicles, this bias was found to be 0.59. This fact and the Boskin Commission recommendation to the United States Senate for the greater use of using the hedonic approach for measuring quality adjusted prices adds more pertinence to this research.

3

The Model and Methodology

The theory of hedonic prices is derived from the characteristic approach to consumer demand proposed by Kevin Lancaster (1971) in "Consumer demand: A New Approach". This theory proposes that the price of a commodity is a function of the "implicit" prices of its different characteristics. The model and methodology of this research as described in this section is drawn from the work of Feenstra (1987) and Griliches (1971).

The primary objective of this thesis is to determine how much of the increase in prices of mid sized American and Japanese automobiles sold in the United States could be attributed to quality enhancements. The methodology of this approach is based on the research done by Feenstra (1987) which also draws significantly on the ideas of hedonic modeling proposed by Griliches (1971). This thesis adds the following new dimensions to the work of Feenstra (1987).

(1) The analysis done by Feenstra (1987) is based on automobile data from 1979 to 1985. This thesis extends this research to analyze the price changes beyond that time, by looking at the price data from 1989 to 1998.

(2) The automobile characteristics measured by Feenstra (1987) include the following: length (in feet), width (in feet), horsepower (in 100 HP), transmission (5 speed or auto), power steering and air conditioning. Feenstra omitted the weight variable in the final regression because he found that its estimated coefficient when included was highly insignificant. Also, omitting

this variable had only a slight effect on other coefficients. Our thesis includes some of these original variables, but build into this model by adding additional variables as, anti-lock brakes, driver side air bag, engine feature (as characterized by being 6 cylinder and/or V-6 as opposed to not being so) and cargo capacity. This incorporates the fact that automobiles sold in the United States have undergone significant characteristic changes since the mid 1980s.

(3) The quality adjusted prices found from this analysis would then be compared with the price data for new cars found in the Consumer Price Index (CPI). The goal would be to estimate the nature of the bias for the CPI for not adequately incorporating quality improvements. We will then attempt to validate the results of this thesis by seeing if they are similar to what the Boskin Commission estimates as quality bias for new cars in the CPI.This is a new addition to original research ideas of Feenstra (1987). This issue of quality bias is a pertinent matter that was highlighted in the presentation made by the Boskin Commission in 1996 to the United States Senate on issues related to bias in the Consumer Price Index.

(4) We will use the Weighted Least Squares approach to derive our results. The details for this are provided in the next chapter. The results obtained by Feenstra (1987) were by using Ordinary Least Squares method.

The Model and Methodology

Most commodities, especially consumer goods like automobiles, are sold in a variety of models. The reason why these different varieties or models sell at different prices must be due to some differences in their properties or other qualities or what we would consider "characteristics". Thus we can write the price, "p" of the commodity as a function of a set of qualities or characteristics "x" and a random disturbance "u". Such an equation would be written as follows:

$$p = f(x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_n)$$

To estimate the implicit price of each characteristic, we use the basic regression equation as used by Feenstra (1987) with the additional variables to address the new characteristics discussed earlier. This equation is as follows:

$$\text{Log } p = b_o + b_1 x_1 + b_2 x_2 + b_3 x_3 + \ldots\ldots\ldots + .b_9 x_9 + \ldots + e \qquad \text{(Equation: 1)}$$

In this equation:

p dollar price of car (base price)

bo intercept term

e normally distributed random error term

x_1 length (measured in feet)

x_2 width (measured in feet)

x_3 horse power (measured in 100HP)

x_4 power steering, a dummy variable with value 1 if there is power steering and 0 if otherwise

x_5 anti lock brakes, dummy variable with 1 if present and 0 if not

x_6 driver side airbag, dummy variable with 1 if present and 0 if not

x_7 engine feature, 1 for 6 cylinder or V-6 and 0 of not

x_8 cargo capacity (in cubic square feet)

The variables of x_5 to x_8 are new variables that have been added to the other variables that have been used from the Feenstra (1987) model. The coefficient of each characteristic obtained from this regression will give the implicit price of that characteristic. This would indicate how that characteristic determines the final price. For example, Feenstra found that in the Japanese car models for the period 1979-85, the coefficient for width was 0.37. This indicated that an increase in width by one foot would raise the estimated price by 37%.

We estimate the equation described in equation 1 for the car price data on American and Japanese mid sized cars for the period 1989 to 1998. These results are further analyzed in the next chapter. It was unlikely that the results would be the same for each period, this creates the general index number problem of changing weights. The implicit price we thus obtain will depend upon the particular period, and this would affect the Laspeyres and Paasche index. As done by Feenstra (1987) and Griliches (1971), since the periods are not too far apart 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". For this purpose, the following regression equation was used;

$$\text{Log } p = b_0 + b_1 x_1 + \ldots\ldots\ldots\ldots b_9 x_8 + g D + e \qquad \text{(Equation: 2)}$$

In the above equation: 2, the variables b and x_1 to x_8 have the same meaning as described earlier. In equation: 2, "D" is a variable that is zero in one period and one in the other period. The coefficient "g" of the variable D provides us with an estimate of the average percentage increase in the prices between the two periods, holding as constant the change in any of the measured quality dimensions. Since we want to impose the same set of weights on more than two cross sectional data sets, this may be done by specifying additional time or dummy variables that take the value of one in their reference period and the value of zero in all other periods. The necessary number of such variables will be less than the number of cross sections that are being estimated together. When using the data set for 1989 to 1998 these dummy variables for time as described above were as follows:

D1: value of 1 if the car model belongs to 1989, zero otherwise.

D2: value of 1 if the car model belongs to 1990, zero otherwise.

D3: value of 1 if the car model belongs to 1991, zero otherwise.

D4: value of 1 if the car model belongs to 1992, zero otherwise.

D5: value of 1 if the car model belongs to 1993, zero otherwise.

D6: value of 1 if the car model belongs to 1994, zero otherwise.

D7: value of 1 if the car model belongs to 1985, zero otherwise.

D8: value of 1 if the car model belongs to 1996, zero otherwise.

D9: value of 1 if the car model belongs to 1997, zero otherwise.

Later in the text and the tables these are referred as year dummies and identified by the year. When this procedure was used, the resulting coefficients of D measured the percentage change in the average price, holding the quality characteristics as constant. The average price of the earliest cross section would be the base of measurement. Thus the primary regression model to be used in this analysis was the following;

$$\text{Log } p = b_0 + b_1 x_1 + b_2 x_2 + \ldots\ldots\ldots b_9 x_9 + g_1 D_2 + e \quad \text{(Equation: 3)}$$

An important issue was to acknowledge that this analysis is sensitive to the estimated coefficients of the year dummies. It was thus necessary to check the sensitivity of these coefficients to the model specification by re-estimating the regression described in equation: 3 but omitting each one of the variable one at a time and noting the new value of the coefficient "g" for the dummy variable D on each occasion. It was found that the range of these coefficients was less than two standard error away (95% level) from the estimates found in the regression equation: 3. It was thus concluded that the regression equation: 3 could be used for the analysis to estimate product quality.

The measure of quality was obtained by computing the predicted price from the hedonic regression, not including the portion explained by the year dummy "D". This is because the year dummies are being used in the regression to control for price changes that took place across the years without having any relation to the car characteristics. The "unit quality" for a specific year was calculated as a weighted average across models. The weights used in this case, as used by Feenstra (1987), were the number of cars sold for that specific model as a proportion of the total number of cars sold for all the the models being considered for that year.

The next item that was computed was the "quality index". This was computed by using constant weight between each two years. The index used, as done by Feenstra (1987) was the Fisher's Ideal Index which is the geometric mean of the Laspeyres and Paasche indexes. This quality index will measure the increase in quality over the time period in consideration.

4

Empirical Results

The different car models used in this data set are listed in Table: 1 and Table : 1a. The period of data was from 1989 to 1998. The car data for Japan had 97 observation and the card data for United States had 227 observations. There were two major sources of data. For car characteristics, the data source was the relevant annual issues of the car Buyer's Guide, published by Harris Publications, New York. For the annual sales figures for different car models, the data source, as used by Feenstra (1987) was the relevant annual issues of the Automotive News Market Data Book. This is published by Crain Communications, Chicago.

The research was initiated with an Ordinary Least Squares regression on the two data sets. The results for the OLS are presented in Table: 2 and Table: 3. There were some problems with the results obtained in this process. The first concern was the lack of significance of several of the year dummies. The Cook-Weisberg test was used to test for heteroscedasticity. For the Japan data, the Chi Square was found to be 1.91, less than the critical value of 3.84 (for 95% level). This indicated that there was no heteroscedasticity present in the car data for Japan. However, for the car data for the United States, the Chi Square value was found to be 11.82, higher than the critical value of 3.84 (for 95% level). This indicated the presence of heteroscedasticity in the car data for the United States. The R2 obtained in both cases were high. The R^2 of 0,79 for the data of Japan indicated that 79% of the variation in prices were explained. And the R^2 of 0.77 for the data for United States indicated that 77% of the variation in prices was explained.

As mentioned earlier, the coefficients of the variables in a hedonic estimation are the implicit prices of these characteristics. For the OLS regression, if we analyze the results for the United States and consider the significant variables, we can make the following observations. From Table: 2, thepositive coefficient of 0.24 for width indicates that a one foot increase in width would result in a 24% increase in price. The anti-lock brake is a dummy variable that appears as 1 if present and 0 if otherwise. Hence, the positive coefficient of 0.06 indicates that its presence would lead to a price increase of 6%. Similarly, the coefficient of 0.12 for power steering indicates that its presence would lead to a price increase of 12%. And the presence of the model engine feature is expected to increase the price by 20%.

We have included the year dummies for different years. The coefficient of those year dummies, when significant, suggest the increase in price in that year that is not explained by any changes in characteristics. For example, in the case of U. S. data for The coefficient of 0.12 for the 1996 year dummy suggests that for that year, 125 of the price increase is not explained by changes in characteristics. Similarly, the coefficient for 1997, another significant year for U. S. data suggests that in that year 15% of the price increase is not explained by any change in characteristics.

For the car data of Japan, the OLS results in Table: 3 suggests that for a significant variable like width, the coefficient of 0.37 implies that an increase in width by one foot would lead to a price increase by 37%. Again, the anti-lock brake is a characteristic measured by a dummy variable that is 1 for its presence and 0 for its absence. This the coefficient of 0.18 for anti-lock brakes suggests that its presence is likely to increase the price by 18%. Similarly, the coefficient of 0.23 for engine suggests that the presence of this engine feature of either V-6 or 6 cylinder was going to increase the price by 23%. Only one of the year dummies was found to be significant for the car data for Japan. The coefficient of –0.18 for the year dummy 1990 suggests that 18% of the price change reflected in that year was not explained by any change in characteristics. The year dummies play a very important role in determining how much of a yearly price rise is not due to any changes in characteristics. Hence to have so many year dummies come out as not significant was a source of concern in proceeding with this method for our final estimation and analysis.

The OLS was used to calculate the estimates and the analysis showed inconsistencies with the estimates of the Boskin Commission. The details of the estimates discussed below are reported in Table: 16, Table: 17 and Table: 18. The OLS estimates indicated that for Japan, the Unit Value (observed price) increased by 43.22% and the Unit Quality (predicted price) increased by 32.33%. Hence 74.8% (32.33 of 43.22) of the increase in price was due to quality. For the USA, the OLS results indicated that the Unit Value (observed price) increased by 26.15% and the Unit Quality (predicted price) increased by 17.74%. Therefore, 67.8% (17.74 of 26.15) of the increase in price was due to quality. We then combined the data of the U. S. and Japan and computed the Unit Value and the Unit Quality for the pooled data set, using proportion of car sales for the U.S. and Japan as weights. From the pooled data we find that the Unit Value (observed price) increased by 23.7% and the Unit Quality (predicted price) increased by 16.24%. Therefore 68.5% (16.24 of 23.7) of the increase in price in the whole data set was due to quality. This is not consistent with the findings of the Boskin Commission (1996). The Boskin Commission estimated the quality bias in the Consumer Price Index to be 0.59%

per year. For our nine year data set, this quality bias would be 5.43%. Hence in our pooled data set, over the nine year period analyzed, we would expect the increase in the Unit Quality (predicted price) to increase by an amount similar to 5.43% and not by 68.5% as computed from the OLS regression estimates. Hence another approach was devised to better design this analysis.

Weighted Least Squares

It should be again noted that the economic foundation of this research is the Lancaster (1971) characteristic approach to consumer demand. In this theory he laid the foundation that a consumer derives utility from the different characteristics that make up the commodity. The final testimony of a consumer's preference for a characteristic or a group of them is the actual purchase of the product. Hence we now used a **Weighted Least Squares** regression on our two data sets. The proportion of sales of each car model was used as the corresponding weight.

The results of the Weighted Least Squares (WLS) for car data for the United States and Japan are presented in Table: 4 and Table: 4a respectively. Several improvements were found as explained below that made it relevant for use for all further estimations and calculations. First, we notice that there is a great improvement in terms of many more of the year dummies becoming significant. This is important as explained earlier. Additionally, we find that the R^2 values are also much higher. The R^2 value of 0.83 for the U. S. indicates that for U. S. car data, 83% of the variation in prices is explained by this analysis. The R^2 of 0.91 for the car data for Japan indicates that 91% of the price variation is explained by this procedure.

However, before we proceeded further, a few more checks were made. A model specification test was done with the Ramsey RESET test. For this procedure the square and the cube of the predicted value was regressed to see if the predicted value correlates with the error term. This should not happen is there are no problems with the model specification. The p value was 0.11 and not significant at the 5% nor 10% level. Hence we conclude that there are no problems with the model specification.

As done by Feenstra (1987) the sensitivity of the coefficients of the year dummies was also checked. This was done by repeating these regressions while omitting one variable at a time and checking the range of the coefficients of these year dummies. This is presented in Table: 6 and Table: 6a. The range of these year dummy coefficients were found to lie within plus minus two standard errors of the coefficients of the primary regression to satisfy the requirements of the 95% level check. This indicates that we can be confident of using the results obtained in the regression analysis presented in Table:4 and Table: 4a. However, the heteroscedasticity proved to be inconclusive in this case of the WLS results. A likely reason is because the residual sum of squares is not very well defined in this case. But the overall assessment indicates this to be a robust and improved analysis and we therefore decide to proceed with using this for all of the future estimations and analysis.

Once again, the coefficients of the significant variables denote the hedonic prices For the U. S. data in Table: 4, for a significant variable like width, the coefficient of 0.43 indicates that and increase in width by one foot will lead to 43% increase in price. Power steering is a characteristic that is measured by a dummy variable that is 1 for its presence and 0 if not present. Hence, the coefficient of 0.08 for power steering indicates that its presence will lead to a 8% increase in price. Similarly the presence of the specified engine feature will lead to a price increase by 17%. The negative coefficients for length and driver side airbag, was unexpected. Incidentally, Feenstra (1987) also had an negative coefficient for length. His explanation is what I would partly use and that is the possibility of some multicollinearity. The correlation matrix is provided in Table: 5 and Table: 5a. There is some correlation between length and width, but overall there is no multicollinearity in the data. Another possible explanation provided by Feenstra (1987) is possible misspecification in his model.

However, our Ramsey RESET test indicated that there is no specification errors in our model. Hence the most acceptable conclusion is that this unexpected result is included in that small part of the variation in prices that remains unexplained as indicated by the R^2 values.

Again the coefficients of the year dummies measure the price changes for a year that is not due to any changes in characteristics. All but the year dummy for 1990 are significant in the case of car data for the U. S. For example, the coefficient of 0.11 for 1991 indicates that 11% of the price rise for that year is not explained by any changes in characteristics. Similarly, the coefficient of .31 for the 1998 year dummy indicates that 31% of the price rise for that year is not explained by any changes in characteristics.

Calculating the Price Increases

Our initial goal is to compute the price increase for the observed prices. The next step would be to get an estimate of the quality price. An estimate of the price rise due to quality is found by computing the predicted price from the hedonic regression but not including the year dummies.

To begin with the observed prices, we first find the Unit Value. This is the value of a typical car for each data set for each year. To compute the Unit Value we take the weighted average price of all the cars for each year for the car data sets. This is done separately for both data sets. The weights used are the units sold of each model as percentage of the total sales. The Unit Value thus calculated for year 1989 to 1997 for the car data of the U. S. and Japan, along with the percentage change for every year is presented in Table: 7. At this point it should be noted that once we have computed our quality component for the observed price increases, we intend to compare this with actual data for new cars for the Consumer price Index (CPI) and test the validity of our results by looking at the implications of the Boskin Commission (1996) findings for quality bias in the Consumer Price Index. Currently, the Consumer Price index for new cars is available upto 1997. Hence, to maintain consistency of our comparisons, all our calculations will be for the period 1989-1997. The range of the Unit Value calculated as in Table: 7 are as follows; for the car data of the U. S. the Unit value for 1989 was $12,973 and for 1987 was $16,366. For the car data of Japan, the Unit Value calculated from the observed prices was $10,412 for the year 1989 and fir the year 1997 it was $14,910. We then proceed to use these annual unit values and the corresponding car units sold for each year for the car data of Japan and the U. S. to compute the index numbers for those years. As done by Feenstra (1987) we use the Fisher's Index for our final computation. This is considered to be the ideal index because it eliminates the bias found in the Laspeyer's Index and the Paasche Index. The Fisher's Index is calculated as the geometric mean of the Lapeyer's and Paasche index. The Unit Quality Fisher Index number for the observed prices of Japan and the U. S. is presented in Table: 10 and Table: 11.

For the period 1989 to 1997, the index for Unit Value, for observed prices, for Japan increased from 83.00 in 1989 to 118.87 in 1997, this is an increase of 43.22%. The base year used for the calculation of the index number was 1993. For the U. S. the increase was from 92.21 in 1989 to116.33 in 1997. This represents an increase by 26.15%.

The next step is to calculate the Unit Quality. The procedure is the same as above, but here we will use the quality prices from the hedonic regression. The hedonic regression is used, without the year dummies, to predict the quality price for each car model. Then for each year, for both Japan and U. S. data, we calculate the Unit Quality by taking a weighted average to find the Unit Quality (price). We again use the units sold for each car model as a percentage of total sales of the year as the appropriate weight for each predicted price. The Unit Quality thus obtained is presented in Table: 8. As shown there, for the U. S. data, the Unit Quality for 1989 was $13,610 and for 1997 was 414,702. For the car data of Japan, the Unit Quality for the year 1989 was $10,973 and for the year 1997 was $13,063.

The next step is to calculate the Fisher Index number for the Unit Quality found for each year for car data of U. S. and Japan. The Unit Quality index numbers for Japan and U. S. are presented in Table: 9 and Table: 9a. The index numbers show that for car data of Japan, the Unit Quality increased from 97.03 in 1989 to 115.51 in 1997; this represents an increase by 19.04%. For the car data of U. S. the Unit Quality index increased from 93.73 in 1989 to 101.25 in 1997; this represents and increase by 8.02%.

Thus, we can make the following conclusion for the period 1989-1997. For car data of Japan, the actual or observed price increase was by 43.22%; but the quality induced price increase (as measured by the increase of the index for Unit Quality) was 19.04%. For data of Japan, 44% (19.04 of 43.22) of the observed price increase was due to quality. Similarly, for the car data of the United States, the actual or observed price increase (as measured by the increase in the index of Unit Value) was 26.15%; but the quality induce price increase at this same time was 8.03%. Thus for the car data of the United States, 30% (8.03 of 26.15) of the price increase in observed prices was due to quality.

Feenstra (1987) found that for the period 1981 to 1985; for car data of Japan, 66% of the increase in price was due to quality. And for the car data of the United States, 33% of the increase in observed prices was due to quality. Our thesis results show that Japanese cars still lead American cars in terms of having quality increases as a part of price increases. However, this gap has narrowed. The quality component in price increase for Japanese cars has fallen from 66% in 1981-1985 to 44% during 1989-1997. While for American cars the decline has been much less, from the quality component being 33% during 1981-1985 to 30% during the period 1989-1997.

Validity of Thesis Results

We now check the validity of our results by comparing it to the Consumer Price Index for new cars. The Bureau of Labor Statistics, Consumer Price Index for new cars is currently available until 1997. This information is presented in Table: 15. This table also shows the CPI for new cars for 1989-1997 with the base year adjusted to 1993 to make the comparison consistent with our earlier calculations of all index numbers using base year as 1993.

To validate our results with the CPI information we first construct an index for our whole data set by combining the data for Japan and the United States. We then proceed to compute the Unit Value of observed prices for each year by again calculating a weighted average. To do this we use the Unit Value prices for Japan and U. S. for each year and as weights we use the percentage of sales for Japan and U. S. compared to the total sales in that year. In a similar way we calculate the Unit Quality for the pooled data set. We use a weighted average for year. To calculate this we use the Unit Quality for each year for Japan and the U. S. and use the percentage of sales for Japan and U. S. for each year's total sales as the weight. Once we have the Unit Value (observed prices) and the Unit Quality (predicted prices) for year for the combined data set, we calculate the Fisher Price Index for the Unit Value (observed prices) and Unit Quality (predicted prices). These steps are presented in Table: 12 , Table: 13 and Table: 14. For example, in Table: 12, in 1989 the sales of Japanese cars was 159,209 and the sale of U. S. cars in the data set was 2,572,726 which gives total sale figure for 1989 as 2,731,935. The weights are the percentage of sales of Japan and U. S. out of the total sales. In Table: 13 we see that the Fisher's index for the Unit Value (observed prices) from the pooled data increased from 94.57 in 1989 to 117.02 in 1997; this represents an increase of 23.7%. From Table: 14 we see that the price index for Unit Quality (predicted prices) increased from 100.06 in 1989 to 105.15 in 1997; this represents an increase of 5.1%. Thus for the pooled data set, 21.518% (5.1 of 23.7) of the increase in price is due to increase in quality.

We can now validate our thesis result in two ways. First, we note that the findings of the Boskin Commission indicates that for new cars the CPI has understated the quality increase by 0.59% per year. This rate per year, over a nine year period, as included in 1989 to 1997 becomes 5.43% (because $100(1.0059)^9 = 105.43$). So according to the Boskin Commisssion findings for the overall CPI for new cars, quality increase over a nine year period, not recognized by the traditional CPI, is 5.43%. This value is very close to the 5.1% increase in quality over a nine year period found in our pooled data for Japanese and American cars sold in the United States.

Our thesis results are also validated in yet another way. Our pooled data indicates that price increased by 23.7% and quality increased by 5.1%. Thus 21.518% of the price rise was quality increase. We eliminate the quality component from the 23.7% price increase to find the price increase without the upward quality bias, this is equal to 23.7(1-.21518) which is equal to 23.7 (0.7848) = 18.5%.

We can do the same with our price increase of 18.87% found in our CPI for new cars with base adjusted to 1993. To do so we can use the Boskin Commission estimate of the bias, which for a nine year period is 5.43% as explained earlier. Factoring out the quality bias from the CPI, we get the unbiased price increase as 18.87 (1-0.0543) which is equal to 18.87 (0.9458) = 17.84%. This is very close to the unbiased price increase of

18.5% calculated earlier from the pooled data set used in this thesis. The proximity of these estimates in both approaches underscores the validity of the results obtained in this dissertation.

5

Conclusion

The results obtained in this thesis have been validated by exhaustive comparisons with actual Consumer Price Index data for new cars and the estimates of the quality bias for new cars presented by the Boskin Commission to the United States Senate in 1996. We can thus conclude that even during the last decade, Japanese cars had a higher quality component in their price increase. But the component of quality has declined in the case of both Japanese and American cars represented in this data set. Feenstra's results for 1981-1985 had 66% and 33% of price rise due to quality for Japanese and American automobiles respectively. Our results for 1989-1997 have 44% and 30% of price rise due to quality for Japanese and American cars respectively. Albeit both have declined between the two time periods, the gap between the quality components for price rise for Japanese and American cars has actually been reduced. This is because the decline of quality as a part of price rise has been much more in the case of Japanese cars than for American cars. It appears that overall, American car makes have been able to do a better job in not losing ground in terms of quality improvements as a component of price increases.

This thesis also reestablishes a very important idea that price rise can often have an important quality contribution. And in that case the rise in prices is not all that bad if the additional quality leads to additional utility from consumption. It implies that we can now do or enjoy more with our money and thus takes us to the classic issue as to if we would rather be a millionaire today or a hundred years ago. Long before the Boskin

Commission (1996), Feenstra (1987) raised this issue of quality increases as a part of price increases. But the Boskin Commission report to the United States Senate has put this issue more into limelight. It is one of the recommendations of the commissions to use the techniques of hedonic estimations to better estimate the quality components of price rise. Based on the popularity and importance of this Commission report and the involvement of the United States Senate, it is reasonable to believe that the use of hedonic prices to account for quality improvements in price increases will gain importance and popularity in coming years. To that effect, this research joins an important trend that may be expected to be much more pertinent over the next several years.

Table 1

Car Models Included

Japan

Daihatsu Charade	Honda Accord	Honda Civic
Isuzu Stylus	Mazda 323	Mazda 626
Mazda Protégé	Mitsubushi Diamante	Mistsubishi Gallant
Mitsubishi Mirage	Nissan Altima	Nissan Maxima
Nissan Sentra	Subaru Esteem	Subaru Impreza
Subaru Legacy	Suzuki Esteem	Toyota Corolla
Toyota Camry	Toyota Tercel	

Table: 1A

Car Models Included

USA

Buick Century	Buick Electra	Buick LeSabre
Buick Roadmaster	Buick Skylark	Chevrolet Caprice
Chevrolet Caprice Impala	Chevrolet Cavalier	Chevrolet Corsica
Chevrolet Lumina	Chevrolet Malibu	Chevy Bereta
Chevy Caprice	Chevy Celebrity	Chevy Lumina
Chrysler Lebaron	Chrysler Cirrus	Chrysler Concorde
Chrysler Fifth Avenue	Chrysler New Yorker	Chrysler LHS
Dodge Aires	Dodge Diplomat	Dodge Dynasty
Dodge Intrepid	Dodge Lancer	Dodge Plymouth Neon
Dodge Omni America	Dodge Shadow	Dodge Spirit
Dodge Stratus	Eagle Primier	Eagle Summit
Ford Contour	Ford Crown Victoria	Ford Escort
Ford Taurus	Ford Tempo	Geo Prism
Mercury Grand Marquis	Mecury Mystique	Mercury Sable
Mercury Salle	Mercury Tracer	Oldsmobile Calais
Oldsmobile Ciera	Oldsmobile 88	Oldsmobile 98
Oldsmobile Achieva	Oldsmobile Ciera	Oldsmobile Royal
Oldsmobile Supreme	Oldsmobile Intrigue	Plymouth Acclaim
Plymouth Breeze	Plymouth Grand Fury	Plymouth Horizon
Pontiac Bonneville	Pontiac Grand Am	Pontiac Grand Prix
Pontiac Sunfire	Saturn Sedan	

Table 2

Regression Results: USA

Ordinary Least Squares	Observations 227		
Adjusted R^2: 0.7586;	R^2:0.7767		
Variable	**Coefficient**	**Std. Error**	
Constant	7.505155	0.261215	*
Length	0.0173419	0.0115109	
Width	0.2400653	0.051809	*
Horse Power	0.008819	0.0071828	
Anti Lock Brake	0.065231	0.0210734	*
Power Steering	0.1221097	0.0308036	*
Airbag, Driver Side	-0.0087292	0.0307634	
Engine	0.2078966	0.0267017	*
Cargo	-0.0074853	0.2612195	*
Year Dummies			
1990	-0.1106673	0.050467	*
1991	-0.0254952	0.049599	
1992	-0.004039	0.047527	
1993	0.0443902	0.047115	
1994	0.0753034	0.079280	
1995	0.0863495	0.053335	
1996	0.1242486	0.052308	*
1997	0.1597616	0.053518	*
1998	0.1410301	0.054658	*

The * denotes significant at 10% level of significance

Table 3

Regression Results: Japan

Ordinary Least Squares;	Observations 97		
Adjusted R^2: 0.7586	R^2:0.7905		
Variable	**Coefficient**	**Std. Error**	
Constant	6.704119	0.697442	*
Length	0.011114	0.010228	
Width	0.375910	0.144159	*
Horse Power	0.040373	0.065042	*
Anti Lock Brake	0.187774	0.095269	*
Power Steering	-0.13114	0.093229	
Airbag, Driver Side	0.037494	0.452744	
Engine	0.235600	0.080714	*
Cargo	0.000963	0.006819	
Year Dummies			
1990	-0.188555	0.08461	*
1991	-0.065094	0.07760	
1992	-0.083594	0.07760	
1993	-0.053955	0.08461	
1994	-0.020548	0.08965	
1995	0.001769	0.08892	
1996	-0.014528	0.10330	
1997	0.06811	0.08866	
1998	0.0.03034	0.09185	

The * denotes significant at 10% level of significance

Table 4

Regression Results: USA

Weighted Least Squares; Observations 227
R^2: 0.8370

Variable	**Coefficient**	**Std. Error**	
Constant	6.574267	0.3917082	*
Length	-0.000668	0.0148382	
Width	0.4358385	0.0760496	*
Horse Power	0.0155852	0.0145447	
Anti Lock Brake	0.0529486	0.0229048	*
Power Steering	0.0845494	0.0399895	*
Airbag, Driver Side	-0.0672117	0.0460436	
Engine	0.171666	0.032902	*
Cargo	0.0085101	0.3917082	*
Year Dummies			
1990	0.0577214	0.0736871	
1991	0.1103112	0.0647747	*
1992	0.1933964	0.0634241	*
1993	0.192708	0.0440828	*
1994	0.2144317	0.0348909	*
1995	0.304509	0.0544282	*
1996	0.248571	0.0403741	*
1997	0.3467136	0.0576161	*
1998	0.3121027	0.0382422	*

The * denotes significant at 10% level of significance

Table 4A

Regression Results: Japan

Weighted Least Squares; Observations 97

R^2: 0.9124

Variable	**Coefficient**	**Std. Error**	
Constant	7.999859	1.049332	*
Length	0.0161065	0.0130854	
Width	0.1085498	0.2182262	
Horse Power	0.5454292	0.0907937	*
Anti Lock Brake	0.0.5957629	0.1676851	*
Power Steering	-0.1501578	0.629582	*
Airbag, Driver Side	-0.1413888	0.0427803	*
Engine	0.1941055	0.1307184	
Cargo	0.0007872	0.0114395	
Year Dummies			
1990	-0.2712091	0.1177759	*
1991	-0.0942	0.0794392	
1992	-0.0684094	0.0821997	
1993	-0.03766	0.0878049	
1994	0.1479638	0.0872502	*
1995	0.10336	0.0880033	
1996	0.1259695	0.085424	
1997	0.227827	0.0874589	*
1998	0.2017186	0.882228	*

The * denotes significant at 10% level of significance

Table: 5

Correlation Matrix

USA

	Sales	Length	Width	HP	Trans	Steering	Brake
Sales	1.00						
Length	-0.06	1.00					
Width	-0.02	0.67	1.00				
HP	-0.02	0.19	0.23	1.00			
Trans	0.01	0.00	0.05	0.02	1.00		
Steering	-0.05	0.33	0.31	0.15	0.18	1.00	
Brake	-0.05	0.11	0.14	0.20	0.07	0.21	1.00
Airbag	0.08	0.15	0.30	0.15	0.13	0.34	0.36
Engine	-0.08	0.58	0.65	0.23	0.00	0.33	0.08
Cargo	-0.15	0.38	0.46	0.10	-0.00	0.05	-0.01
Lprice	-0.16	0.59	0.72	0.32	0.01	0.51	0.36

	Airbag	Engine	Cargo	Lprice
Airbag	1.00			
Engine	0.11	1.00		
Cargo	-0.02	0.36	1.00	
Lprice	0.42	0.68	0.36	1.00

Note:
Lprice: LogPrice
Steering: Power Steering
Brake: Anti Lock Brake
Airbag: Driver Side Airbag
Cargo: Area of cargo space
HP: Hoorse Power

Table: 5A

Correlation Matrix

Japan

	Sales	Length	Width	HP	Trans	Steering	Brake
Sales	1.00						
Length	0.10	1.00					
Width	0.53	0.55	1.00				
HP	0.21	0.44	0.62	1.00			
Trans	-0.08	0.02	-0.17	-0.02	1.00		
Steering	0.08	-0.27	-0.12	-0.12	-0.02	1.00	
Brake	0.08	0.04	0.08	-0.03	0.39	0.02	1.00
Airbag	0.16	0.31	0.40	0.19	-0.12	-0.19	0.10
Engine	-0.07	0.09	0.13	0.22	0.31	-0.02	0.39
Cargo	0.14	0.24	0.22	0.19	-0.01	-0.11	0.02
Lprice	0.20	0.49	0.68	0.73	0.14	-0.25	0.21

	Airbag	Engine	Cargo	Lprice
Airbag	1.00			
Engine	0.01	1.00		
Cargo	-0.18	0.10	1.00	
Lprice	0.45	0.34	0.15	1.00

Note:
Lprice: LogPrice
Steering: Power Steering
Brake: Anti Lock Brake
Airbag: Driver Side Airbag
Cargo: Area of cargo space
HP: Hoorse Power

Table: 6

Range of Coefficients for Year Dummy
Regressions omitting one variable at a time
Weighted Least Squares

USA

Year Dummy	Coefficient Range		
1990	0.01	to	0.10
1991	0.04	to	0.14
1992	0.15	to	0.23
1993	0.12	to	0.24
1994	0.14	to	0.23
1995	0.20	to	0.35
1996	0.18	to	0.29
1997	0.23	to	0.38
1998	0.05	to	0.35

The range of these coefficients were found to be within plus minus two standard errors of the coefficients of the primary regression (95% level).

Table: 6A

Range of Coefficients for Year Dummy
Regressions omitting one variable at a time
Weighted Least Squares

Japan

Year Dummy	Coefficient Range		
1990	-0.34	to	-0.26
1991	-0.19	to	-0.07
1992	-0.61	to	-0.06
1993	-0.14	to	-0.02
1994	0.02	to	0.15
1995	0.01	to	0.11
1996	0.02	to	0.14
1997	0.12	to	0.23
1998	0.02	to	0.21

The range of these coefficients were found to be within plus minus two standard errors of the coefficients of the primary regression (95% level).

Table: 7

Annual Unit Value (From Actual Prices)

	USA		Japan	
	Unit Value	% Change Per Year	Unit Value	% Change Per Year
1989	$12,973		$10,412	
1990	$13,421	-3.45	$8,608	-17.33
1991	$13,885	+3.45	$12,432	+44.44
1992	$13,347	-3.87	$11,804	-5.05
1993	$14,068	+5.40	$12,543	+6.26
1994	$11,393	-19.00	$13,623	+8.61
1995	$15,076	+32.32	$14,146	+3.83
1996	$15,531	+3.02	$14,797	+4.60
1997	$16,366	+5.38	$14,910	+0.76
1998	$16,530	+1.00	$14,688	-1.49

The Unit Value per year was calculated by taking the weighted average of the actual prices of the car models. The sales of one model as a proportion of total annual sales was the weight used.

Table: 8

Annual Unit Quality
(From Predicted Quality Prices)
Weighted Least Squares

	USA		Japan	
	Unit Quality	% Change Per Year	Unit Quality	% Change Per Year
1989	$13,610		$10,973	
1990	$16,465	-20.97	$9,900	-9.78
1991	$15,513	-5.78	$12,784	+29.12
1992	$14,426	-7.01	$11,797	+7.72
1993	$14,519	+0.65	$11,308	-4.14
1994	$10,905	-24.89	$11,290	-0.16
1995	$14,435	+32.37	$10,374	-8.11
1996	$15,021	+4.06	$11,899	+14.7
1997	$14,702	-2.12	$13,063	+9.78
1998	$14,951	+1.69	$11,868	-9.14

The Unit Quality was the obtained by finding each predicted price with the regression coefficients excluding the year dummies. Then a weighted average for each year was calculated where the proportion of sales of each model was used as the weight.

Table: 9

Index Numbers for Unit Quality
From Predicted Prices
(Fisher's Index)
Weighted Least Squares

	USA		Japan	
	Unit Quality Index Number	% Change Per Year	Unit Quality Index Number	% Change Per Year
1989	93.73		97.03	
1990	113.40	-20.99	87.54	-9.78
1991	106.84	-5.78	113.04	+29.12
1992	99.35	-7.01	104.31	+7.72
1993	100	+0.70	100	-4.13
1994	75.10	-24.90	99.83	-0.17
1995	99.41	+32.37	91.73	-8.11
1996	103.45	+4.06	105.22	+4.71
1997	101.25	-2.12	115.51	+9.77
1998	102.96	+1.69	104.95	-9.14

<u>For the period 1989 to 1997</u>

For Japan: The Unit Quality Index increased from 97.03 to 115.51. This represents and increase by 19.04%

For USA: The Unit Quality Index increased from 93.73 to 101.25. This represents and increase by 8.02%

Table: 9A

Data For Calculating Index Numbers
For Unit Quality
(From Predicted Prices)
Weighted Least Squares

USA

Year	Unit Quality (predicted price)	Annual Sales	Fisher's Index
1989	$13,610	2,572,726	93.73
1990	$16,465	1,744,047	113.40
1991	$15,513	1,573,708	106.84
1992	$14,426	2,873,204	99.35
1993	$14,519	2,890,481	100.00
1994	$10,905	697,273	75.10
1995	$14,435	3,721,481	99.41
1996	$15,021	3,861,083	103.45
1997	$14,702	3,739,310	101.25
1998	$14,951	3,199,915	102.96

Japan

Year	Unit Quality (predicted price)	Annual Sales	Fisher's Index
1989	$10,973	159,209	97.03
1990	$9,900	472,253	87.54
1991	$12,784	1,225,645	113.04
1992	$11,797	1,535,691	104.31
1993	$11,308	1,447,640	100.00
1994	$11,290	1,655,609	99.83
1995	$10,374	1,979,525	91.73
1996	$11,899	538,584	105.22
1997	$13,063	1,942,612	115.51
1998	$11,868	1,919,635	104.95

The Fisher's Index Number was calculated as the Geometric Mean of the Laspeyer's and Paasche's Index Numbers. 1993 was used as the base year.

Table: 10

Index Numbers for Unit Value
From actual or observed Prices
(Fisher's Index)

	USA		Japan	
Year	Unit Value Index Number	% Change Per Year	Unit Value Index Number	% Change Per Year
1989	92.21		83.00	
1990	87.86	-4.72	68.63	-17.34
1991	98.70	+12.33	99.11	+44.44
1992	94.87	-3.88	94.11	-5.04
1993	100	+5.4	100	+6.26
1994	80.98	-19.02	108.61	+8.61
1995	107.16	+32.23	112.77	+3.83
1996	110.4	+3.02	117.96	+4.60
1997	116.33	+5.38	118.87	+0.77
1998	117.5	+1.00	117.10	-1.49

For the period 1989 to 1997

For Japan: The Unit Value (from observed prices) Index increased from 83.00 to 118.87. This represents and increase by 43.22%

For USA: The Unit Value (from observed prices) Index increased from 92.21 to 116.33. This represents and increase by 26.15%

Table: 11

Data For Calculating Index Number
For Unit Value
(From observed or actual prices)

USA

Year	Unit Value (observed price)	Annual Sales	Fisher's Index
1989	$12,973	2,572,726	92.21
1990	$13,421	1,744,047	87.86
1991	$13,885	1,573,708	98.70
1992	$13,347	2,873,204	94.87
1993	$14,068	2,890,481	100.00
1994	$11,393	697,273	80.98
1995	$15,076	3,721,481	107.16
1996	$15,531	3,861,083	110.40
1997	$16,366	3,739,310	116.33
1998	$16,530	3,199,915	117.50

Japan

Year	Unit Value (observed price)	Annual Sales	Fisher's Index
1989	$10,412	159,209	83.00
1990	$8,608	472,253	68.63
1991	$12,432	1,225,645	99.11
1992	$11,804	1,535691	94.11
1993	$12,543	1,447,640	100.00
1994	$13,623	1,655,609	108.61
1995	$14,146	1,979,525	112.77
1996	$14,797	538,584	117.96
1997	$14,910	1,942612	118.87
1998	$14,688	1,919,635	117.10

The Fisher's Index Number was calculated as the Geometric Mean of the Laspeyer's and Paasche's Index Numbers. 1993 was used as the base year.

Table: 12

Pooled Data for US and Japanese Cars

Number of Cars Sold Each Year for Models in the Data Set

Year	Sales Japan	Sales USA	Total Sales
1989	159,209	2,572,726	2,731,935
1990	472,253	1,744,047	2,216,300
1991	1,225,645	1,573,708	2,799,353
1992	1,535,691	2,873,204	4,408,895
1993	1,447,640	2,890,481	4,338,121
1994	1,655,609	697,273	2,352,882
1995	1,979,525	3,721,481	5,701,006
1996	538,584	3,861,083	4,399,667
1997	1,942,612	3,739,310	5,681,922
1998	1,919,635	3,199,915	5,199,550

This data was used to calculate the weights used for the weighted averages and index numbers for the pooled data for USA and Japan.

Table:13

Pooled Data for US and Japanese Cars

Unit Value of a car in this data set
And the Corresponding Fisher's Index
(From actual or observed prices)

Year	Unit Value Japan	Unit Value USA	Weighted Average Pooled Data
1989	$10,412	$12,973	$12,823
1990	$8,608	$13,421	$12,395
1991	$12,432	$13,885	$13,248
1992	$11,804	$13,347	$12,809
1993	$12,543	$14,068	$13,559
1994	$13,623	$11,393	$12,962
1995	$14,146	$15,076	$14,753
1996	$14,797	$15,531	$15,441
1997	$14,910	$16,366	$15,868
1998	$14,688	$16,530	$15,840

Index Numbers for Unit Value (from observed prices) in Pooled Data

Year	Weighted Unit Value	Total Sales in Data Set	Fisher's Index
1989	$12,823	2,731,935	94.57
1990	$12,395	2,216,300	91.41
1991	$13,248	2,799,353	97.70
1992	$12,809	4,408,895	94.46
1993	$13,559	4,338,121	100.00
1994	$12,962	2,352,882	95.59
1995	$14,753	5,701,006	108.80
1996	$15,441	4,399,667	113.87
1997	$15,868	5,681,922	117.02
1998	$15,840	5,119,550	116.81

Base Year is 1993

For the period 1989-1997 the index increases from 94.57 to 117.02 showing an increase of 23.7.

Table: 14

Pooled Data for US and Japanese Cars

Unit Quality of a car in this data set
And the Corresponding Fisher's Index
(From predicted prices)
Weighted Least Squares

Year	Unit Quality Japan	Unit Quality USA	Weighted Average Pooled Data
1989	$10,973	$13,610	$13,456
1990	$9,900	$16,465	$15,066
1991	$12,784	$15,513	$14,318
1992	$11,797	$14,426	$13,510
1993	$11,308	$14,519	$13,448
1994	$11,290	$10,905	$11,176
1995	$10,374	$14,435	$13,025
1996	$11,899	$15,021	$14,639
1997	$13,603	$14,702	$14,142
1998	$11,868	$14,951	$13,795

Index Numbers for Unit Quality (from predicted prices) in Pooled Data

Year	Weighted Unit Quality	Total Sales in Data Set	Fisher's Index
1989	$13,456	2,731,935	100.06
1990	$15,066	2,216,300	112.03
1991	$14,318	2,799,353	106.47
1992	$13,510	4,408,895	100.46
1993	$13,448	4,338,121	100.00
1994	$11,176	2,352,882	83.10
1995	$13,025	5,701,006	96.85
1996	$14,639	4,399,667	108.85
1997	$14,142	5,681,922	105.15
1998	$13,795	5,119,550	102.58

Base Year is 1993

For the period 1989-1997 the index increases from 100.06 to 105.15 showing an increase of 5.1%.

Table:15

Consumer Price Index
For new cars

Year	Consumer Price Index	Consumer Price Index Base Adjusted to 1993
1989	119.2	90.65
1990	121.0	92.01
1991	125.3	95.29
1992	128.4	97.64
1993	131.5	100.00
1994	136.0	103.42
1995	139.0	105.70
1996	141.4	107.52
1997	141.7	107.75

<u>For the period 1989 to 1997</u>

The consumer price index (base year adjusted to 1993, same base as used in the calculations of the other Fisher's Index numbers) has increased from 90.65 to 107.75. This is an increase by 18.87%.

Table: 16

Annual Unit Quality
(From Predicted Quality Prices)
Using ORDINARY LEAST SQUARES

	USA		Japan	
	Unit Quality	% Change Per Year	Unit Quality	% Change Per Year
1989	$12,471		$10,387	
1990	$16,094	+29.05	$9,701	+6.60
1991	$15,144	-5.90	$12,251	+26.28
1992	$14,040	-7.29	$11,979	-2.22
1993	$14,051	+0.08	$12,577	+4.99
1994	$10,789	-23.21	$12,844	+2.12
1995	$14,438	+33.82	$11,888	+7.44
1996	$14,670	+1.60	$13,961	+17.43
1997	$14,675	+0.03	$13,745	-1.54
1998	$14,946	+1.84	$13,688	-0.41

The Unit Quality was the obtained by finding each predicted price with the regression coefficients excluding the year dummies. Then a weighted average for each year was calculated where the proportion of sales of each model was used as the weight.

Table: 17

Index Numbers for Unit Quality
From Predicted Prices
(Fisher's Index)
USING OLS

	USA		Japan	
	Unit Quality Index Number	% Change Per Year	Unit Quality Index Number	% Change Per Year
1989	88.76		82.58	
1990	114.54	+29.04	77.12	+6.61
1991	107.78	-5.90	97.40	+26.29
1992	99.92	+7.29	95.24	-2.26
1993	100	+0.08	100	+4.99
1994	76.78	-23.32	102.12	+2.12
1995	102.75	+33.82	94.51	+7.45
1996	104.40	+1.60	111.00	+17.44
1997	104.44	+0.04	109.28	-1.55
1998	106.37	+1.84	1-8.82	-0.42

<u>For the period 1989 to 1997</u>

For Japan: The Unit Quality Index increased from 82.58 to 109.28. This represents and increase by 32.33%.

For USA: The Unit Quality Index increased from 88.70 to 104.44. This represents and increase by 17.74%.

Table: 18

Pooled Data for US and Japanese Cars

Unit Quality of a car in this data set
And the Corresponding Fisher's Index
(From predicted prices)
Using Ordinary Least Squares

Year	Unit Quality Japan	Unit Quality USA	Weighted Average Pooled Data
1989	$10,387	$12,471	$12,350
1990	$9,701	$16,094	$14,732
1991	$12,251	$15,144	$13,877
1992	$11,979	$14,040	$13,322
1993	$12,577	$14,051	$13,559
1994	$12,844	$10,789	$12,235
1995	$11,888	$14,438	$13,552
1996	$13,961	$14,670	$14,583
1997	$13,745	$14,675	$14,357
1998	$13,688	$14,946	$14,474

Index Numbers for Unit Quality (from predicted prices) in Pooled Data

Year	Weighted Unit Quality	Total Sales in Data Set	Fisher's Index
1989	$12,350	2,731,935	91.08
1990	$14,732	2,216,300	108.64
1991	$13,877	2,799,353	102.34
1992	$13,322	4,408,895	98.25
1993	$13,559	4,338,121	100.00
1994	$12,235	2,352,882	90.23
1995	$13,552	5,701,006	99.95
1996	$14,583	4,399,667	107.55
1997	$14,357	5,681,922	105.88
1998	$14,474	5,119,550	106.74

Base Year is 1993

For the period 1989-1997 the index increases from 91.08 to 105.88 showing an increase of 16.24%.

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ABSTRACT

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Using Hedonic Prices to estimate Quality Changes in American and Japanese Cars

Dissertation directed by Dominick Salvatore, Ph.D.

The economic foundation of this thesis lies in the idea of characteristic approach to consumer demand proposed by Kevin Lancaster (1971). This opines that a good per se does not provide consumers with utility, rather the characteristics inherent in the good give rise to utility. Thus every characteristic, from the perception of the consumer, has a price. This is the hedonic price or implicit price. The hedonic pricing approach was later used by Feenstra (1987) to find how much of price increases in Japanese and American cars during 1981-1985 could be attributed to quality improvement. This research takes forward the techniques of Feenstra to car price changes of the last decade and further adds new dimensions to it by incorporating new characteristics and using a different regression technique. The overall finding of Feenstra regarding Japanese cars having a higher quality improvement is found again, but to a lesser degree. The results of this research are then validated by comparisons with the Consumer Price Index for new cars and adjusted for the quality bias proposed in 1996 by the Boskin Commission.

Vita

Biswa Pratim Bhowmick, son of Bejon and Maya Bhowmik, was born on May 22, 1966 in Calcutta, India. After graduating from St. Xavier's College, Calcutta, he entered the graduate program in Economics at Fordham University and was a recipient of a Presidential Tuition Scholarship and a graduate assistantship. In 1990 he received the M.A. in Economics.

After completing all coursework towards the PhD. in 1991, he joined the Higher Education Opportunity Program (HEOP) of Fordham University, Rose Hill campus as a full-time administrator in September 1991 and has worked there since then. His current position is Associate Director for Administration. Before starting his doctorate dissertation he took a leave of absence to pursue the M.B.A. at Fordham University which he got in 1995. He is also an adjunct instructor at Fordham University.