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Product Quality, Gasoline Prices, And Japanese Shares In The U.S. Automobile Market

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There are many casual explanations of the factors that have helped Japanese automobile producers to penetrate the U.S. market. However, both the theoretical explanation and empirical analysis of the effects of such factors are still lacking. The purpose of this study is to formally propose a hypothesis based on the state-dependent consumer theory and further, to econometrically test such a hypothesis. Our hypothesis is that quality, in addition to low prices and fuel economy, has helped Japanese automobile producers penetrate the U. S. market. A time series index of quality for Japanese and domestic cars is constructed using the "trouble index" reported in Consumer Reports. The index is then used, along with other relevant data, to estimate the joint effect of gasoline price and quality on the Japanese share of the U. S. automobile market. Our results show that these factors have had a statistically significant effect on the Japanese share, indicating that domestic producers could regain significant market share by improving their quality and reliability.

I. INTRODUCTION

Japanese automobile producers began to expand their sales in the U. S. market in the late 1960s. With total sales of 69,200 cars in 1967, the Japanese share of the U. S. market was less than one percent at the time. The sales of Japanese cars exceeded one million (reaching 1.39 million) for the first time in 1977. Their car sales continued to grow through the 1980s even after the voluntary export restrictions (VER) became effective in 1981. In recent years, the VER, dollar devaluation, quality improvement in domestic cars, and transplant operations by Japanese car makers in the U.S. have all contributed to reducing automobile imports from Japan. However, the combined (imports plus transplant production) Japanese market share in the U.S. has continued to grow. By 1992, the combined Japanese share had reached 31.8% of total U.S. passenger car sales.[1]

On the issue of Japanese penetration of the U. S. automobile market, many have suggested that low prices, fuel economy, and quality have made that possible. That is, economy and quality are important factors.[2] It has also been suggested that despite the decline in their traditional advantages of low prices and high gasoline mileage since the 1980s, Japanese producers have been able to maintain and even improve their position in the U.S. automobile market because of the quality of their products.[3]

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The goal of this study is twofold. First, the goal is to provide a theoretical explanation and, second, the goal is to empirically test the hypothesis we propose on the factors contributed to the successful penetration of Japanese automobiles in the U.S. market. Although the above casual observations seem to be reasonable, the theoretical explanation and empirical evidence have been insufficient. The conventional consumer theory fails to explain why consumers didn't consider Japanese cars as a viable alternative choice in the 1960s when they were inexpensive and fuel-efficient. Based on the state-dependent consumer theory, we propose that three major factors--the gasoline price increase in the 1970s, the delay of producers' response, and the quality and reliability of Japanese cars--have jointly contributed to the success of Japanese penetration into the U.S. market. Empirical studies of the impact of their quality on the demand for Japanese cars have been impeded by the fact that appropriate data on quality are not available. In the latter part of this paper, we will construct an econometric model inspired by our hypothesis and use a quality index compiled from the consumer survey information published by the Consumer Reports to empirically substantiate our proposition.

This paper is organized as follows. Section II uses the state-dependent consumer theory to explain why and how the three major factors--the increased gasoline prices, the delayed producers' response, and product quality and reliability--have jointly contributed to Japan's success in the automobile market. Section III summarizes the results from previous empirical studies on this issue. Section IV describes the econometric model employed in this study; and Section V presents and discusses empirical estimates of the structural equations. Section VI then analyzes the impact of increased Japanese market share on individual U.S. domestic producers. Concluding remarks are presented in Section VII.

II. THEORETICAL FOUNDATION

In contrast to the traditional rationality hypothesis that assumes that a consumer establishes a preference ordering over all the available alternatives, we use the "state-dependent framework" to build our model. In this (state-dependent) framework, a consumer will first identify a subset (of goods and services) that is relevant to his/or her choice in his/or her given state from all available alternatives. The consumer will then establish a preference ordering over the relevant alternatives before a choice is made [12]. In this paper, we use transportation and automobiles as examples to demonstrate how the state-dependent framework can be applied to explain many economic issues. We propose that three major factors--the increased gasoline prices, the delayed producers' response, and product quality and reliability--have jointly contributed to Japan's success in the automobile market.

A. Consumer Response to Gasoline Price Increase

On the issue of shifts in the demand from large to small cars, Toder, Cardell and Burton [22] have observed that "the gasoline price increases and fears of shortage and the decline in real income during two recessions (1971-72 and 1974-75) encouraged a shift to smaller, more economical cars." Many of the consumers whose demands had shifted, however, had never considered small cars until that time. For such consumers, shifts in demand from large to small cars could have materialized only after they had added small cars to the alternatives in their choice set. That is, *demand shifts could have occurred only after the consumption space was expanded to include small cars*. We provide an explanation of why an increase in gasoline price can cause the consumption space to change.

Transportation is an integral part of almost all-human activities, such as employment, education, social activities, obtaining goods and services, and vacation, etc. Thus, the flows of transportation are derived from the flows of other human activities. In fact, transportation is required to facilitate efficient production of other human activities. A requirement of this type is functional in nature and is therefore called a functional requirement. For example, there is a functional requirement for transportation associated with an individual's employment. This requirement can be quantified by the frequency of trips and the travel distance between the individual's residence and his or her work place. If the travel distance is 7.5 miles, then the functional requirement for transportation to and from work is 15 miles each day.

Beyond the example of employment, there are many other activities for which transportation is required. How the functional requirements for transportation are satisfied depend on the means that are available. These can include using public transportation, driving, and/or using one's own feet; in the U. S., the primary method is driving. The functional requirement for transportation will thus in turn give rise to a requirement for gasoline. However, given an individual's functional requirement for transportation, his or her need for gasoline further depends on the type of car he or she is driving. To illustrate, assume that an individual is required to drive 200 to 250 miles per week to be able to perform various activities efficiently. If the available automobile is a large car yielding 10 miles per gallon, then the individual would need 20 to 25 gallons of gasoline per week to be able to meet his or her transportation requirement. However, if the individual drives a small car yielding 20 miles per gallon, the need for gasoline is between 10.0 and 12.5 gallons for the same amount of driving. The example is illustrated in Figure 1. It shows that functional requirements for transportation and technical constraints imposed by the available cars jointly limit the alternatives about gasoline that are relevant to one's choices. These alternatives are called the state-dependent consumption set for gasoline.

To show how a consumer who maintains a lifestyle built on a large car will consider a small car when the price of gasoline increases, assume that the individual uses a two-stage budgeting process. The consumer first allocates his or her spending among functionally separable categories of expenditures. In Figure 2, the budget allocated for transportation is represented by the length OA on the vertical axis; gasoline usage is on the horizontal axis. The state-dependent consumption set involving gasoline usage is in the interval of 20-25 gallons when a consumer drives a large car and is in the interval of 10.0-12.5 gallons when a consumer drives a small car. Before the gasoline price increase, the consumer's allocated budget is given by the line AB. In this case, the amount that the consumer has allocated for transportation is sufficient to maintain a lifestyle built on a large car. Now suppose that there is a sharp increase in the price of gasoline such as that occurred in 1973; the budget line rotates from line AB to AC. The consumer is no longer able to maintain his or her established lifestyle with the allocated budget and a large car; i. e., this individual is unable to produce activities efficiently. Instead of a large car, a small car will, however, make it possible for the individual to satisfy the functional requirements for transportation. Small cars are therefore one alternative that a consumer will consider when the gasoline price is increased to the extent that the allocated budget is not sufficient for meeting the gasoline requirement with a large car.

Figure 1
Gasoline Usage and Transportation Requirement

Figure 2
Budget and Gasoline Usage

In the 1960s, when Japanese producers first entered the U. S. market, they entered as niche players. Meanwhile, developments in the U. S. had opened a window of opportunity for Japanese producers to become major suppliers. These developments include the rising inflationary pressure in the late 1960s and the sharp increase in the gasoline price that resulted from the oil embargo imposed by OPEC in 1973.[4] Inflationary pressure had caused consumers to search for lower priced products while the increase in gasoline prices caused more consumers to shift their demand from large to small cars. However, the domestically produced small cars in the U. S. not only were inadequately supplied at the time but also were fuel inefficient. For example, Toder et al. [22] suggest that "the inferiority of U. S. small cars in fuel economy compared to Japanese and German competitors accentuated the shift to imports." In fact, Volkswagen (VW) was the only small car producer that had an established position in the U. S. market at that time.[5] These dynamics of the automobile market are observed by Toder et al. [22, p. 30] noting that "throughout the 1960s, cars sold in the United States became bigger and more powerful as incomes rose and real gas prices fell; at the same time U.S. manufacturers abandoned the small-car field to foreign competitors." The window of opportunity was therefore opened for Japanese producers to become major suppliers when the domestic supply of small cars responded only slowly to the shift in consumer demand.

B. Delay in Producer Response

While consumers had expanded their choice space to include small cars, the production space of U. S. automakers continued to be limited to mostly large cars during the 1970s. There are several reasons why U. S. producers had responded very slowly to the changes in the market condition.

On the revenue side, a small car, by its nature, has a low profit margin. A small car is bought because of its low price and its economical operation. People with low incomes most often buy such cars. The extent to which prices of such cars can be increased may be quite limited even in a period of rising demand.

On the cost side, there were problems of high wage rates and high capital costs associated with the rising interest rate throughout the 1970s.[6] Wage rates have been higher in the United States than in Japan until recently. U. S. wage rates had increased from the late 1960s through the early 1980s.[7] Problems of high wages and wage growth are particularly serious if they are not matched by high level and growth rate of labor productivity. Wage settlements that exceed increases in labor productivity are particularly acute for products with low profit margins.

Aside from the problem of low profit margin and high cost of production, supply responsiveness also was limited because well-established and mature industries have a limited ability to adapt to new conditions. In the 1970s, the U. S. capital stocks and technological know-how were devoted to the production of large cars. Moreover, there was uncertainty regarding whether the increased demand for small cars was permanent since the domestic producers had previously been unsuccessful in producing such cars. Added to all of these difficulties were the decisions made by domestic producers to use available opportunities to raise domestic prices instead of using pricing restraints to counter the expansion of imports. Therefore, considering the American automobile market as a whole, the American and Japanese automobile producers became complementary producers that served different segments of the market in the 1970s.

C. The Role of Quality and Reliability

Although the sharp increase in gasoline prices has broadened consumers' choice space, the effect could well have been temporary. Consumers could have ceased to consider Japanese cars once the rate of gasoline price increase moderated or once U. S. producers began to produce small cars. Indeed, the real price of gasoline has decreased since the early 1980s and U. S. producers have produced many small cars. But consumers continued to buy Japanese cars. A plausible explanation for this is that in addition to the increase in gasoline prices and delayed producers' response, a high level of quality and reliability also helped Japanese producers to increase and maintain their market share. On the other hand, until recent improvement, domestically produced cars have been defects-prone.

While consumers were very aware of the shortcomings of domestically produced automobiles, few alternatives were available before the entry of Japanese cars. The 1950s and 1960s were time periods in which inflation was not a problem. The gasoline price was low and falling in real terms. The primary concerns of consumers then were with styles, new features, and sizes of automobiles. Only when inflationary pressure began to rise in the late 1960s and gasoline prices increased sharply in the 1970s did reliability and operational economy became major concerns. Figure 3 depicts the quality index we have constructed for Japanese and U. S. cars between 1967 and 1992.

Figure 3
The Quality Index

Since the early 1980s, Japanese producers' advantages of low prices and fuel economy have been considerably reduced. But they have been able to maintain their market position because of the continuing quality and reliability superiority of their products. In this section, we have used the state-dependent framework to propose the following hypothesis: *Initially, the inflationary pressure in general and the gasoline price increase in particular had caused U. S. consumers to add small cars to their choice space. However, it is their quality and reliability that have made Japanese cars a "permanent" element in the U. S. consumption space.*

In the next section, we will summarize previous empirical studies on this issue, followed by our econometric study inspired by the hypothesis we have posted in this section.

III. PREVIOUS EMPIRICAL STUDIES

Empirical studies of the impact of automobile quality on the demand for automobiles are impeded by lack of an appropriate and commonly agreed set of data on automobile quality. Researchers have used two different approaches to take explicit account of the impacts of quality. One approach, used by Toder, Cardell and Burton [22], Levinsohn [13], and Feenstra [6], is to use physical characteristics such as weight, length, options, and roominess to represent automobile quality in their demand studies. Physical characteristics, however, may be a better measure of product heterogeneity than of quality. The other approach, used by Ohta and Griliches [18] and Trandel [23] is to construct a proxy quality index from the information published by the Consumers Union and the Environmental Protection Agency.

In Ohta and Griliches' study, mileage per gallon (MPG) is chosen to represent fuel economy (one aspect of quality) and the MPG is used in addition to some physical characteristics to study whether U.S. consumers have significantly changed their tastes in used cars in the face of rising gasoline costs in the 1970s. Trandel's work includes the period 1982-1985 only and estimates a single demand equation for 70 different car models sold in the U.S. Neither Ohta and Griliches' work nor Trandel's work focuses on the question of how quality affects the demand for Japanese cars; the former authors do not distinguish Japanese (used) cars from domestic ones, and the latter author lumps all cars that are not produced in the U.S. in one category--foreign cars. Dardis and Soberon-Ferrer [5] use the "cost index" and "trouble index" published by Consumer Reports, miles per gallon, weights, and depreciation rate combined with data from the 1986 BLS Consumer Expenditures Survey to study the relationship of automobile attributes and household characteristics to consumer preferences for Japanese cars in a two-stage probit analysis.

No one would dispute the importance of "quality" in consumers' purchasing decisions. However, we would like to know quantitatively how important quality is in affecting the Japanese share of the U.S. automobile market. There is no uniform definition of "quality." As a matter of fact, the definition of "quality" itself seems to change over time. Physical characteristics (of automobiles) such as horsepower certainly represent some aspects of "quality." However, from consumers’ points of view, if a car with large horsepower also needs frequent repairs, it represents poor quality. For this reason, instead of using physical characteristics to represent product quality, we use the “trouble index” published by Consumer Reports to better capture the concept of “quality.” The “trouble index”[8] is compiled from reports of its subscribers based on their experiences. Data compiled in this way not only contain information about the realized actual quality and reliability but also contain information about individuals’ perception, attitude, and sentiment about a particular brand name of automobile. Such data are therefore especially useful in explaining consumer demand for a particular product. For this reason, we construct a time series index of automobile quality from 1967 to 1990 for Japanese, General Motors, Ford, Chrysler, and Volkswagen automobiles. We then use this index together with annual passenger car sales data during the same period to estimate the effect of realized actual quality and quality perception (hereafter, referred to as “quality”) on the Japanese share of the U. S. automobile market.

IV. MODEL SPECIFICATION

To empirically substantiate the idea that gasoline prices and quality have helped Japanese producers gain and maintain their market share in the U.S., a simultaneous equation model has been constructed and estimated. In addition to assessing the joint effects of gasoline prices and automobile quality, the model is designed to determine the effect that the increase in Japan’s share has had on other aspects of U.S. automobile demand--specifically, how Japan’s market share has influenced Volkswagen’s share, how it affects perception about Japanese cars, how it affects the median age of automobiles in use, how it affects the stock of automobiles, and how the increased stock affects automobile demand in general.

The endogenous variables in the model are:

JS	Japanese share (including imports and transplant products) in the U. S. (passenger) automobile market in percent,
JQ	Japanese car quality index,[9] compiled from the “trouble index” in the annual issues of Consumer Reports,[10]
VW	Volkswagen share in the U. S. automobile market in percent,
MA	Median age of automobiles in stock in years,
ST	Mid-year stock of automobiles per capita,
YD	Demand for new automobiles per capita.

The predetermined variables in the model are:

IN	Disposable personal income per capita in constant 1987 dollars,
DP	Price index of domestic automobiles,
MP	Price index of all imported cars,
DQ	Quality index of domestic cars,
VQ	Quality index of Volkswagen,
PG	Price index of gasoline,
LG	Price of gasoline lagged one period,
LA	Median age of automobiles lagged one period,
LS	The stock of automobiles per capita lagged one period,
LJ	Lagged Japanese market share,

LY Lagged demand for new automobiles per capita,
T A time variable (T = 1, 2, ..., 24)

Before discussing model specifications, it is noted that in the absence of any theoretical basis for ascertaining an appropriate functional form, we have estimated linear, log-linear, and other forms of relationships. The estimates obtained from these different functional forms are then compared using the R-squares, Durbin-Watson statistics, and t-ratios. As a result of this comparison, we have chosen the log-linear form as the most appropriate relationships for this study. To simplify the representation, lower-case letters will be used to designate the logarithmic form of each variable, i.e., $js = \log_e JS$, etc.

To explain Japan's market share (js), we have included, in addition to the traditional demand variables of income (in) and relative price (rp), various other variables: gasoline price (pg), relative quality, as measured by the ratio of Japanese quality (JQ) to domestic quality (DQ), and lagged Japanese market share (lj) as explanatory variables.[11] Gasoline price and relative quality are entered in the market share equation as an interaction variable, gq, where $GQ = PG*(JQ/DQ)$.[12] Japan's market share, lagged one period, is used as a proxy for the shift inconsumption space. The market share equation is

$$js = \alpha_1 + \alpha_2\, rp + \alpha_3\, gq + \alpha_4\, in + \alpha_5\, lj + u_1\ ,\ \alpha_2 < 0;\ \alpha_3, \alpha_4, \alpha_5 > 0 \qquad (1)$$

U.S. producers had long established their position in the U.S., but Japanese cars were relatively new alternatives and thus consumers would have considered them only gradually as they were exposed to them. Therefore, while quality of Japanese cars affects Japan's market share in the model, the increased exposure that results from increased use may also affect the attitude toward and the acceptability of Japanese cars. Japan's market share is a measure of its use and exposure. The acceptability can also change gradually over time. For this reason, we treat the quality index for Japanese cars as an endogenous variable and relate it to Japan's market share (js) and time (T). The equation is as follows:

$$jq = \alpha_1 + \alpha_2\, js + \alpha_3\, T + u_2\ ,\ \alpha_2 > 0;\ \alpha_3\ ? \qquad (2)$$

To determine the extent to which Japan's gain had been at the expense of Volkswagen, a VW market share equation is formulated using lagged Japanese market share (lj), VW's quality index (vq), VW's lagged market share (lv), and a dummy variable for the year 1970, as explanatory variables. The dummy variable is included because, as previously noted, rising inflationary pressure and recession in 1970 had caused a major shift in demand to small cars and VW was the only small car producer to have an established position to benefit from this demand shift. The equation is

$$vw = \alpha_1 + \alpha_2\, lj + \alpha_3\, lv + \alpha_4\, vq + \alpha_5\, D70 + u_3\ ,\ \alpha_2 < 0;\ \alpha_3, \alpha_4, \alpha_5 > 0. \qquad (3)$$

Improved quality should increase the length of time over which an automobile is used. For this reason, median age (ma) of automobiles in stock is related to the quality index for Japanese automobiles (jq). A lagged median age variable (la) is also used as an explanatory variable to capture the habitual aspect of keeping a car for a certain length of time. The equation is

$$ma = \alpha_1 + \alpha_2\ jq + \alpha_3\ la + u_6\ ,\ \alpha_2, \alpha_3 > 0 \qquad (4)$$

It is assumed that an increase in the length of time over which automobiles are used has the effect of increasing the automobiles in stock, measured on a per capita basis. The stock of automobiles per capita (st) is therefore related to the lagged median age (la) and the lagged automobile stock (ls). The latter is used as an explanatory variable since it changes slowly over time. The equation is

$$st = \alpha_1 + \alpha_2\ ls + \alpha_3\ la + u_5\ ,\ \alpha_2, \alpha_3 > 0 \qquad (5)$$

Finally, an increase in the stock of automobiles, viewed in a stock-adjustment framework, should have a negative effect on the current demand. Per capita demand for new cars (yd) is therefore related to the stock of automobiles lagged one period (ls). Other explanatory variables that are used include disposable income (in), the domestic new car price index (dp), and the price of gasoline lagged one period (lg).[13] We include the gasoline price index as an explanatory variable in this equation to test the hypothesis that, since fuel economy of new cars has improved over the years, increased gasoline price had induced consumers to accelerate their purchase of new, fuel efficient cars. The equation is

$$yd = \alpha_1 + \alpha_2\ in + \alpha_3\ dp + \alpha_4\ ls + \alpha_5\ lg + u_6\ ,\ \alpha_{2,}\ \alpha_5 > 0;\ \alpha_3, \alpha_4 < 0. \qquad (6)$$

V. ANALYSIS OF ESTIMATES

Annual data for the United States over the period of 1967 to 1990 are used in this study. Sources of data include *Consumer Reports* [4], *Economic Reports of the President* [21], *MVMA Motor Vehicle Facts and Figures* [17], *Statistical Abstracts of the United States* [20], and *Ward's Automotive Yearbook* [24].

To correct for contemporaneous correlation in the error terms between structural equations, the three-stage least squares method (3SLS) is used in our estimation. All variables except the time variable (T) and the year dummy (D70) are transformed into natural logarithms before estimation. Durbin-Watson or Durbin-h test is performed on each estimated equation. The results indicate that there is no problem of first order autocorrelation. The estimates, with t-ratios in parentheses, are presented in Table 1.

It should be noted that the R-squares are provided by SAS in the second stage estimation. The system weighted R-square is 0.990, which indicates that the model has a promising explanatory power. All estimated coefficients have the expected signs and, with the exception of that for lagged gasoline price index (lg) in (6E) and that for lagged median age variable (la) in (5E), they are statistically significant.[14]

Table 1
Estimation Results

$$js = -4.863 - 1.556\ rp + 0.164\ gq + 2.059\ in + 0.774\ lj \qquad (1E)$$
$$(2.21)\quad (2.11)\qquad (2.76)\qquad (2.36)\qquad (9.24)$$
$$R^2 = 0.98 \quad SEE = 0.13 \quad \text{Durbin-h} = 0.87 \quad \rho = 0.16$$

$$jq = 1.142 + 0.222\ js - 0.019\ T \qquad (2E)$$
$$(20.05)\quad (4.80)\qquad (3.16)$$
$$R^2 = 0.54 \quad SEE = 0.08 \quad \text{Durbin-h} = 1.85 \quad \rho = 0.03$$

$$vw = 0.493 - 0.170\ lj + 0.558\ lv + 0.242\ vq + 0.288\ D70 \qquad (3E)$$
$$(1.87)\quad (3.21)\qquad (5.15)\qquad (2.30)\qquad (2.08)$$
$$R^2 = 0.9 \quad SEE = 0.14 \quad \text{Durbin-h} = 0.32 \quad \rho = 0.06$$

$$ma = -0.012 + 0.147\ jq + 0.894\ la \qquad (4E)$$
$$(0.20)\quad (3.63)\qquad (26.85)$$
$$R^2 = 0.98 \quad SEE = 0.02 \quad \text{Durbin-h} = 1.50 \quad \rho = 0.30$$

$$st = 0.433 + 0.873\ ls + 0.047\ la \qquad (5E)$$
$$(3.61)\ (19.60)\qquad (1.31)$$
$$R^2 = 0.99 \quad SEE = 0.01 \quad \text{Durbin-h} = 0.07 \quad \rho = 0.04$$

$$yd = 2.787 + 3.380\ in - 0.543\ dp - 1.884\ ls + 0.008\ lg \qquad (6E)$$
$$(1.75)\quad (2.90)\qquad (2.27)\qquad (2.29)\qquad (0.07)$$
$$R^2 = 0.67 \quad SEE = 0.08 \quad \text{Durbin-h} = 1.25 \quad \rho = 0.23$$

Turning to specific issues, the estimated market share equation (1E) shows that the variable (GQ), which represents the interaction of gasoline price and quality, has a statistically significant effect on Japan's share in the U. S. market. The effects of relative price and disposable personal income are negative and positive, respectively, as expected.

Equation (2E) shows that Japanese market share has a positive effect on quality. That means that increasing exposure to Japanese cars does help to improve perceived quality of Japanese cars. The estimates in equation (3E) are consistent with the hypothesis that Japanese products partly replaced Volkswagen in the U. S. market. In Equation (4E), we find that quality of Japanese cars has a positive effect on the median age of automobiles in stock. Equation (5E) shows that increased length of use, as represented by the median age, has a positive but statistically not significant effect on the stock of automobiles measured on a per capita basis. The increased automobile stock, as shown in equation (6E), in turn, has a negative effect on automobile sales. The sales per capita, as expected, are a positive function of income and a negative function of prices. The gasoline price, while exhibiting a positive sign, does not have a statistically significant effect on the demand for new automobiles. This indicates that, while gasoline price affects the type of cars that consumers purchase, it does not affect the number of new cars being demanded.

To further test and evaluate the estimated model, a historical simulation over the estimation period and a simulation beyond the estimation period are also performed [19]. The results of our simulation, together with the original series for Japan's and VW's market shares are presented in Figures 4 and 5.[15] These figures show that the simulated series well fit the original series within the estimation period, confirmed by relatively small values of the RMS (root-mean-square) simulation error and the mean simulation error presented in columns 2 and 3 in Table 2.

Table 2
Results of Historical Simulation (1967-1990)

	Japan	VW	GM	Ford	Chrysler
Mean (%)	15.22	2.97	42.56	21.14	11.19
RMS	0.41	0.07	0.43	0.25	0.15
Mean Error	0.18	-0.02	-0.00	-0.02	-0.01

For simulation beyond the estimation period, we have collected the actual statistics for the exogenous variables in the model for the years 1991 and 1992. We then calculate Japanese market share under several hypothetical cases about improvements in quality for U. S. domestic cars. In this simulation, quality index for Japanese cars is assumed to remain at the 1990 level of 4.34. The results of this simulation are presented in Table 3.

Table 3
Japanese Market Share 1991-1992 (%)

	Actual	Simulated Value if Domestic Quality Index is:				
		2.49	3.0	3.5	4.0	4.34
1991	31.26	32.35	28.10	25.02	22.62	21.27
1992	31.82	31.37	27.26	24.27	21.95	20.64

As shown in the table, the actual market share of Japanese producers was 31.26% in 1991 and 31.82% in 1992. These values are quite close to the simulated Japanese market share values of 32.35% for 1991 and of 31.37% for 1992, which are obtained under the assumption that the domestic quality index remains at the 1990 level of 2.49. The table also shows that if the domestic quality index had been higher, the Japanese market share would have been substantially lower. The results indicate that relative quality can affect the Japanese share in the U. S. market to a very important extent. One implication is that, assuming that the cost of production and prices are unaffected, domestic producers could regain significant market shares by improving their quality and reliability.

Figure 4
Japan’s Market Share

Figure 5
Volkswagen’s Market Share

VI. IMPPACTS ON INDIVIDUAL U. S. PRODUCERS

Since Japanese producers have become important suppliers in the U.S. automobile market, we also consider several issues that are associated with the market position of each individual domestic producer. These are the following: how has the market share of each domestic producer been directly affected by Japan's market share gains? How is each producer affected by its own quality? How is each producer affected by its own brand loyalty? And, how is each producer affected by the recessions that commenced in 1970 and 1974? The years 1970 and 1974 were critical not only for the U.S. automobile industry as a whole but also for individual U.S. producers because these are both critical times in which the pattern of demand underwent a fundamental change.

To provide answers to the above questions, the market shares of General Motors, Ford, and Chrysler are related to the Japanese market share, own quality, lag of own market share, and dummy variables representing the years 1970 and 1974. The estimated equations, with t-ratios in parentheses, are presented in Table 4.[16]

Table 4

Impacts on Individual U.S. Producers

Market Share Equations

Independent Variables	General Motors	Ford	Chrysler
Intercept	- 0.262 (2.11)	- 0.627 (2.65)	- 1.598 (3.80)
Lagged Market Share	0.838 (6.73)	0.674 (5.69)	0.420 (2.52)
Own Quality Index	0.118 (1.58)	0.018 (0.15)	0.036 (0.34)
Japanese Share	- 0.005 (0.22)	-0.041 (1.90)	- 0.122 (2.82)
Dummy Variable for:			
1970	- 0.184 (3.02)	0.092 (1.22)	0.138 (1.52)
1974	- 0.072 (1.22)	0.087 (1.17)	0.090 (1.02)
R^2	0.81	0.83	0.89
SEE	0.06	0.07	0.08
Durbin-h	0.93	1.94	2.06
ρ	0.16	0.33	0.26

As shown in Table 4, the effect of Japanese market share on each domestic producer's market share is negative. The coefficient of Japanese market share in the market share equation for General Motors, however, is not statistically significant. The evidence is different for Ford and Chrysler. Specifically, Japanese market share has had statistically significant negative effects on Ford's and Chrysler's market shares. The effect of own quality, while positive, is not statistically significant for each producer. A plausible explanation for these results is that quality is a relevant variable. But, considering the fact that domestic producers had made little progress in their pursuit of quality during the sample period, the own quality index had little explanatory power.

The estimates in Table 4 also show that lagged market share has a positive and statistically significant effect on the market share of each individual producer. This implies that brand loyalty has enabled each producer to retain its market share.

Moreover, the differences in the lagged market share coefficients imply that brand loyalty is different for these producers. Specifically, the estimates indicate that GM, with the coefficient of 0.838, had the greatest brand loyalty (probably because GM has produced the largest variety of automobiles); while Chrysler, with the coefficient of 0.42, had the least brand loyalty among the three producers between 1967 and 1990. The estimates also show that the recessions that commenced in 1970 and 1974 affected GM adversely. In contrast, these two recessions have positive though not statistically significant effects on Ford and Chrysler market shares.

A historical simulation of the market share variable is also performed for each domestic producer. The results, shown in Figures 6, 7, and 8, indicate that the simulated series reproduces the general behavior of the actual series quite well. The RMS simulation errors and the mean simulation errors, summarized in Columns 4, 5, 6 in Table 2, are relatively small.

VII. CONCLUDING REMARKS

In this paper, we have suggested that Japan’s success in the U. S. automobile market is a result of the convergence of many factors. In the 1960s and 1970s, Japan had a comparative advantage in the production of small cars and it aggressively expanded its exports of small cars. Although Japanese producers entered the U. S. market initially as niche players, a window of opportunity was opened for them to become major suppliers when consumer demand shifted to small cars due to the rising inflationary pressure in general and the rising gasoline price in particular. U.S. producers, however, were slow and ineffective in their response to the shift in consumer demand.

Empirical evidence obtained in this study supports the hypothesis that gasoline price and quality jointly enabled Japanese producers to expand and maintain their market share in the United States. The increased importance of Japanese products, in turn, has other effects on U. S. automobile demand. Specifically, quality and its perception prolong the median age of the automobile stock, which in turn increases the stock of automobiles measured on a per capita basis. Finally, the increase in automobile stock has a negative effect on the demand for automobiles.

Although coincidental and complementary developments helped Japanese automobile producers to penetrate the U.S. market, recent evidence indicates that producers in these two countries have entered a new stage of competition. The traditional advantages of Japanese cars in low list prices and fuel economy have disappeared as U.S. producers now produce both large and small cars that are competitive in prices and fuel efficiency. The devaluation of the US dollar, without a doubt, is an important factor in the increase in the relative price of imported Japanese cars; furthermore, there are some indications that the quality differential has been narrowed in recent years.[17] Nevertheless, based on our simulation results, we predict that even if the quality gap were to be closed, Japanese cars would not disappear from the choice menu of U.S. consumers. It is reasonable to believe that Japanese automobiles have become a permanent alternative in the U.S.

consumption space.

Figure 6
General Motors' Market Share

Figure 7
Ford's Market Share

Figure 8
Chrysler's Market Share

NOTES

1. The market shares of various producers must sum to one. Here, in our study, we focus only on the major producers in the U.S. markets. As of 1992, Chrysler's market share in the U.S. was 7.5%; Ford's; 21.1%; GM's 33.5%; Japanese combined, 31.8%. Other foreign automobile producers combined constituted 6.1% of the passenger car market in the U.S.
2. For example, in 1967 the average list price of Japanese cars was about 65 percent of U. S. average list prices, and their average gasoline mileage per gallon was about 70 per cent higher than U. S. average fuel mileage. The differences are largely due to automobile size differences.
3. For related studies on this subject, see Aizcorbe, Winston, and Friedlander [1], Chow [2], Cole and Yakushiji [3], Hess [7], Hogarty [8], Kwoka [11], Mannering and Winston [15, 16], and Womack [26].
4. The consumer price index for all items had increased from 100.0 in 1967 to 289.1 in 1982. In the case of the gasoline price index, it had increased from 100.0 in 1973 to 347.8 in 1981.
5. VW's market share was 4.9 percent in 1967, it reached a peak of 6.8 percent in 1970, but it had declined from that time to 1.4 percent in 1990 largely for reasons other than competition from Japanese counterpart.
6. The interest rate on 3-year T-bonds increased from 5.0 percent in 1967 to 14.4 percent in 1981. During most of the 1980s, this interest rate had ranged from 8 to 10 percent.
7. Specifically, wage rate settlements had ranged from 6.1 to 9.1 percent during the period 1969 to 1981. After 1981, wage rate settlements had been less than 4 percent.
8. Quality measurements for automobiles, such as "Initial Quality Study," "Vehicle Dependability Study," or "Customer Satisfaction Study" published by J.D. Power and Associates, all deal with different aspects of automobile quality. However, the time series are too short for the

statistical purpose here.

9. The true variable here is consumer perception, which is unobservable. The index that we construct is a proxy for the true variable. As Maddala [14] has noted, unless the measurement error in the proxy is uncorrelated with both the error in the regression and the true variable, “the least-squares estimator will underestimate” the population parameter. Since we are not interested in the precise point estimate of the parameter, we use Maddala’s observation that “This conclusion should not be taken too seriously in econometric work unless one believes in the restricted assumptions. . . .”
10. The trouble index is calculated based of the survey on “Frequency-of-Repair” records of several trouble spots. The index ranks each car by model year according to whether it is much worse than average, worse than average, average, better than average, or much better than average. In our construction of the quality index, we assigned an index value ranging from 1 for a model rated “much worse than average” to 5 for a model rated “much better than average.” The index values constructed in this way are then averaged for Japanese and for domestic producers.
11. As the average price of Japanese cars is unavailable, we use the average price of imported cars as a proxy for the price of Japanese cars. In the 1970s and 1980s, Japanese imports constituted 70 to 80% of total automobile imports, which justifies our use of the proxy.
12. In the original estimation, gasoline price and relative quality were treated as two separate variables. The resulting coefficients were statistically insignificant, and there were problems of autocorrelation. Conceptually, it is more meaningful to consider fuel efficiency together with quality. When consumers are considering the purchase of a car, they consider both the fuel efficiency (especially after the 1970s) and reliability. This collinearity problem may explain why insignificant estimates were obtained when the two variables entered the equation separately.
13. Prices (gasoline and automobiles) are determined outside of the model; thus, both prices are treated as exogenous in the estimation.
14. We have also considered the issue of whether or not the dependent and independent variables are co-integrated. However, given the fact that our sample size is small, the power of any test of cointegration is limited. For information, the log-likelihood ratio tests statistics for each equation are obtained by using Johansen’s Full Information Maximum likelihood method [9, 10]. The number of co-integrating vectors, r, is determined sequentially. These statistics indicate the rejection of the null hypothesis of no co-integration among the variables in all equations; i.e., each dependent variable has a long-run relationship with its explanatory variables.
15. In figures 6 to 8, actual and simulated points are also plotted for years 1991 and 1992 to see how our model performs beyond the sample period of 1967 to 1990.
16. Note that again, all variables except year dummies are transformed into natural logarithms before estimation.

17. Quality improvements in domestic cars are widely reported in various media. See, for example, "The Quality Gap's Narrowing, But Don't Pop Corks Just Yet," in *Ward's Auto World* [25].

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