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PRODUCT DIFFERENTIATION AND OLIGOPOLY IN INTERNATIONAL MARKETS: THE CASE OF THE U.S. AUTOMOBILE INDUSTRY

BY PINELOPI KOUJIANOU GOLDBERG[1]

This paper develops and estimates a model of the U.S. Automobile Industry. On the demand side, a discrete choice model is adopted, that is estimated using micro data from the Consumer Expenditure Survey. The estimation results are used in conjunction with population weights to derive aggregate demand. On the supply side, the automobile industry is modelled as an oligopoly with product differentiation. Equilibrium is characterized by the first order conditions of the profit maximizing firms. The estimation results are used in counterfactual simulations to investigate two trade policy issues: the effects of the VER, and exchange rate pass-through.

KEYWORDS: Discrete choice models, product differentiation, automobile industry, VER, exchange rate pass-through.

1. INTRODUCTION

DURING THE PAST DECADE models of imperfect competition have received increasing attention among international trade theorists and policymakers. Such models provide an alternative to traditional theories based on comparative advantage, and are useful in explaining two-way trade between developed economies, pricing to market, and the low degree of exchange rate pass-through on import prices. On the normative side, imperfect competition in international markets offers a justification for an activist trade policy. Equilibria in imperfectly competitive markets are characterized by positive price-marginal cost margins; government intervention can thus raise national welfare by securing a larger share of rent-yielding activities.[2]

Although the theoretical aspects of imperfect competition in international markets have been extensively treated in the literature, applied work remains limited.[3] The lack of empirical results is unfortunate, as optimal government intervention depends critically on assumptions about market structure and conduct.[4] To evaluate the welfare impact of different trade policies it is

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[2] See Helpman and Krugman (1985, 1989).

[3] Among the applied work in this field are Dixit (1988) and Krishna et al. (1989). The relevance of their results is limited because they are based on calibration rather than formal estimation. Other empirical work includes Feenstra (1984, 1985, 1988), Levinsohn (1988), and Feenstra and Levinsohn (1989). These papers focus on the automobile industry.

[4] Eaton and Grossman (1986) undertake an integrative treatment of the welfare effects of trade policy under imperfect competition. They conclude that the optimal trade policy depends on the choice of the firms' strategic variables. While Cournot behavior implies that export subsidies are first best, under Bertrand competition taxes are optimal.

essential to have reliable econometric models of the targeted industries. This paper develops and estimates such a model for the automobile industry.

The automobile industry provides an excellent opportunity for studying imperfect competition in international trade. Since the late 1970's the market has been characterized by rivalry between American and Japanese producers. The number of competing firms is small enough to justify the assumption of oligopoly. Products are highly differentiated. Furthermore, the industry has been a major target of trade policy; throughout the 1980's, U.S. imports of foreign passenger cars have been subject to a tariff rate of 2.9%, while compact trucks have faced a tariff rate of 25%. In addition, Japanese auto sales in the United States have been limited by the "Voluntary Export Restraint" (VER) that began in April, 1981.[5]

Previous studies of the automobile industry fall into two broad categories; those that use disaggregate consumer data and those that use aggregate industry data. The first group is primarily composed of logit-based models that estimate automobile demand at the individual level.[6] Compared to aggregate studies, these models allow for a high degree of product differentiation and account for consumer heterogeneity. Moreover, from an estimation perspective, such approaches circumvent the problem of price endogeneity by assuming that a single household has no impact on vehicle prices and characteristics. On the negative side, disaggregate demand models neglect supply side and market equilibrium considerations.[7] While the assumption of exogenous prices is reasonable for the estimation of micro level demand functions, it is clearly inadequate in a forecasting context, as prices are determined by market forces; this limits the use of such approaches for policy formulation.

Aggregate industry models must explicitly consider the endogeneity of prices. The demand equation error term includes unobserved (to the econometrician) product characteristics that are correlated with prices. By ignoring this correlation one obtains inconsistent parameter estimates and counterintuitive results, such as an upward-sloping demand curve. One solution to the endogeneity problem is to estimate the reduced form. However, as Berry (1994) shows, the existence of a well defined reduced form often requires strong assumptions about the functional form of the demand system. Logit and exponential models, for example, which have a well defined reduced form, imply unintuitive substitution patterns as reflected in the cross price elasticities of demand.[8] Since price elasticities of demand are crucial for many policy questions, it is desirable to consider estimation of more general demand structures.

[5] The voluntary export restraint (VER) originally constrained Japanese passenger car sales to the United States to 1.68 million annually. It was supposed to expire in 1984, but under U.S. pressure it was extended for several more years.

[6] An overview is provided in F. Mannering and K. Train (1985).

[7] There have been a few attempts to incorporate the supply side in discrete choice models, such as in Manski and Sherman (1980) and Berkovec (1985). These approaches rely on simplifying assumptions about the supply side that limit their empirical relevance.

[8] An extensive discussion of the issues involved in estimating models with unobserved product characteristics can be found in S. Berry (1994), and Berry et al. (1992).

An additional shortcoming of previous automobile studies is that most ignore the existence of an outside good. Absent an outside good consumers do not respond to a general price increase; since all consumers enter the market, demand depends only on the relative prices of the "inside goods." It is therefore impossible to derive the aggregate demand curve.

This paper attempts to avoid these pitfalls by combining a disaggregate model of automobile demand with an aggregate oligopoly model. The empirical model of the automobile market builds on three elements: demand, supply, and market equilibrium. Estimation proceeds in two steps: First, a discrete choice model of demand is developed. Unlike traditional static logit models, a transactions approach is adopted. The process of buying a specific vehicle is modelled as a nested sequence of logit models with the choice between a car and the outside good at the highest level, and the choices of market segment, origin, and model at subsequent nodes. This demand model is estimated using micro data from the Consumer Expenditure Survey. The nesting of the automobile purchase process allows explicit consideration of the outside good and avoids the unintuitive substitution patterns imposed by a simple logit model. Prices are assumed to be exogenous to each household at this stage.

Estimation results from the first stage are used in conjunction with population weights provided by the Consumer Expenditure Survey to determine aggregate demand. This aggregation process does not require any a priori assumptions about the shape of the aggregate demand curve; total demand is defined as the weighted sum of individual household demands.

The second step of the estimation involves the supply side. The automobile industry is modelled as an oligopoly with differentiated products. The equilibrium concept is Nash with prices as strategic variables. Equilibrium is characterized by the first order conditions of the profit maximizing firms. By estimating the parameters of the cost function, a model of the demand and supply side of the automobile market is obtained.

The disaggregate nature of the model makes it broadly applicable. Our main interest lies in international competition. Import penetration and the welfare implications of strategic trade policy can be studied. Here I investigate two trade issues that were relevant for the automobile industry during the 1980's: quota restrictions and exchange rate pass-through. I quantify the effects of the VER on market shares, automobile prices, and quality upgrading for the period 1983–87 by using the parameter estimates to compute market equilibrium under free trade and under quota restrictions. I also compare quotas to an equivalent tariff and find that their effects on automobile prices and quality differ substantially. Second, I seek an explanation for the observed insensitivity of import prices to exchange rate movements. Specifically, I estimate the effects of exchange rates on import prices to explain price inertia during periods of dollar appreciation. I decompose price changes during 1983–87, and assess the significance of trade restrictions, quality upgrading, and exchange rate pass-through in determining prices of domestic and imported automobiles.

The paper is organized as follows. Section 2 develops the theoretical model and describes the estimation procedure. Section 3 briefly describes the data.

The identification assumptions of the model are discussed in Section 4. Section 5 reports and interprets the estimation results. The nesting structure is tested against alternative specifications, and the fit of the model is examined. Section 6 considers international trade issues.

2. AUTOMOBILE MARKET MODEL

The model consists of statements about three components: demand, supply, and market equilibrium. The following subsections describe each.

2.1. *Automobile Choice Model*

The demand system is derived from a discrete choice model of consumer behavior. The model assumes a time horizon of one year as the vast majority of households do not purchase a car in a given year, while those who do usually buy only one. Consumers are assumed to maximize an indirect utility function of the form

$$U_j^h = \overline{V}_j^h + \varepsilon_j^h$$

where j and h stand for vehicle and household respectively, $\overline{V}_j^h$ denotes the deterministic component of the utility function that is a function of the vehicle attributes as well as the consumer's characteristics, and ε_j^h is a residual that captures the effects of unmeasured variables, personal idiosyncrasies, maximization error, etc.

Let us partition the whole set of vehicles into k disjoint subsets according to the criteria of newness (n), market segment (c), and origin (o), so that each vehicle make (m) is indexed by a quadruple subscript, (n, c, o, m). Then the utility function can be expressed as

$$U_{b,n,c,o,m}^h = \overline{V}_{b,n,c,o,m}^h + \varepsilon_{b,n,c,o,m}^h$$

where the subscript b stands for buy. The empirical implementation of the model requires specific functional form assumptions about the deterministic component of the utility function as well as distributional assumptions about the error term. Following the literature on discrete choice, I assume that $\overline{V}$ is a linear function of consumer and vehicle characteristics, and furthermore additively separable into a component that varies only with the decision to purchase, a component that reflects the utility derived from owning a new as opposed to used car, and three components that are specific to owning a car of a particular market segment, origin, and make, respectively. Under these assumptions the utility function can then be written as

$$U_{b,n,c,o,m}^h = \alpha' B_b^h + \beta' N_{b,n}^h + \gamma' C_{b,n,c}^h + \delta' O_{b,n,c,o}^h + \zeta' M_{b,n,c,o,m}^h + \varepsilon_{b,n,c,o,m}^h$$

where the Greek letters denote parameter vectors to be estimated and B_b^h,

$N^h_{b,n}$, $C^h_{b,n,c}$, $O^h_{b,n,c,o}$, and $M^h_{b,n,c,o,m}$ are vectors of explanatory variables specific to the categories of "buying," "new," "market segment," "origin," and "make," respectively. These variables include household characteristics, vehicle attributes, and interactions of the previous two.

With respect to the error term ε, I assume that it follows the generalized extreme value distribution and test whether the general choice model can be nested according to Figure 1.[9]

In accordance with automobile industry publications, the empirical analysis distinguishes between nine market segments: subcompacts, compacts, intermediate, standard, luxury, sports, pick-up trucks, vans, and miscellaneous (models like utility vehicles that are not assigned to any of the previous categories). This classification is based primarily on vehicle characteristics and prices.[10] Each year there are approximately 200 new models on the market; because the choice of a particular brand and make is conditioned on market segment and origin according to Figure 1,[11] the choice set at the last level of the tree depicted in Figure 1 is much smaller—it typically consists of 10–30 products.

The joint probability of choosing a new vehicle type (b, n, c, o, m) is

$$P^h_{b,n,c,o,m} = P^h_b * P^h_{n/b} * P^h_{c/n,b} * P^h_{o/c,n,b} * P^h_{m/o,c,n,b}$$

where $P^h_{b,n,c,o,m}$ denotes the joint probability of household h selecting the vehicle type (b, n, c, o, m), P^h_b is the marginal probability of purchasing an automobile during the current year, $P^h_{n/b}$ is the probability of buying a new car conditional on buying a car, and $P^h_{c/n,b}$, $P^h_{o/c,n,b}$, and $P^h_{m/o,c,n,b}$ represent probabilities of selecting class, origin, and vehicle make respectively, conditional on the previous stage decision.

[9] For a detailed discussion of the nested logit model and its derivation from the theory of stochastic utility maximization, see McFadden (1978). For previous applications of the framework on consumer demand see Berkovec (1985), Berkovec and Rust (1985), Hocherman et al. (1983), and Mannering and Winston (1985).

[10] It should be noted here that this classification is somewhat subjective; it does not correspond exactly to the segmentation proposed in the Automotive News Market Data Book (ANMDB) under "EPA Mileage Ratings for 198* Models" in which the only criterion for defining market segments is fuel efficiency (defined as miles per gallon (MPG)). The latter classification suffers from the obvious shortcoming that it groups together products with very different characteristics, such as a BMW and a Toyota Corolla. In addition to MPG, I use information on prices, body type, and size, as reported elsewhere in the ANMDB, to assign vehicles to one of the above categories.

[11] The exact definition of "domestic" vs. "foreign" depends on whether I refer to the demand or the supply side of the model. For the demand estimation the basic criterion for defining imports is the brand name rather than the location of production. This is based on the presumption that most consumers do not pay much attention to the actual production site; even when they do, it is nontrivial to find out where a vehicle was actually produced as most dealers are reluctant to release that information. From the supplier's perspective, however, the criterion for distinguishing imports from domestic products is the country of production. (A Dodge Colt, for example, is treated here as a Japanese product.) More problematic is a "grey" area of products that are produced both domestically and abroad, such as the Honda Accord, the Toyota Camry, etc. In the absence of information in the CES as to where the purchased cars were actually produced, I decided to treat such cases as foreign products. While this treatment is far from perfect, I believe it does not bias the results significantly; between 1983 and 1986 domestic production of foreign brands was limited. The interpretation of the results for 1987 is, however, more problematic; see also Section 6.1.1.

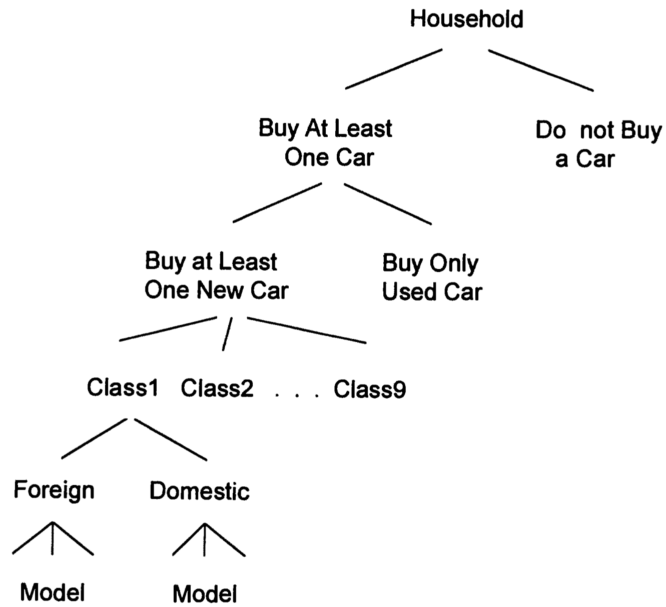

FIGURE 1.—Automobile choice model.

As shown in McFadden (1978, 1981), the assumption of the generalized extreme value distribution implies that the conditional choice probabilities at each node s of the tree, as well as the marginal probability of purchasing a car, will be given by multinomial logit formulas that have the following general form:

$$P^h_{i_s/j_{s-1}} = \exp\left(X^h_{i_s}\theta_s/\lambda_{j_{s-1}} + I^h_{i_s}\lambda_{i_s}/\lambda_{j_{s-1}}\right) \Big/ \sum_{k \in C_{j_{s-1}}} \exp\left(X^h_{k_s}\theta_s/\lambda_{j_{s-1}} + I^h_{k_s}\lambda_{k_s}/\lambda_{j_{s-1}}\right)$$

where

$$I^h_{i_s} = \log\left[\sum_{p \in C_{i_s}} \exp\left(X^h_{p_{s+1}}\theta_{s+1}/\lambda_{i_s}\right)\right].$$

The subscript i_s denotes a specific alternative within the choice set $C_{j_{s-1}}$, where j_{s-1} denotes the previous stage choice on which the current decision is conditioned (similarly the subscript $s+1$ refers to one tree node below the current one), $X^h_{i_s}$ represents a vector of explanatory variables specific to alternative i_s at stage s, and θ_s is the parameter vector specific to stage s to be estimated. The inclusive value terms $I^h_{i_s}$ measure the expected aggregate utility of subset i_s while the coefficients $\lambda_{i_s}/\lambda_{j_{s-1}}$ which are estimated along with the parameters θ in the model, reflect the dissimilarity of alternatives belonging to a particular subset. As McFadden (1978) has shown, the nested structure depicted in Figure 1 is consistent with random utility maximization if and only if the coefficients of the inclusive value terms lie within the unit interval. As the dissimilarity coefficients approach 1, the distribution of the error terms tends towards an iid extreme value distribution and the choice probabilities are given by the simple multinomial logit model. As the coefficients approach 0, the error terms become perfectly correlated and consumers choose the alternative with the highest strict utility. If the parameters of the inclusive values are greater than 1, there is substitution across the nests and, as noted above, the nesting is not consistent with utility maximization.[12]

Because of the large number of parameters involved in the empirical specification (there are over 200 parameters to be estimated) and the size of the choice set, direct maximization of the likelihood function associated with the nested logit model of Figure 1 is infeasible. The computational burden can, however, be significantly reduced by sequential maximum likelihood in which the estimation is decomposed in five stages. It is well known that this procedure results in consistent (though not efficient) parameter estimates but fails to produce consistent estimates of the covariance matrix; to correct the latter, the recursive formulas derived in McFadden (1981) were applied. More details about the estimation procedure as well as the empirical specification can be found in Section 5.

The demand model differs from other logit analyses common to this literature, in that it adopts a transactions rather than a holdings approach.[13] This offers several advantages: The modelling of the first stage of the decision process (purchase of a vehicle) incorporates an outside good in the demand estimation. Furthermore, a transactions approach provides a more realistic description of automobile demand since the estimation is based on those households that actually entered the automobile market and expressed, through their choices, preference for specific vehicle characteristics. Finally, the approach allows us to utilize data on past purchases; information on previous automobile holdings for each household is incorporated in the model, accounting for the temporal dependence in the automobile choice process.

Nevertheless, the treatment of dynamics is not entirely satisfying. One of the most striking aspects of automobile demand concerns the timing of the purchases; depending on their expectations about future economic conditions as well as the maintenance cost of their existing vehicles, households may decide to defer the purchase of a new car and instead repair their old vehicles, buy relatively early to take advantage of low prices in a weak market, sell a relatively new car in a strong market, etc. The static nature of the model fails to take these intertemporal substitution possibilities into account. To the extent that dynamics are incorporated in the model, this occurs in a one-sided fashion: Past purchases affect current choices, but expectations about future periods are not incorporated as a determinant of purchase decisions. The static character of the model is primarily dictated by data requirements; panel data sets on automobile

[12] The nesting of Figure 1 does not imply that consumers actually make decisions sequentially; the nesting reflects correlation patterns among unobserved factors across alternatives as they result from patterns in the econometrician's lack of information rather than from the household's decision process. In a previous paper (Goldberg (1993a)) I actually used the schematic of Figure 1 to describe the consumer's decision process under the assumption that selecting a particular vehicle model involves high search and transactions costs, so that consumers use a decision tree to sequentially eliminate alternatives from their choice set rather than maximize expected utility.

[13] Transactions models have been used by Hensher and Le Plastrier (1983) and Hocherman et al. (1983). The latter paper uses a stratified sample of 1300 Israeli households.

purchases or detailed information on car repairs and maintenance are not currently available. In addition, a dynamic approach would present further modelling and estimation difficulties. In view of these difficulties, I will proceed with the model described above, treating it as a starting point that captures certain features of the automobile market satisfactorily. Generally, in the context of Figure 1, one would expect the neglect of dynamics to bias predictions concerning the volume of new car sales each year, but to have a weaker effect on predictions concerning the composition of these sales.

The demand system intentionally focuses primarily on the sale of new vehicles. This focus presumes that only new car sales are relevant for automakers' profit maximization. Used vehicles enter the model only to the extent that they constitute part of the current automobile holdings and that they represent substitutes for new cars at the second node of the tree. In principle, the model could be extended to incorporate demand for specific used car vehicles and the effect that the second hand market has on the prices of new products. The data on used cars are, however, noisy, and since the primary interest of the paper is in the equilibrium in the new car market I abstract from competition in the second-hand market by focusing on the "average" used car (rather than individual models) as an alternative to new cars.

The nested structure of the automobile choice model places less structure on the car selection process than simple multinomial logit models. It does so by dropping the assumption of "independence of irrelevant alternatives (IIA)." The nested logit structure assumes instead, that choices within each stage are similar in unobserved factors, so that IIA holds for any pair of alternatives within each stage, but not for the entire choice set.[14] The relaxation of the IIA property translates into more plausible substitution patterns,[15] enabling the econometrician to capture the consumer specific response to unobserved characteristics that are common to products within a specific class. Consider, for example, the choice between domestic and foreign automobiles. One factor that affects this choice, but is hard to quantify, is quality or reliability of the product; the common wisdom is that foreign cars are more reliable and have higher resale values than American cars. To a certain extent such effects could be accounted for by putting origin-specific dummies in the last stage of the estimation (thus treating unobserved factors as fixed rather than random effects). Given the large number of products included in the choice set, however, the nesting of Figure 1 seems more appropriate as it not only accounts for a more flexible correlation pattern in the unobserved factors but also reduces the size of the choice set at each stage of the estimation.

By decomposing the process of choosing a car into several stages, I effectively impose a specific structure on the pattern of substitutability between different types of automobiles at the individual level. The implications of the nesting for

[14] See McFadden (1978).

[15] See Berry (1994). The simple multinomial logit gives rise to unintuitive cross-price elasticities, as the elasticities are functions of the market shares alone. Such undesirable properties do not arise in the context of nested models.

the substitution patterns *in the aggregate* are, however, less restrictive than Figure 1 may indicate, because the specification includes interactions of consumer and vehicle specific attributes. For example, one of the characteristics that is included in the last stage of the demand estimation is size of the car interacted with household size; suppose that the price of a certain model increases; then one would expect households with similar family sizes to be quite similar in their substitution behavior—large households would most likely substitute towards large cars. The interaction of vehicle and household characteristics thus introduces more flexibility in the substitution patterns so that even within a nest the restrictive implications of the simple multinomial logit for the *aggregate* price elasticities do not hold.[16] In this sense the model described here is very similar to the random coefficients model considered in Berry et al. (1992).[17] The substitution patterns are not solely determined by the functional form but also by the distribution of relevant attributes in the consumer population as reflected in the CES micro data.

Among the various characteristics that enter the demand estimation, prices have a special place as the price elasticities and their relation to price-cost markups are of direct interest. In principle, prices are treated here as every other vehicle characteristic;[18] at the lowest level of the tree they enter the demand estimation directly while at higher levels they only have an indirect effect through the inclusive value terms. A noteworthy feature of the nested model of Figure 1 is that it provides—via the inclusive value terms—a theoretically consistent way to endogenously compute price indices for various classes of automobiles. This feature will be especially relevant in the context of trade policies that affect prices of foreign automobiles altogether; not only does the model offer the appropriate weights by which the prices of specific vehicle makes have to be multiplied in order for the aggregate effects to be derived, it also lets these weights be consumer specific. Like other vehicle characteristics, prices are interacted with household attributes—income and previous car purchases in particular. These interactions can be made explicit by rewriting the last term of the utility function, $\zeta' M^h_{b,n,c,o,m}$, as follows:

$$\zeta' M^h_{b,n,c,o,m} = \zeta_1' M1^h_{b,n,c,o,m} + \zeta_2\left(INC^h - PRICE_{b,n,c,o,m}\right).$$

The vector $M1^h_{b,n,c,o,m}$ includes all relevant characteristics other than price and income, INC stands for income of household h, and ζ_2 is the price parameter to be estimated. The price and income variable can be thought of as proxies for the capital cost of the vehicle and the lifetime wealth of the

[16] Without the vehicle-consumer interaction terms, the counterintuitive substitution patterns of the multinomial logit would still be present locally, that is within a nest, though the nesting would have led to more plausible price elasticities globally.

[17] The main difference is that the error terms here are homoskedastic, or equivalently, that there is no unobserved dispersion in preferences for characteristics.

[18] A crucial difference between prices and other car characteristics arises from the fact that in the current model prices are used as a strategic variable by firms. This gives rise to potential simultaneity bias. Discussion of these issues is deferred to Section 4, after the exposition of the supply side of the model.

individual respectively; other variables that may affect the (intertemporal) budget constraint such as assets, origin, and brand of the automobile—the latter can be thought of as proxying expectations about future maintenance costs—are also included in the empirical specification. Note that in the above specification in which the parameter ζ_2 does not vary with the alternative, income effects cancel out so that choice probabilities do not depend on current income.[19] To allow for more plausible price-income interactions, I interact the term $(INC^h - PRICE_{b,n,c,o,m})$ with dummies indicating the income class to which a particular household belongs; put differently, I let the parameters ζ_2 vary with the income class. Assuming declining marginal utility of income, one would expect households with higher income to be less price sensitive. Interactions of price and "previous ownership" effects are treated in a similar manner; different price effects are estimated for households that have bought a particular brand before and for households that enter the market for a specific brand for the first time. These interactions result in more flexible substitution patterns by making the price elasticities dependent on the distribution of consumer characteristics.

The sequence adopted here is—as is inevitably the case with parametric assumptions—only one among various possible alternatives. To assess the model and its applicability to policy questions, extensive specification testing is needed. This will be discussed in detail in Section 5. Here, however, I provide a brief preview of the specification testing plan. As a first step I choose among the infinity of possible functional forms for automobile demand three "plausible" specifications that may compete with the current one; these alternative specifications are primarily concerned with the nesting at the lower levels of the tree, especially the sequence of the nests concerning market segments and origin, since these are the ones that would have the strongest impact on policy implications. I estimate the model using these specifications and use the coefficients of the inclusive value terms to eliminate models that are not consistent with utility maximization. Next, I perform several tests of the IIA property corresponding to alternative ways of grouping products and use likelihood ratio tests to decide on the set of variables included at each stage of the estimation. The fit of the model is examined by conducting the χ^2-tests both at the aggregate level and at a more disaggregate level using alternative consumer and product subsets for defining cells. Finally, I use data from the Consumer Expenditure Survey in 1989 and 1990 that are not included in the estimation to perform out-of-sample predictions and compare those to actual data.

[19] This is not the case if ζ_2 is choice specific. In fact, in the empirical implementation of the model I make the price parameters dependent on market segment, and let ζ_2 vary with the "newness" of a car, so that income can directly be included in higher levels of the estimation. In addition, income can often be thought of as a proxy for various other unobserved factors that influence automobile demand. This justifies inclusion of income as an explanatory variable in the estimation even if ζ_2 is not choice specific.

2.2. *Aggregation*

Once the individual selection probabilities are estimated, demand and supply sides are linked by aggregate demand for each vehicle model. Aggregate demand is defined as the sum of individual household demands; the Consumer Expenditure Survey provides weights for each household that reflect the representativeness of that household in the United States population. These population weights are derived on the basis of such characteristics as age, income, sex, race, and household size. They sum up to the total number of the United States households each year.[20] Thus, by definition, aggregate demand for each model is equal to

$$D_{b,n,c,o,m} = \sum_h P^h_{b,n,c,o,m} w^h + \sum_h \eta^h_{b,n,c,o,m} w^h$$

and expected demand is given by

$$ED_{b,n,c,o,m} = \sum_h P^h_{b,n,c,o,m} w^h$$

where $D_{b,n,c,o,m}$ represents the aggregate demand for model (b,n,c,o,m), $P^h_{b,n,c,o,m}$ is the selection probability for the specific model, w^h is the individual household weight, $\eta^h_{b,n,c,o,m}$ is a mean zero, stochastic component that is not observed by either the econometrician or the firm, and $ED_{b,n,c,o,m}$ is the expected aggregate demand.[21]

The main advantage of this method, compared to a reduced form estimation of the parameters of the aggregate demand curve using aggregate data, is that it preserves the micro relationships that are structurally stable. Consider for example a change in the demographic composition or income distribution of the U.S. population. Reduced form approaches based on aggregate data estimate the slope of the aggregate demand curve taking these factors as given; thus they fail to account for changes in the slope of the demand curve that result from such demographic shifts. Model simulations based on reduced form parameter estimates are therefore going to yield incorrect predictions in periods when demographics change. The same arguments apply to exchange rate changes or trade policies; to the extent that these affect different consumer groups nonuniformly, they change the slope of the aggregate demand curve, so that a reduced form approach is not suitable to analyze their effects.

[20] A detailed discussion of the procedures involved in deriving these weights can be found in the annual Consumer Expenditure Survey.

[21] Just as in the case of a continuous demand function, the discrete choice model of Section 2.1 explains the *expected value* of the quantity purchased. If we write 1 when a particular alternative is chosen, and 0 otherwise, the expected value of the variable is P, the probability of choosing that alternative. The unobserved stochastic error term η^h, is the difference between the observed value and the expected value of the indicator variable.

Digression: Transaction vs. Retail vs. Wholesale Prices

Before describing the supply side of the model a note on prices is necessary. Both demand and supply depend on automobile prices. However, an important feature of the automobile market is that the price the consumer sees is different from the price the producer charges. Consumer decisions depend on transaction prices. These differ from suggested retail prices in that they include transportation costs, local or state taxes, and dealer-specific discounts. Transaction prices for each household purchase are available from the CES; their use bears, however, two potential problems: The first is that transaction prices for alternatives that were not actually purchased are not observed. The second problem is that transaction prices depend on the negotiating power of individual households, and so cannot be considered exogenous in the demand estimation.[22] To avoid these problems I compute transaction prices as averages over options-corrected purchases of CES households, by year and, when possible, geographic region.

For the estimation of the supply side, on the other hand, wholesale rather than retail or transaction prices are needed. To compute the wholesale prices I use a rough approximation proposed by Bresnahan (1986) that relates retail to wholesale prices as follows:[23]

Intermediate, Standard, Luxury:	Wholesale price = 75% of retail price;
Subcompacts:	Wholesale price = 83% of retail price;
Other:	Wholesale price = 79% of retail price.

2.3. *Supply Side and Market Equilibrium*

The automobile industry is an oligopoly with multiproduct firms. As noted by Rosen (1974), supply decisions and market equilibria for differentiated products involve two stages: A long-run stage, in which firms determine the product-mix and the quality of their products, and a short-run stage in which producers set prices conditional on product types. This paper concentrates on the second aspect of the problem; changes in product types or quality are thus assumed to be exogenous to the firm in the short run. The firms participating in the market are of three types: domestic, foreign non-Japanese, and Japanese producers

[22] This claim, however, is not reflected in the data. As a check on the exogeneity of transaction prices I regressed the percent difference between transaction and retail prices (corrected for options) on a series of household characteristics, such as income, education, sex, race, and age, on year and quarter dummies, and on origin specific dummies (see Goldberg (1993b)). None of the household characteristics was significant at the 5% level. On the other hand, origin specific and brand dummies were highly significant.

[23] This approximation is based on average dealer markups reported in Consumer Reports. Using this approximation effectively assumes that dealer markups are exogenous in the model. From the perspective of manufacturers, dealer margins are data. Thus our approach ignores the interdependent price setting of automakers and dealers. A better treatment of the manufacturer-dealer relationship is provided in Bresnahan and Reiss (1985) where the pricing decision of the dealer is considered explicitly in the framework of a successive monopoly model.

facing the VER. In the following, I concentrate on the United States automobile market ignoring sales of those firms to other countries. This is clearly a simplification, but it can be justified in view of the size of the United States market. Firms play a one-shot pricing game and they have Nash conjectures when they set their prices.

Before we proceed to the solution of the game, certain assumptions about the cost function are necessary: Costs for firm f are assumed to take the form

$$C_{ft}(Q_{ft}, X_{ft}) = F_{ft}(X_{ft}) + \sum_{i=1}^{n_{ft}} c_{it} q_{it}$$

where C_{ft} is the total cost of firm f, n_{ft} is the number of products supplied by the firm, q_{it} is the production of product i, X_{ft} and Q_{ft} are respectively the vectors of products and quantities sold by that firm, F_{ft} is the fixed cost, and c_{it} is the marginal cost which is assumed to be constant. The actual marginal cost is observed by all suppliers, but is unknown to the researcher. From the perspective of the econometrician, the expected marginal cost is a function of product characteristics and input prices. Specifically, I assume that marginal cost is of the form

$$c_{it} = c_0 + \alpha Z_{it} + u_{it}$$

where c_0 is a constant, Z_{it} is a vector of product characteristics, u_{it} is a stochastic i.i.d. component, and α is a firm-independent parameter vector.

Producers not subject to quantity constraints maximize expected profits period by period with respect to price. The supplier's problem is thus:

$$\max_{p_{it}^{w}} E_t \Pi_t^f = E_t \left\{ \sum_{i=1}^{n_{ft}} (p_{it}^{w} - c_{it}) q_{it} - F_{ft}(X_{ft}) \right\}$$

where E_t is the expectations operator with respect to demand, p_{it}^{w} is a vector of wholesale prices for firm f's products, and Π_t^f denotes the firm's profits in period t. Given that marginal costs are observed by the firm, and firms choose prices, the only uncertainty comes from the demand side; so the expected profit maximization problem for the firm becomes

$$\max_{p_{it}^{w}} \left\{ \sum_{i=1}^{n_{ft}} (p_{it}^{w} - c_{it}) E_t q_{it} - F_{ft}(X_{ft}) \right\}.$$

At the equilibrium, expected production must equal expected demand. Expected demand is the weighted sum of the household purchase probabilities. Thus we can write

$$E_t q_{it} = E_t D_{it} = E_t \left\{ \sum_h P_{it}^h w^h + \sum_h \eta_{it}^h w^h \right\} = \sum_h P_{it}^h w^h.$$

Foreign producers facing quota restrictions solve a constrained profit maximization problem. They maximize the Lagrangian:

$$\max_{p_{it}^w, \lambda_{ft}} E_t L_t^f = E_t \left\{ \sum_{i=1}^{n_{ft}} (e_t p_{it}^w - c_{it}) q_{it} - F_{ft}(X_{ft}) + \lambda_{ft} \left(D_{ft} - \sum_{j' \in V_f} q_{j't} \right) \right\}$$

where e_t is the current exchange rate, expressed as foreign currency per US dollar, and i, j denote products produced by the same firm. The prices p_{it}^w, p_{jt}^w are expressed in US dollars while marginal costs are in terms of the producer's own currency.[24] V_f stands for the set of products produced by firm f that are subject to quotas, D_{ft} is the quota allocated to firm f in period t, and λ_{ft} is the Lagrange multiplier associated with the quantity constraint.

Solving for the Nash equilibrium in the presence of export restraints requires specifying the rationing rule, that is, the way consumers would react to shortages in the market for a specific good. Note that the specification of the rationing rule is a required assumption rather than an empirical question, as it refers to off the equilibrium responses which are never observed in practice. (In practice, prices are set so as to clear the markets: demand equals supply and no consumers are rationed.) The rationing rule adopted here is the one of "no spillovers;" it assumes that the excess demand for a Japanese product does not affect the demand for domestic products. While arbitrary, this assumption is necessary, as otherwise a pure strategy equilibrium would not exist.[25] It should be noted, however, that the "no spillovers" assumption, though necessary, is not sufficient for the existence of a pure strategy equilibrium. In fact, a general proof of existence has not yet been provided by the theoretical literature on product differentiation; Caplin and Nalebuff (1990) prove the existence of a pure strategy equilibrium for one-product firms, and for a certain class of utility functions (including the logit), yet their proof has not been extended to the case of multiproduct firms. Given this state of theoretical work, I therefore *assume* that a pure strategy equilibrium exists, as long as the necessary assumption of "no spillovers" is satisfied.

After substituting the expression $E_t D_{it}$ for $E_t q_{it}$ in the profit maximization problem we can write the first order conditions for the domestic, the foreign,

[24] The assumption that foreign producers use the US dollar rather than foreign currency price of their products as strategic variable, presumes that foreign car sales in the US are invoiced in dollars. This premise is consistent with the facts: According to Hamada and Horiuchi (1987), approximately 82% of the foreign car sales in the US are invoiced in dollars.

[25] See Itoh and Ono (1984) and Krishna (1989). Krishna (1989) considers a duopoly with substitute goods and shows that under the alternative assumption that the excess demand for the foreign product affects the domestic demand, there is no pure strategy equilibrium; there is, however, a mixed strategy equilibrium at which the domestic firm obtains Stackelberg profits, while the prices of both the domestic and foreign products are higher than in free trade. While Krishna's assumption seems plausible in a duopoly setting with two substitutable commodities, it is less compelling in a model with several multiproduct firms and with a more complex pattern of product differentiation.

and the "subject to quotas" foreign firm:

(a) *Domestic Firm*:

$$(1) \qquad E_t D_{it} + \sum_{j=1}^{n_{ft}} \left(p_{jt}^w - c_{jt}\right) \frac{\partial E_t D_{jt}}{\partial p_{it}^w} = 0 \qquad (i = 1, \ldots, n_f).$$

(b) *Foreign Firm*:

$$(2) \qquad e_t E_t D_{it} + \sum_{j=1}^{n_{ft}} \left(e_t p_{jt}^w - c_{jt}\right) \frac{\partial E_t D_{jt}}{\partial p_{it}^w} = 0 \qquad (i = 1, \ldots, n_f).$$

(c) *"Subject to Quotas" Foreign Firm*:

$$(3) \qquad e_t E_t D_{it} + \sum_{j=1}^{n_{ft}} \left(e_t p_{jt}^w - c_{jt}\right) \frac{\partial E_t D_{jt}}{\partial p_{it}^w} - \lambda_{ft} \sum_{j' \in V_f} \frac{\partial E_t D_{j't}}{\partial p_{it}^w} = 0 \qquad (i = 1, \ldots, n_f).$$

$$\sum_{j' \in V_f} E_t D_{j't} \leqslant D_{ft}, \qquad \lambda_{ft} \geqslant 0.$$

The quota constraint as negotiated by the American and the Japanese governments refers to the total sales of Japanese passenger cars in the U.S. market rather than to individual firm sales.[26] It is allocated to specific firms by the Japanese government. The specific formulas for the company-by-company allocations have never been discussed publicly; anecdotal evidence suggests, however, that the Japanese government allocated quotas on the basis of previous years' market shares and that the big winners were Toyota and Nissan.[27] The identification of the Lagrange multipliers λ_{ft} imposes some challenges. From equation (3) it is evident that λ_{ft} has the same effect on costs as a year dummy specific to a Japanese firm producing passenger cars. Thus, if Japanese firms produce both passenger cars and trucks or vans, it is possible to identify λ_{ft}, by including the appropriate dummies in the cost estimation. In cases, however, where firms produce only passenger cars (or produce only a small share of trucks that does not appear in the sample), the Lagrange multipliers are not identifiable as firm specific dummies. This is the case with Honda, for example. Since Honda owns a significant share of the market for Japanese passenger cars, it does not seem appropriate to exclude it from the VER only because λ_{ft} is not identified in this case. To circumvent this problem I estimate an *average Lagrange* multiplier for the Japanese firms in the sample; in other words, I assume that $\lambda_{ft} = \lambda_{f't} = \lambda_t$, for $f \neq f'$, and identify λ_t as a year dummy, specific to Japanese passenger cars facing quota restrictions. This treatment of the Lagrange multipliers corresponds to the assumption that the Japanese govern-

[26] This specification of the quota constraint ignores domestic production of foreign makes, such as the Honda Accord. This simplification is inevitable since the CES does not provide information on the country of production of vehicles purchased by the sample households.

[27] See, for example, Lohr (1983).

ment allocated quotas so as to equalize the shadow price of the quantity constraint among firms. This interpretation is not completely implausible; by allocating quotas on the basis of the previous year's market shares the Japanese government was essentially trying to equalize the "cost" of the VER across firms. It is important to note that this treatment of the Lagrange multipliers is not related to any data issues or computational difficulties; it is simply an identification issue.[28]

Note that the first order conditions involve the own and cross-price derivatives of expected demand for each product; these can be derived in a manner similar to the way the aggregate demand for each product was obtained: the price derivatives are the weighted sum of individual derivatives. The individual household derivatives can in turn be obtained by a straightforward application of the chain rule to the nested logit model and by using the parameter estimates provided by the estimation of the demand system.

Suppose there are N models available in the market in a specific year. Then the first order conditions define a system of N simultaneous equations, linear in marginal cost, each of which must hold exactly at the equilibrium if firms have perfect information. This system can be solved for the marginal cost of each product. Regressing the obtained values of the marginal costs on product characteristics and input prices provides an estimate of the expected marginal cost. This way, a two-step estimator of the cost parameters is obtained. This completes the specification of the supply side and market equilibrium. Finally, estimation of the demand and supply sides of the model requires specific identification assumptions. Because these are often dictated by data availability, I first provide a brief overview of the data in Section 3, and then return to identification in Section 4.

3. THE DATA

The demand estimation uses data from the Consumer Expenditure Survey (CES). This is a relatively new survey conducted by the Bureau of Labor Statistics to compute the Consumer Price Index. Each quarter about 4,500 households are interviewed and asked to answer questions on family characteristics, income, employment, and expenditures; 75% of these are reinterviewed the next quarter, while the remaining 25% are replaced by a new group. Since 1984 the CES also contains detailed information on the automobile holdings of the interviewed households, including the make/model and purchase price of each car, the financing of new purchases, disposal of old vehicles, and a large set of vehicle characteristics. Between 1983 and 1987 approximately 32,000 distinct households were interviewed.

Tables A1–A3 in the Data Appendix provide some summary statistics on the households in the sample. A comparison with Census data shows that the

[28] We also experimented with estimation with firm specific Lagrange multipliers when possible. More details about these results can be found in Section 5.

sample is representative of the U.S. population in terms of socioeconomic data in Table A1. Moreover, the annual import shares (Table A2) correspond roughly to those reported in industry journals, such as the Automotive News Market Data Book. The use of the CES is therefore promising.

A potential problem with the CES is that on average only 9% of the sample households purchase a new vehicle each year. This percentage seems to underestimate the total sales of new vehicles in the United States,[29] but it is consistent with other publications of the Bureau of Labor Statistics and the U.S. Department of Commerce that refer to auto purchases of the household sector. One explanation for this divergence is the existence of fleet sales, which rose substantially during this period.

Another problem with CES is that the number of new car models in the sample is relatively small. As can be seen from Table A2, households in the sample buy 400 new cars per year. There are approximately 200 new models each year, so that infrequently bought models never appear in the sample (or sometimes there is only one observation per year); to the extent that utility is derived from automobile characteristics, the absence of a few models from the sample does not represent a problem for the demand estimation. This absence does limit our ability to introduce model fixed effects.

The CES was supplemented by information on approximately 200 models per year for the period 1983–87.[30] Such information includes sales, list prices, and vehicle attributes that reflect the size (e.g. length, width), performance (horsepower, cylinders), fuel efficiency (miles per gallon), and standard options (power steering, power brakes, automatic transmission, air-conditioning) of each model. A detailed list of these characteristics is provided in the Data Appendix. Models in each year are categorized into the nine vehicle classes described in Section 2.1. Within each class a further distinction between foreign and domestic automobiles is made. This classification results in 17 automobile classes. (No foreign automobiles were assigned to the standard car class.) Tables A4 and A5 provide some information on the number of models and the distribution of vehicle characteristics within each class.

4. IDENTIFICATION ASSUMPTIONS

The main identification assumption is that the variables on the right-hand side of the demand system are uncorrelated with the individual error term in the demand equation. Among the variables included in the demand equation,

[29] The total sales of new vehicles in the United States over 1983–87 are approximately 14 million per year; given the number of U.S. households (ca. 93 million) this implies that 15% of households buy a new vehicle each year. The U.S. Department of Commerce on the other hand reports that the household sector spent 100 billion dollars on automobiles in 1986. Divided by the average car expenditure, estimated to $12,000, and by the number of households, this implies that 9% of U.S. households bought a new vehicle in 1986. The above numbers can be found in "MVMA Motor Vehicles: Facts and Figures," various issues.

[30] I am particularly grateful to J. Levinsohn for providing this data. The information comes from annual issues of the Automotive News Market Data Book.

there are two sets for which the above assumption may seem suspect: those referring to the existing stock of cars, and prices. I now discuss endogeneity issues associated with these variables.

The issues associated with the inclusion of variables related to the existing stock of cars are identical to the ones associated with the use of lagged dependent variables; if the error term of the demand equation is serially correlated, the obtained parameter estimates are inconsistent. However, dealing with serial correlation in the nested logit model is difficult.[31] Eliminating these variables from the demand estimation would lead to implausible purchasing patterns, as the decision to buy clearly depends on the current stock. Therefore, I maintain the assumption that the error terms in the demand specification are not serially correlated.

Similarly, I assume that prices are not correlated with the consumer specific error term of the demand equation. This assumption is justified on the basis of two considerations:

1. *Use of Micro Data*: To the extent that there is no common aggregate component in the error terms, the use of micro data alleviates (though does not eliminate) the problem of simultaneity. In principle, an aggregate component in the error term can arise from two sources.

The first source is a macroeconomic shock, such as a recession. Such a shock manifests itself in household characteristics that are observed, such as income, employment status, assets, etc. By controlling for these variables in the demand estimation I remove the aggregate component from the error terms.

A second aggregate component in the error term is unobserved product characteristics that are perceived in the same way by all consumers (Berry (1994) and Berry et al. (1992)). In the presence of these unobserved characteristics the utility function becomes

$$U_j^h = \overline{V}_j^h + \xi_j + \varepsilon_j^h .$$

The term ξ_j captures unobserved product characteristics, including quality of the product, reliability, reputation, etc. Many of these characteristics correspond to figures published in the *Consumer Reports*.[32] Among the unobserved characteristics, those that are individual specific are already captured in the iid error component ε_j. Thus, the presence of ξ_j in the demand specification is justified, *only if* there is an aggregate component to the unobserved product attributes. Micro data allow one to estimate this aggregate component as a fixed

[31] Work on serial correlation in binary discrete choice models has been undertaken by Heckman (1981).

[32] The *Consumer Reports* publish, for example, estimates of repair costs and consumer rankings for various models. An inspection of these figures shows a uniform pattern: Japanese models are associated with the highest rankings and the lowest repair costs while the opposite is true for American automobiles. German cars usually lie in the middle. Given this pattern, I did not use the *Consumer Reports* figures in the demand estimation since they are essentially equivalent to origin specific dummies. It should be pointed out, however, that the *Consumer Reports* evaluations provide an additional argument in favor of the nesting approach, as they show that domestic and foreign automobiles are perceived differently by consumers.

effect. This requires the assumption that model specific unobserved characteristics are time invariant within the sample period. Given the nature of these characteristics, this assumption does not seem unrealistic; the perception, for example, that Toyotas are reliable cars does not change from year to year. In the ideal case of a large sample with multiple observations per model the issue of price endogeneity would thus be less severe. In the current data set, however, new automobile models are sometimes associated with only one observation in the sample so that model specific effects cannot be estimated. To accommodate this unfortunate feature of the data, I decompose the product specific unobserved attributes ξ_j into a component specific to the market segment (ξ_j^c), a component specific to the origin of the car (ξ_j^o), and a term specific to the brand (ξ_j^{br}):

$$\xi_j = \xi_j^c + \xi_j^o + \xi_j^{br}.$$

This allows me to estimate fixed effects associated with the origin of the car, its market segment, and the brand name. This procedure leaves out the aggregate components of unobserved features that are specific to a particular make (e.g., Ford Escort), but not the brand (Ford). Given the argument pertaining to unobserved characteristics, the impact of the latter attributes on automobile demand should be rather small—reputation or reliability effects are typically brought up in connection with a certain brand or origin (Toyotas, Japanese cars, etc.) and not with a specific model. Any remaining simultaneity bias would affect both demand elasticities and predicted choices, leading, as discussed in Berry (1994), to large deviations of predicted from actual market shares.[33] In the empirical section I therefore compare predicted with actual market shares for various models to get an idea of the severity of the problem.[34]

2. *Expected Profit Maximization*: The second argument supporting the exogeneity of prices in this model comes from the assumption that producers maximize expected profits. This assumption implies that under fairly general conditions prices are uncorrelated with the demand error. To clarify this point let us without loss of generality concentrate on the maximization problem of a domestic producer. This can be written as

$$\max_{p_{it}^w} E_t\left\{ \sum_{i=1}^{n_{ft}} (p_{it}^w - c_{it})\left(\sum_h P_{it}^h w^h + \sum_h \varepsilon_{it}^h w^h \right) \right\}.$$

[33] Note that the introduction of market segment and origin specific fixed effects in the demand estimation implies that the aggregate market shares of cars of a specific origin or market segment (e.g., market share of domestic subcompacts) is going to be predicted *exactly*, by construction. So the comparison of predicted and actual market shares is only meaningful in the context of specific makes.

[34] Alternative identification assumptions are considered, for example, in Berry et al. (1992); their assumptions require product characteristics other than prices to be exogenous and unobserved characteristics to be uncorrelated with observed characteristics. The latter assumption implies that the unobserved characteristic of car reliability is uncorrelated with the observed characteristic of brand name.

As was pointed out in Section 2.3, firms observe the actual marginal cost c_{it} while the econometrician only observes the deterministic component $\bar{c}_{it}$. Thus from the econometrician's perspective the supplier's problem is

$$\max_{p_{it}^{w}} E_t\left\{\sum_{i=1}^{n_{ft}}(p_{it}^{w}-\bar{c}_{it}-u_{it})\left(\sum_{h}P_{it}^{h}w^{h}+\sum_{h}\varepsilon_{it}^{h}w^{h}\right)\right\}$$

where u_{it} denotes the mean zero, stochastic component of the marginal cost. Assuming that the error terms of the cost and demand equations, u_{it} and ε_{it}^{h}, are independent,[35] the application of the expectations operator in the above expression implies that the demand error drops out of the maximization condition so that it does not affect the determination of prices. In this sense prices are by construction exogenous in this model.

5. EMPIRICAL RESULTS AND INTERPRETATION

This section summarizes the results from the estimation of the demand and supply systems. First, I present the results from estimating the automobile choice model and testing alternative specifications. Next, I analyze the implications of the estimated parameters for aggregate market shares and price elasticities of demand. Finally I report the supply side results, with emphasis on the marginal costs, markups, and cost parameters implied by the model.

5.1. *Estimation Results of the Automobile Choice Model*

The automobile choice model is estimated sequentially in five steps, each of which corresponds to a branch of the tree depicted in Figure 1. The parameter estimates, standard errors, and t statistics are reported in Appendix B. The utility derived by a household from buying a car is expressed as a function of five types of variables: household characteristics, vehicle attributes, year dummies, variables related to the age and composition of the existing vehicle stock that capture the dynamic aspects of the selection process, and macroeconomic variables such as employment, interest rates, and per capita income that reflect households' perceptions about the state and future of the economy. A complete list of variables is provided in Appendix A. To increase the sample size and obtain more precise parameter estimates I pool data between 1983 and 1987; the automobile market was quite stable during that period. Year-specific effects are captured through year dummies, when possible. The estimation results at each stage are summarized below.

5.1.1. *Model Choice*

Three separate equations are estimated at this stage: One for small cars (subcompacts and compacts), one for luxury automobiles (including sports cars),

[35] The independence assumption may be problematic if the same unobserved characteristics are included in the error terms of the cost and demand equations.

and one for the remaining models. This split allows different behavior within each subcategory. In addition, likelihood ratio tests unambiguously reject the hypothesis that the coefficients in the three estimating equations are equal; the log-likelihood falls from -1267.2 to -1489.0, while 36 degrees of freedom are gained, when the equality constraints are imposed.

Most of the variables included at this stage are vehicle characteristics; to limit the number of parameters, household characteristics are used only in interaction with vehicle attributes. In principal, all three specifications use the same variables; only characteristics that do not exhibit variation within a subcategory are excluded from a specific equation.[36] A potential problem associated with vehicle attributes is collinearity; the correlation coefficients between characteristics such as horsepower and number of cylinders, or length/width and fuel efficiency, range between .80 and .90. The collinearity between vehicle attributes is compounded by the nested structure of the model; automobile classes are comprised of relatively homogeneous products that exhibit little variation with respect to observable characteristics. It is not obvious how this problem can be circumvented; defining broader classes would probably mitigate collinearity but violate the "IIA" assumption; defining narrower classes would eliminate the need for including vehicle characteristics. To alleviate the consequences of collinearity, preference was given to specifications that reduce the number of collinear variables to a minimum. The final specification includes prices (interacted with income and previous purchase dummies), measures of performance (horsepower interacted with age), measures of size (interacted with family size), fuel efficiency (gallons per mile × regional gasoline price), options (automatic transmission, power steering, air-conditioning) and an extensive set of brand dummies that proxy the effect of unobserved characteristics on automobile demand.

As is evident from Tables B1–B3, most of the estimated coefficients are precisely estimated and have the expected signs. The price parameters are lowest for the class of luxury automobiles and sports cars and highest for subcompacts and compacts. As noted above, prices are interacted with income class dummies. Two income classes are distinguished; one that corresponds to incomes below $75,000 and one for incomes above $75,000. We also experimented with alternative classifications, but the price coefficients were not significantly different. The results indicate that price responsiveness decreases with higher income. Luxury and sports cars constitute the only exception to this pattern. Price effects do not depend on income in this category; therefore only one price parameter for all incomes was estimated.

A key question in marketing that has far reaching implications for import penetration and exchange rate pass-through is whether brand loyalty affects current automobile demand. In the absence of panel data I cannot resolve this issue. The disaggregate data and the information on previous automobile

[36] For example all small cars have 4 cylinders, so cylinders have to be excluded when estimating model demand within small cars.

holdings do allow me to address a related question: "Are households that purchased specific models in the past less price elastic than households that buy a model for the first time?" To investigate this issue I introduce two sets of price parameters in the estimation; the first (PPL1, PPH1, PP1) measures the price sensitivity of households that have purchased a specific model in the past while the second (PPL0, PPH0, PP0) refers to first time buyers. As reported in Tables B1–B3 in the Appendix, the second set of parameter estimates is almost twice as large in magnitude as the first, and likelihood ratio tests reject the hypothesis that the two sets of coefficients are equal.[37] The interpretation of this result is less straightforward. The apparent temporal dependence in automobile demand could be state dependence generated by brand loyalty and/or transaction costs, or the result of unobserved heterogeneity that induces serial correlation in the error terms; hence the estimated price coefficients do not allow any conclusions about the significance of brand loyalty. Still, one feature that clearly emerges is that current price elasticities of demand are affected by past purchases.

5.1.2. *Foreign vs. Domestic*

The parameter estimates from the first stage are used to compute inclusive value terms that enter the second stage estimation. Consistent with the estimation of three separate equations at the last node of the tree, three inclusive value terms are included in estimation of the branch corresponding to the choice between domestic and foreign: one for small, one for large, and one for luxury and sports cars. Given that the choice set consists of two alternatives at this stage (domestic vs. foreign), it is now feasible to include a large set of consumer specific attributes such as age, income, education, race, and regional dummies. In addition, choice specific dummies proxy the impact of unobserved characteristics on automobile demand; the popular belief that foreign cars are more reliable than domestic cars, for example, can be captured through the constant term and the market segment dummies.

The results are reported in Table B4 in the Appendix. The estimated inclusive value coefficients are consistent with the hypothesis of random utility maximization as they lie in the unit interval.[38] The other parameter estimates conform to common wisdom: The probability of buying a foreign car is positively correlated with income and education, and negatively correlated with age. Furthermore, the widespread belief that foreign cars are most popular in the West and least popular in the Midwest is reflected in the parameter estimates associated with geographic area.

[37] The log-likelihood decreases to -542.3, -445.3, and -342.8 for small, large, and luxury cars respectively.

[38] With the exception of luxury and sports cars, the coefficients of the inclusive value terms tend to be quite high. It is interesting to note that the coefficients are substantially lower if the constant term and the year and market segment dummies are omitted from the estimation, or if the number of brand dummies at the previous stage is reduced. Thus, it seems that choice specific dummies account for a large fraction of the correlation in unobserved characteristics among products within each class.

5.1.3. *Class Choice*

Results from this step are similar to those of the previous stage. The explanatory variables include the inclusive value based on previous stages, consumer characteristics such as income, age, family size, and number of children, and choice dummies. Given that income and age are already incorporated in the estimation—indirectly, through the inclusive value—their inclusion on the right-hand side merits some justification. Introducing age, for example, as an explicit explanatory variable at this stage means that age acts through two channels. The first is related to the percentage of cars in each market segment that are foreign produced; if younger households prefer foreign cars, they may choose market segments that have a higher percentage of foreign cars (subcompacts, for example). This effect is captured through the inclusive value term. But in addition, younger households may strictly prefer certain market segments (e.g., sports cars). It is this second effect that the inclusion of household attributes captures at this stage.

The treatment of the inclusive values also raises modelling questions. In principle, one could introduce more than one inclusive value at this node and estimate separate equations for the corresponding classes at the preceding stage. To keep the number of parameters within reasonable limits and the results transparent, preference was given to the current specification with three inclusive values at the second node and only one inclusive value at higher stages. The proportionality constraints implied by the nested logit were not imposed at any stage, as this would eliminate the computational advantages of sequential estimation. There is, however, no reason to constrain the coefficients ζ to one value in the lower level; allowing for different ζ's for small, large, and luxury cars respectively, eliminates the need to test the proportionality constraints.

5.1.4. *Used vs. New and Buy vs. Not Buy*

The variables that enter at these stages are primarily household characteristics (income, assets, occupational, and race dummies, etc.), macroeconomic variables (regional unemployment rate, personal disposable income, and interest rate) and variables related to the existing vehicle stock. Year-specific effects that affect all households in the same manner are reflected in the year effects D84–D87 and in the dummies D1–D19.[39] The inclusive value parameter for the stage used vs. new is quite low indicating that new and used cars are viewed as rather poor substitutes. Similarly, the estimated coefficient on the inclusive value term at the buy vs. not buy level was very close to zero (-0.01) and statistically insignificant (t statistic $= 0.87$). Because negative inclusive value

[39] These dummies refer to the interview period of each household: In the CES, households are interviewed for four consecutive quarters; each quarter 25% of the households are dropped and replaced by a new sample. The rolling sample structure of the survey results in 19 household specific time intervals, each consisting of four consecutive quarters.

parameters are not consistent with the utility maximization paradigm, the parameter was set equal to zero and the model reestimated without the inclusive value term.

Generally, the estimated coefficients have the expected signs. The dominant factor in the new vs. used decision is economic ability. The impact of financial status on newness is directly reflected in the signs of the parameters corresponding to income and value of assets, and implicit in many other parameters associated with the age, education, race, and employment status of the household head. The results for the buy vs. not buy stage are similar. The estimated macroeconomic effects are rather puzzling; while the estimated parameters for unemployment and interest rates are plausible, the income coefficients imply that the probability of buying a (new) car increases with declining income. Because individual income is already included and other macroeconomic factors are captured through interest rates, unemployment, and time dummies, macroeconomic income effects may be poorly identified.

The estimation results that concern the role of dynamics require some comment. As indicated in Tables B6 and B7, coefficients that link the current household purchase to the age and composition of the existing vehicle stock or previous purchases are highly significant. While these parameters clearly indicate the importance of dynamics in the automobile choice process, they are difficult to interpret. The problem with the interpretation is that they do not permit a distinction between cause and effect. Consider, for example, the vehicle age dummies A11–A33; the parameter estimates indicate that households with relatively new cars tend to buy new rather than used cars. This correlation can be attributed either to the financial status of such households or to preference for newness. As an alternative to vehicle age dummies I also considered including the *value* of the household stock as an explanatory variable.[40] This effort resulted, however, in a large number of missing values without a more useful interpretation. Therefore, only vehicle age and composition dummies are included in the final specification. The source of all interpretation problems seems to lie in the fact that our data give only a snapshot of a household during the four quarter interview period. Supplementing this snapshot with information on automobile purchases and disposal preceding or following the interview period might shed more light on automobile holding and replacement patterns.

Generally, the estimation results are quite plausible and the inclusive value coefficients indicate that the nesting conforms to the random utility maximization paradigm. The model overall predicts 80% of the choices correctly.[41]

[40] The stock value variable was constructed by using information on the blue book values of the cars a household owns. I am grateful to Orazio Attanasio for providing this information.

[41] A prediction is defined as "correct" if the predicted probability of the household's actual choice is higher than the predicted probability of any other alternative. The 80% correct prediction rate refers to all consumer choices; given that ca. 90% of the consumers do not purchase a new car at all, this rate is perhaps not remarkable. For the subset of consumers who purchased a new car, the correct prediction rate is 60%; at each node of the tree, the conditional correct prediction rate is around 85%.

Percent correct predictions are, however, a very crude measure of fit. Therefore, I now turn to a more detailed discussion of the specification testing.

5.2. *Specification Testing*

5.2.1. *Alternative Specifications*

Figure 1a presents three nesting structures that may be plausible alternatives to the nested model estimated in the previous section. The first two are the most likely to alter the policy implications of the previous model, as they let domestic and foreign models directly compete with each other at lower levels of the tree. The third specification reverses the sequence of market segment and foreign vs. domestic, without altering the composition of the nests at the lowest level.

I start by estimating the four-stage model that omits the node foreign vs. domestic; the choice of each vehicle model at the last level of the estimation is thus conditioned on market segments but not origin. Since this specification results in more broadly defined choice sets at the bottom stage, a natural way to test this model against the original specification is to test for possible violations of the IIA property. To this end, I estimate the model using both the entire sample and a restricted choice set that is selected at random, and apply the Hausman-McFadden (1984) statistic:

$$T = \left(\hat{\beta}_r - \hat{\beta}_u \right)' \left(\hat{V}_r - \hat{V}_u \right)^{-1} \left(\hat{\beta}_r - \hat{\beta}_u \right)$$

where $\hat{\beta}_u$ and $\hat{\beta}_r$ refer to the parameter estimates obtained by applying maximum likelihood on the unrestricted and restricted choice sets respectively, and $\hat{V}_u$ and $\hat{V}_r$ are the estimate covariance matrices corresponding to the two

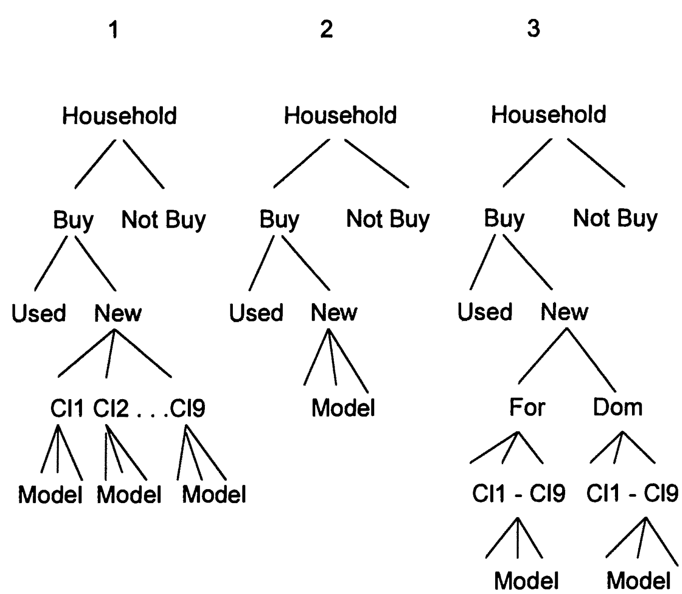

FIGURE 1A.—Alternative preference trees.

choice sets. The results are reported in Table C1 in Appendix C. For small, large, and luxury cars the null hypothesis of a simple multinomial logit structure at the last node of the tree is clearly rejected. Next, I apply the same procedure to the original specification to test for the IIA property when the choice at the last level is conditioned both on origin and market segment. The results are reported in Table C2 in the same Appendix. The χ^2 tests cannot now reject the IIA property for the cases of small and luxury cars. In the case of large cars the Hausman-McFadden test rejects the IIA property, but the χ^2 value is substantially lower than in the previous case. It appears that introducing an additional node corresponding to the origin of automobiles improves the specification, though an even finer classification of products might further decrease violations of the IIA property.[42] These results also imply that the second specification, which omits the market segment node completely, can be rejected since an even broader definition of classes at the lowest level will also violate the IIA property.

Next I estimate the third specification.[43] Note that in this specification the first stage is identical with the original model.[44] While the estimation results at the second stage are consistent with utility maximization (the inclusive value parameters lie in the unit interval), the inclusive value coefficients at higher stages lie well above one. For example, in the third node (foreign vs. domestic) the coefficient on the inclusive value term is 2.78 with a standard error of 0.086. These results were robust to alternative product groupings and vehicle characteristics and indicate that consumers substitute across the nests.

In summary, the model estimated in the previous section is the only one among the alternatives considered here that is consistent with random utility maximization and does not violate the IIA assumption at each node of the tree. Below, I therefore concentrate on the original specification and examine the fit of the model via χ^2 tests.

5.2.2. *The Fit of the Model*

Aggregate Market Shares: A first idea about the fit of the model can be obtained by comparing the predicted and actual aggregate market shares. To calculate expected market shares, I apply the aggregation method described in Section 2.2 to derive the aggregate demand for each vehicle model for the period 1983–87.

The difference between actual and expected ones can be split in two components. The first measures the discrepancy between the CES and the actual market shares. This difference provides a measure of the sampling error. As

[42] As was pointed out in the previous section, the problem with a finer classification is that the automobile classes end up consisting of homogeneous products that exhibit very little, if any, variation in observed characteristics.

[43] The results from estimating the alternative models are available upon request.

[44] In the first stage I again estimate three separate equations for small, large, and luxury cars and adjust the number of inclusive value terms at higher nodes correspondingly.

TABLE I
AGGREGATE MARKET SHARES

	Estimated			Actual		
Year	Car Sales	Imports	% Import	Car Sales	Imports	% Import
1983	8,219,423	2,383,633	29.0	9,181,530	2,386,064	25.9
1984	7,936,201	2,785,601	35.1	10,393,532	2,441,713	23.4
1985	9,298,155	2,436,117	26.2	11,046,243	2,839,226	25.7
1986	8,932,734	3,099,659	34.7	11,470,939	3,248,430	28.3
1987	9,938,719	3,627,632	36.5	10,225,304	3,144,042	31.0
Year	Truck Sales	Imports	% Import	Truck Sales	Imports	% Import
1983	2,004,378	348,762	17.4	3,129,000	471,000	15.0
1984	2,985,525	623,975	20.9	3,931,274	650,026	16.5
1985	3,672,620	569,256	15.5	4,517,668	805,822	17.8
1986	3,003,741	633,789	21.1	4,714,337	936,584	19.8
1987	3,633,452	832,060	22.9	4,962,938	870,041	17.5
Year[a]	Class	Cl. Share	% Import	Class	Cl. Share	% Import
1986	1	27.7	58.0	1	28.1	49.3
1986	2	27.2	40.3	2	25.3	41.1
1986	3	23.4	3.4	3	26.9	2.4
1986	4	9.3	0.0	4	8.7	0.0
1986	5	9.0	28.3	5	10.8	30.9

[a] For brevity, I only report data for 1986. Class and import shares for the other years are similar.

discussed in the Data Section, the CES sample is fairly representative of the United States population. This is also reflected in Table I which reports total demand for passenger cars and trucks along with class and import shares for each year. The left-hand side of the table presents our estimates while the right-hand side refers to data reported in the Automotive News Market Data Book. The figures in the table indicate that the results tend to underestimate total sales.

As noted earlier, this is a feature inherent in the data, probably due to ignoring fleet sales.[45] This explanation is consistent with the slight overestimate of import shares, as fleet sales consist primarily of domestic automobiles. My estimates of class and market shares, however, are very close to the true ones; slight deviations of predicted from actual shares can almost entirely be explained by differences in the definitions of classes and imports between the Automotive News Market Data Book and this paper. This, however, is evidence in favor of the sample rather than the estimation procedure.

The second source of discrepancy between expected and actual aggregate market shares is the difference between estimated and CES shares. It is this second component that should be used to measure fit. In this context, it is

[45] The annual publication "MVMA Motor Vehicles: Facts and Figures" reports that between 1983 and 1987 approximately 7 million passenger cars were in operation by fleets with 10 or more vehicles. Assuming an average turnover period of 3 years, this number translates into 2.5 million fleet sales per year which added to our estimates of the annual car sales comes close to the actual figures.

important to note that the estimation procedure predicts the CES market shares at the higher nodes of the tree *exactly*. The specification includes choice specific dummies and time effects, so that *at the aggregate* the model fits the data exactly. Put differently, if the population weights were not used, the left-hand side of Table I would coincide with the actual market shares of the CES. In terms of the price endogeneity discussion of Section 4, the part of the unobserved characteristics ξ_j that is specific to the origin and market segment of the automobile is captured through the appropriate choice dummies. This is not true at the last level of the model. As noted earlier, the last stage of the model includes brand but not model specific dummies; the predicted aggregate market shares for specific vehicle makes deviate from the actual shares of the CES sample. This deviation turns out to be quite small, suggesting that potential simultaneity bias arising from the omission of choice specific dummies at the lower level is not important in practice.[46]

χ^2 *Tests*: Given the large set of choice specific and time dummies, it is not surprising that the model fits the aggregate data well. A better idea about the fit of the model can be obtained by performing χ^2 tests at a more disaggregate level based on finer consumer and vehicle classifications.[47] A detailed discussion of the specification testing using χ^2 tests can be found in Appendix C. In the following, I summarize the main findings. The results are sensitive to both the number of cells and the way the cells are defined; increasing the number of cells tends to increase the probability of rejection, but lowers the power of the test. Using age as a criterion for defining the cells yields the most favorable results for the model, while defining the cells on the basis of income alone almost always results in rejection of the model.[48] These tradeoffs are reflected in Tables C3–C10 in which a subset of the χ^2 test results is reported. The consumer attributes used to define these cells are age, income, and education; depending on the combination of these characteristics 3, 9, or 18 alternative consumer groupings are considered. The vehicle choices are split into various subsets, most of which conform to the classification used in the estimation of

[46] As noted by Berry (1994), simultaneity bias in discrete choice models often manifests itself as overfitting, meaning that deviations of predicted from actual market shares are too large to be explained by sampling error alone.

[47] The χ^2 tests were computed using the approach outlined in Andrews (1988); this formulation takes into account the fact that the expected cell frequencies are based on parameters estimated sequentially using micro data. In particular, the test statistic is given by

$$\chi_n^2(\hat{\theta}) = \nu_n(\hat{\theta})'\hat{W}\nu_n(\hat{\theta})$$

where n denotes the sample size, $\hat{\theta}$ is the estimated parameter vector, $\nu_n(\hat{\theta})$ corresponds to the difference between actual and expected cell frequencies, and $\hat{W}$ is a weight matrix. The weight matrix was computed using formula (3.13) on page 1432 in Andrews' article ($\hat{W} = \hat{\Sigma}_{3n}$).

[48] This is probably due to the fact that the observations are more evenly distributed across cells when age rather than income is used as the classification criterion; the distribution of observations corresponding to the age based classification is 25% in the first cell, 34% in the second cell, and 41% in the third cell. In contrast, an income based classification results in 60% of the observations in the first cell, 37% in the second cell, and only 3% in the third cell. As a result, one or two poor predictions for individual observations have a relatively large impact on the test statistic. Classifications based on other criteria such as education lie somewhere between the previous two extremes.

the nested logit. The finest classification used in the χ^2 tests involves brands; finer cell definitions based on specific vehicle makes result in tests with low power because of the enormous number of cells involved. Two types of tests are performed; unconditional tests that examine the overall fit of the model and conditional tests, in which choices are conditioned on the previous stage nest or on a subset of the vehicle space.

The results reported in the Appendix are intended to convey the general picture. The unconditional tests generally reject the model (with the exception of two cases where age alone was used as a criterion for defining cells). The conditional χ^2 tests are more favorable. Tests at the lower levels of the tree that condition on the previous stage nest fail to reject the model. This is also true for tests that condition on the subset of new cars. These results indicate that a weakness of the model is the poor treatment of dynamics; if the dynamic aspects are most important in determining whether a consumer enters the market for new cars, their neglect results in poor predictions of new car purchases at a disaggregate level. The inclusion of vehicle stock age and composition dummies only partially substitutes for the absence of a dynamic model of automobile purchase and replacement. Conditional on the purchase of a new car the model does a much better job in predicting the market segment, origin, and brand of the preferred vehicle.

5.2.3. *Out of Sample Predictions*

The final specification tests involve out-of-sample predictions. These predictions are performed for the years 1989 and 1990 which are covered by more recent CES surveys. To obtain an independent household sample, the year 1988 is skipped; because of the rotating panel character of the data, a large number of households interviewed in the last year included in the estimation (1987) also appear in 1988.

The out of sample predictions involve both comparisons of aggregate market shares and χ^2 tests. The results from the latter tests have the same flavor as within sample testing; the χ^2 tests tend to reject the model, but the rejection is weaker for conditional tests at the lower level of the tree. The model predicts aggregate market segment and origin specific market shares quite accurately, while predictions about the total number of new car purchases in 1989 and 1990 are rather poor.[49] Overall, statistical testing rejects the hypothesis that the predicted outcomes equal the observed ones, but the results are not a disaster.

5.2.4. *Summary*

The specification test results are mixed. Although the estimated model fits the aggregate data quite well, both in years within and out of sample, disaggregate χ^2 tests tend to reject the model. Because conditional tests perform much better than unconditional tests, these rejections seem to point to the important

[49] These predictions are reported in Table C11.

TABLE II
PRICE ELASTICITIES OF DEMAND (AVERAGE BY CLASS)

Class	Origin	Elasticity	Elasticity (first time buyer)	Elasticity (repeat buyer)
Subcompacts	DOM	−3.2857	−3.6245	−2.9816
	FOR	−3.6797	−5.2531	−2.9488
Compacts	DOM	−3.419	−4.8722	−3.1546
	FOR	−4.0319	−5.7229	−3.3733
Intermediate	DOM	−4.1799	−5.3153	−2.8420
	FOR	−5.1524	−6.2232	−4.9274
Standard	DOM	−4.7121	−5.932	−4.3730
Luxury	DOM	−1.9121	−2.5981	−1.1137
	FOR	−2.7448	−3.1272	−1.9959
Sports	DOM	−1.0654	−2.3468	−1.3959
	FOR	−1.5254	3.0211	−1.1429
Pick-ups	DOM	−3.5259	−5.1391	−3.1647
	FOR	−2.6883	−3.9822	−2.1483
Vans	DOM	−4.3633	−5.4977	−3.9790
	FOR	−4.6548	−4.8837	−2.4376
Other	DOM	−4.0884	−4.3185	−3.5694
	FOR	−3.0271	−3.3185	−2.3345

role of dynamics. Despite this shortcoming, the restrictions on the inclusive value parameters implied by utility maximization are not rejected; in fact, the estimated model is the only one among the alternative specifications considered here that conforms to the utility maximization paradigm. It is also interesting to note that a "sequential elimination" model like the one estimated in a previous paper (Goldberg (1993a)) fits the data much better at both the aggregate and a more disaggregate level. Such a model is not based on utility maximization and therefore was not given further consideration here. The model of Figure 1 predicts the allocation between various vehicle classes accurately, so the policy analysis employs the original specification. The main policy questions concern more the composition of vehicle sales under various scenarios than their total volume.

5.3. *Price Elasticities of Demand*

Price elasticities of demand are crucial for many of the questions associated with oligopolistic behavior. One of the strengths of our approach is that it gives plausible own and cross price elasticities of demand. This is the result of using household specific information in weighting vehicle price changes to compute aggregate price indices. If a particular household is unlikely to buy a certain vehicle, fluctuations in the price of that vehicle are not going to affect the household's behavior significantly; accordingly, this household will receive low weight in the derivation of the aggregate price effect.[50] The estimated own price

[50] All elasticities reported in this section are *transaction price elasticities*. They differ from the wholesale price elasticities that enter the manufacturer's profit maximization problem in that they include dealer markup behavior and other types of transaction costs.

elasticities of demand for specific products range from -1.00 to -10.13. The average unweighted elasticity is -3.28. All are greater than one in absolute value. A comparison of elasticities of demand across classes also shows an intuitive pattern. Table II reports price elasticities of demand by car size and country of origin. The most price elastic classes are those corresponding to intermediate and standard automobiles, with average elasticities of -4.6 and -4.71 respectively, while luxury and sports cars are the least price elastic—the average elasticities for these classes are -2.02 and -1.35 respectively.

This is also evident in Table III, where the price elasticities of selected, "class representative," models are reported.[51]

As noted in Section 5.1.1, the demand system estimates suggest that the price effects depend upon past purchases. This result is reinforced by the price elasticities of demand. To this end, I split the sample into two groups—households that purchased a specific model in the past and those that have not—and I compute two separate price elasticities of demand for each vehicle. The results are displayed in Table II. First time buyers are indeed more price elastic than repeat buyers. Their average price elasticity of demand is -4.1 as opposed to -2.1 for repeat buyers.

The substitution patterns, evident in the cross price elasticities of demand, are also intuitive. Table III reports cross price semi-elasticities between selected models.[52]

Consistent with utility maximization, and since consumers buy only one car model, all cross price elasticities are positive. Furthermore, their magnitude

[51] Price elasticity of demand refers here to the percent change in the *expected* demand of a model resulting from a one percent change in price. Accordingly, they are computed using the formula $(\partial ED_{(c,o,m)}/\partial p_{c',o',m'})(p_{c',o',m'}/ED_{(c,o,m)})$. The price derivatives are in turn obtained by aggregating individual household price derivatives over the sample. Individual price derivatives are computed according to the formula:

$$\begin{aligned}\frac{\partial P^h_{(c,o,m)}}{\partial p_{(c,o,m)}} &= \frac{\partial P^h_b}{\partial p_{(c,o,m)}} * P^h_{n/b} * P^h_{c/n,b} * P^h_{o/c,n,b)} {}^* P^h_{m/o,c,n,b} \\ &+ \frac{\partial P^h_{n/b}}{\partial p_{(c,o,m)}} * P^h_b * P^h_{c/n,b} * P^h_{o/c,n,b} * P^h_{m/o,c,n,b} \\ &+ \frac{\partial P^h_{c/n,b}}{\partial p_{(c,o,m)}} * P^h_b * P^h_{n/b} * P^h_{o/c,n,b} * P^h_{m/o,c,n,b} \\ &+ \frac{\partial P^h_{o/c,n,b}}{\partial p_{(c,o,m)}} * P^h_b * P^h_{n/b} * P^h_{c/n,b} * P^h_{m/o,c,n,b} \\ &+ \frac{\partial P^h_{m/o,c,n,b}}{\partial p_{(c,o,m)}} * P^h_b * P^h_{n/b} * P^h_{c/n,b} * P^h_{o/c,n,b}\end{aligned}$$

where $P^h_{(c,o,m)}$ is the probability of household h buying product $((c,o,m))$, and $p_{(c,o,m)}$ is the price of the respective good.

[52] Table III reports semi-elasticities rather than elasticities to control for large price differences between models that would create the illusion that relative price increases of expensive cars are associated with large substitution effects.

TABLE III

CROSS PRICE SEMI-ELASTICITIES FOR SELECTED MODELS

	Chevette	Civic	Tercel	Escort	Accord
Chevette	−3.2	49.1E − 07	16.4E − 07	0.9E − 07	9.0E − 07
Civic	7.6E − 07	−3.4	35.5E − 07	0.8E − 07	14.9E − 07
Tercel	7.7E − 07	109.8E − 07	−3.4	0.8E − 07	11.6E − 07
Escort	6.3E − 07	34.6E − 07	11.3E − 07	−3.4	12.5E − 07
Accord	6.1E − 07	66.2E − 07	16.2E − 07	1.3E − 07	−3.4
Mazda 626	6.4E − 07	50.1E − 07	15.3E − 07	1.7E − 07	72.2E − 07
Century	5.5E − 07	28.0E − 07	9.6E − 07	0.8E − 07	7.1E − 07
Skylark	5.5E − 07	28.6E − 07	9.9E − 07	0.8E − 07	7.1E − 07
Audi 5000	5.7E − 07	48.6E − 07	16.6E − 07	0.8E − 07	10.1E − 07
Diplomat	4.9E − 07	25.5E − 07	8.7E − 07	0.8E − 07	6.6E − 07
Cad. Fleetwood	0.3E − 07	2.1E − 07	0.7E − 07	0.1E − 07	0.5E − 07
Park Avenue	0.3E − 07	2.1E − 07	0.7E − 07	0.1E − 07	0.5E − 07
Jaguar	0.3E − 07	3.2E − 07	1.0E − 07	0.0E − 07	0.6E − 07
Fiero	0.4E − 07	3.0E − 07	1.0E − 07	0.1E − 07	0.7E − 07
Ferrari	0.4E − 07	4.0E − 07	1.3E − 07	0.1E − 07	0.8E − 07

	Mazda 626	Century	Skylark	Audi 5000	Diplomat
Chevette	18.0E − 07	0.3E − 07	0.1E − 07	7.8E − 07	0.1E − 07
Civic	21.8E − 07	0.2E − 07	0.1E − 07	10.2E − 07	0.1E − 07
Tercel	20.7E − 07	0.3E − 07	0.1E − 07	10.7E − 07	0.1E − 07
Escort	32.4E − 07	0.3E − 07	0.1E − 07	7.1E − 07	0.2E − 07
Accord	140.9E − 07	0.3E − 07	0.1E − 07	9.2E − 07	0.1E − 07
Mazda 626	−3.4	0.3E − 07	0.1E − 07	8.1E − 07	0.2E − 07
Century	16.0E − 07	−4.8	0.3E − 07	11.1E − 07	0.2E − 07
Skylark	15.9E − 07	0.7E − 07	−3.8	11.4E − 07	0.2E − 17
Audi 5000	17.0E − 07	0.5E − 07	0.2E − 07	−4.0	0.2E − 07
Diplomat	18.2E − 07	0.4E − 07	0.1E − 07	7.1E − 07	−3.8
Cad. Fleetwood	1.2E − 07	0.0E − 07	0.0E − 07	0.5E − 07	0.0E − 07
Park Avenue	1.2E − 07	0.0E − 07	0.0E − 07	0.5E − 07	0.0E − 07
Jaguar	1.1E − 07	0.0E − 07	0.0E − 07	0.6E − 07	0.0E − 07
Fiero	2.2E − 07	0.0E − 07	0.0E − 07	0.6E − 07	0.0E − 07
Ferrari	1.5E − 07	0.0E − 07	0.0E − 07	0.7E − 07	0.0E − 07

	Fleetwood	Park Avenue	Jaguar	Fiero	Ferrari
Chevette	3.0E − 07	3.4E − 07	6.8E − 07	1.0E − 07	0.7E − 07
Civic	3.0E − 07	3.4E − 07	11.0E − 07	1.2E − 07	1.2E − 07
Tercel	3.2E − 07	3.5E − 07	11.3E − 07	1.2E − 07	1.2E − 07
Escort	3.1E − 07	3.4E − 07	6.2E − 07	1.1E − 07	0.7E − 07
Accord	2.9E − 07	3.4E − 07	9.4E − 07	1.2E − 07	1.0E − 07
Mazda 626	3.9E − 07	4.6E − 07	9.8E − 07	2.0E − 07	1.0E − 07
Century	3.8E − 07	4.7E − 07	7.0E − 07	0.9E − 07	0.5E − 07
Skylark	3.9E − 07	4.8E − 07	7.2E − 07	0.9E − 07	0.5E − 07
Audi 5000	3.6E − 07	3.9E − 07	10.7E − 07	1.0E − 07	1.1E − 07
Diplomat	4.8E − 07	5.0E − 07	8.1E − 07	1.0E − 07	0.5E − 07
Cad. Fleetwood	−0.9	38.9E − 07	1.6E − 07	0.1E − 07	0.0E − 07
Park Avenue	33.5E − 07	−0.9	1.5E − 07	0.1E − 07	0.0E − 07
Jaguar	0.6E − 07	0.7E − 07	−0.9	0.1E − 07	0.1E − 07
Fiero	0.3E − 07	0.3E − 07	0.6E − 07	−0.9	0.1E − 07
Ferrari	0.2E − 07	0.2E − 07	0.9E − 07	0.1E − 07	−1.0

Note: Each entry (i, j), where i is the row and j is the column, refers to the percent change in the demand for model j when the price of model i changes by \$1.

depends on the degree of similarity between products; automobiles that belong to the same class and origin—and are therefore similar in characteristics—exhibit on average higher cross price semi-elasticities than products of different classes and origin. The cross price elasticities are smallest in the segment of domestic intermediates and standards; this is due to the large number of models included in each of these segments. An interesting feature of the cross price elasticities concerns the choice between domestic vs. foreign automobiles belonging to the same market segment. The cross price elasticities for these products are often smaller than the cross price elasticities between two foreign products belonging to different market segments; for example, the cross price elasticity between the Honda Civic and the Chevrolet Chevette is lower than the cross price elasticity between the Civic and the Honda Accord or the Mazda 626. This suggests that the choice between domestic and foreign automobiles is not very price sensitive. When foreign cars become more expensive, consumers tend to substitute across classes rather than buying cars from a different country of origin. Note that this result goes against the structure imposed on the demand system. Given that the choice between foreign and domestic lies below the choice of market segments in the decision tree, one would expect the cross price elasticities between foreign and domestic automobiles belonging to the same class to be larger than the elasticities between cars belonging to different market segments. One possible explanation for this pattern is that the decision concerning the origin of the automobile is driven more by household characteristics such as income, education, age and region, and less by prices.

5.4. *Marginal Costs and Markups*

The first order conditions for profit maximization in Section 2.3 can be solved for the marginal cost of each product. Then the markup for a specific model can be calculated as

$$\text{Markup} = \frac{\text{Wholesale Price} - \text{Marginal Cost}}{\text{Wholesale Price}}.$$

Table IV summarizes marginal costs and markups for each automobile class and for some representative models for 1986. The cost figures are stable over time when they are expressed in the local currencies of the producing countries (variation in costs is due primarily to variation in vehicle characteristics) while their dollar value equivalents are highly correlated with exchange rate changes. This can be interpreted as evidence that the model is correctly specified. In general, the marginal cost estimates are all positive and they indicate that production costs increase with vehicle size. The markup figures, on the other hand may seem too high. According to my calculations, markups are on average 38% while previous studies of the industry estimated them to be around 15%.[53] To check their plausibility the marginal cost estimates were compared to data

[53] See, for example, Bresnahan (1986).

TABLE IV
MARGINAL COSTS AND MARKUPS

Class	Origin	Cost	Price	Markup	(Price − Cost)
1	DOM	3906	6628	0.36	2722
1	FOR	5688	7840	0.27	2152
2	DOM	3213	6391	0.43	3178
2	FOR	5430	6610	0.19	1180
3	DOM	4773	7134	0.33	2361
3	FOR	9300	12781	0.30	3421
4	DOM	4866	8632	0.40	3766
5	DOM	7247	13458	0.46	6301
5	FOR	10379	18499	0.43	8129
6	DOM	3715	10105	0.69	6390
6	FOR	5822	12823	0.56	7001
7	DOM	5101	8229	0.37	3128
7	FOR	2758	5611	0.41	2583
8	DOM	6937	9634	0.30	2697
8	FOR	12691	15291	0.17	2600
9	DOM	8333	10121	0.15	1788
9	FOR	2750	5174	0.44	2424
Model		**Cost**	**Price**	**Markup**	**(Price − Cost)**
Civic		4884	5680	0.14	796
Escort		3068	4565	0.33	1497
Lynx		3069	4325	0.29	1256
Accord		5286	5854	0.10	567
Audi 5000		7353	14165	0.48	6812
Oldsmobile 98		5372	11295	0.52	5923
Jaguar		10768	19091	0.44	8323
Mercedes 300		13188	22662	0.42	9474
Porsche 944		5714	13136	0.56	7422
Ferrari		7679	19698	0.61	12018

from the Annual Survey of Manufactures (ASM). This survey provides data on payroll and material costs for the automobile industry that can be used to approximate the actual variable cost.

The ASM data are consistent with the 15% markup figure reported in other studies as the sum of labor and material costs accounts for approximately 85% of the value of shipments. Of course, marginal cost is not observable; average payroll and material costs only provide a rough, and in many respects inadequate, approximation to the *average variable* cost. One could argue that a large component of the labor cost does not depend on the production volume. Treating a fraction of the payroll as fixed cost would bring marginal costs closer to our estimates. Moreover, our cost estimates refer to short run marginal cost which in periods of capacity underutilization, such as in the 1980's, can be substantially lower than the average production cost. The reported 38% short-run markups are not inconsistent with the widespread belief that the automobile industry was losing money during that period. Another piece of evidence related to the magnitude of markups comes from Bresnahan and Reiss (1985). They find that the ratio of dealer to manufacturer markups is 0.71. Moreover, they cannot reject the hypothesis that this ratio is equal to 0.5. According to Consumer Reports, dealer markups are between 15 and 25%, and the reported ratio implies that manufacturer margins are between 22 and 50%. These numbers are consistent with my estimates of manufacturer markups.

5.5. *Cost Parameters*

The parameters of the cost function are estimated by regressing the estimated marginal costs of specific automobile models on vehicle characteristics and year dummies. Our marginal cost estimates seem to reflect the relative production costs of different vehicle classes. The cost function parameters are thus identified up to a constant. Three separate equations were estimated: One for American cars, one for Japanese, and one for cars from other countries of origin, predominantly Germany. The costs of these vehicles—initially expressed in U.S. dollars—were multiplied by the current exchange rates to obtain their local currency equivalents. Implicit in these regressions is the assumption that the marginal cost of an additional unit of a vehicle characteristic, expressed in the producer's local currency, is constant over the period 1983–87. Alternatively, one could assume that the marginal cost of vehicle characteristics, expressed in dollar terms, remained constant over that period. The latter assumption would justify pooling data for American and foreign cars,[54] but it would eliminate the possibility of analyzing the effects of exchange rate changes on prices. Since I am interested in exchange rate pass-through in the automobile industry, I chose the first option. The estimation results are reported in Tables D1–D3 of the Appendix. The parameters associated with cylinders, horsepower and air-conditioning are positive and significant indicating the higher production cost of big and luxury cars. The variables "*QUOT1-QUOT5*" are dummies specific to Japanese passenger cars that have been interacted with year dummies. As was noted in Section 4, the effect of the Lagrange multipliers in the firm's first order condition (3) is to shift the costs of Japanese passenger cars by a constant amount. This implies that they can be treated as year dummies, specific to the firms that produce cars subject to quotas. As long as Japanese firms produce other cars (trucks, vans, and utility vehicles that are not subject to the VER), we can get an idea about the shadow price of the VER by estimating the coefficients associated with the above dummies. The variables "*QUOT1-QUOT5*" can be viewed as the average Lagrange multipliers associated with the quota constraints for these cars. Under this interpretation, the estimated coefficients suggest that the quantity constraint was binding throughout the 1983–87 period, and had the strongest effects in the first three years. Table D4 describes similar cost regressions in which separate time effects for several Japanese firms as well as firm specific interactions of time effects and passenger car dummies were included; the latter can be interpreted as the deviations of the firm specific

[54] When data for American and foreign cars are pooled, however, the hypothesis that the coefficients for American, Japanese, and German cars are equal, is rejected.

Lagrange multipliers from the averages.[55] These results indicate that Toyota and Nissan were less constrained than the average firm, while Mazda faced a higher than average opportunity cost in the years 1984, 1985, and 1986.[56] By determining the cost side parameters, I obtain a fully estimated automobile market model that can be used to address various questions in industrial organization and international trade.

6. MODEL APPLICATIONS

In this section I use the model to investigate two major issues in international trade: quantitative restrictions on imports and exchange rate pass-through. The method employed is counterfactual simulations. The parameter estimates obtained in the previous section are substituted into the model which is solved under various assumptions concerning trade restrictions and/or exchange rates. The equilibrium quantities and prices are then compared and differences are attributed to changes in trade policy or exchange rates. This approach requires assumptions about the uniqueness of the equilibrium; given that, as was pointed out in Section 2.3, a formal proof of uniqueness or even existence of an equilibrium in the presence of multiproduct firms does not yet exist, I assume that the equilibrium is—at least locally—unique. I begin by analyzing the impact of a quota on the equilibrium outcome. I then examine the effects of exchange rate changes on import prices.

6.1. *Quotas*

For the April, 1981–March, 1984 period, Japanese sales to the United States were subject to a limit of 1,832,500 cars per year. In April, 1984 the constraint was raised to 2,016,000 units. The following year the Japanese government volunteered to limit Japanese auto sales in the U.S. market to 2.5 million annually, and has continued this policy ever since. In each period the quotas were allocated to specific firms by the Japanese government.

Theoretical work analyzing the effects of export restraints in imperfectly competitive markets shows that the effects of a quota depend critically on the market structure and the particular way in which the restraint is implemented.[57] In view of this sensitivity to alternative assumptions, I apply the empirical model developed in the previous sections to assess the impact of export restraints, both in qualitative as well as in quantitative terms.[58] In particular, I focus on the

[55] As was pointed out in Section 3, including an exhaustive set of firm specific Lagrange multipliers is not feasible, as the latter would not be identified in the case of firms producing only passenger cars.

[56] These results are consistent with anecdotal evidence. See Lohr (1983).

[57] Krishna (1990b) reviews this literature.

[58] An empirical investigation of the quota effects in the automobile industry appears in Feenstra (1984, 1985, 1988). Feenstra finds that quotas induced a quality upgrading of Japanese imports and raised prices for both domestic and foreign automobiles. His results are based on hedonic price regressions.

following issues:

1. Were the quota constraints binding during the 1983–87 period?

2. How did the export restraint affect the equilibrium outcome in the automobile industry? In particular what were the effects on sales and market shares, on prices, and on the quality mix?

3. How does the quota constraint compare to an equivalent tariff?

Throughout the simulations I focus on the new car market, abstracting from the impact of the quota constraint on the prices of used cars. Moreover, in accordance with the focus on the second stage of the suppliers' decision process (price setting), I abstract from the effects of the VER on direct investment in the U.S., and model introduction/design decisions. The simulation results have to be interpreted with caution; the simulation experiment does not reveal what *actually* happened in the market, but what *would have* happened, if the other exogenous variables in the model had remained constant.

6.1.1. *Were the Quota Constraints Binding*?

To address this question I solve the model under two regimes: one in which quota constraints exist so that Japanese firms maximize a Lagrangian, and one in which free trade prevails. Computing the equilibrium allows me to explicitly solve for the Lagrange multipliers as the shadow prices of the quota constraint. Note that when the supply side was estimated, the Lagrange multipliers were treated as product specific dummies (*QUOT1-QUOT5*) and thus as components of the deterministic part of the marginal costs.[59] To avoid double counting, it is necessary to remove these product specific dummies from the calculation of the expected marginal costs for Japanese passenger cars, when the Lagrange multipliers are computed directly as part of the equilibrium price vector. Comparing the import shares with and without the quota constraint and examining the value of the Lagrange multiplier in each year can provide insights as to the extent to which the export constraint was binding. The results are summarized in Table V. The first two columns of the table report the import shares with and without quotas, while the third column refers to the Lagrange multiplier. The positive values of Lagrange multipliers and the import shares imply that in the first two years, 1983 and 1984, the export restraint had an economically significant impact on Japanese sales in the United States. The quota constraint had a smaller effect in 1985, the year in which the Japanese government volunteered to extend the restraint for another period; it became binding again

[59] For the reasons explained in Section 2.3, I work with average Lagrange multipliers in this section. In principle, one could use firm specific multipliers, as identification is no longer an issue. But this would not be consistent with the estimation approach; furthermore, data on firm specific VER's each year are nontrivial to find, as only trade associations have precise information on the yearly allocations.

TABLE V

IMPORT SHARES AND LAGRANGE MULTIPLIERS

Year	No Quota	Quota	Lagrange Multiplier
1983	0.314	0.271	2155
1984	0.363	0.340	2018
1985	0.249	0.243	67
1986	0.339	0.328	402
1987	0.390	0.378	1961

TABLE VI

EFFECTS OF THE VER ON SALES

Year	Total	Passenger Cars	American	Japanese	Other
1983	−33,478 (0.3%)	−90,899 (1.1%)	+209,990 (2.0%)	−340,321 (15.0%)	+39,432 (7.0%)
1984	−37,808 (0.3%)	−124,990 (1.6%)	+140,807 (1.5%)	−298,477 (9.4%)	+32,680 (6.4%)
1987	−29,991 (0.02%)	−106,632 (1.0%)	+57,510 (0.5%)	−185,843 (4.5%)	+21,702 (2.8%)

in 1986 and 1987, though its effects in these years were smaller than the effects in 1983–84.[60]

6.1.2. *The Quota Effects*

In the following, I analyze the effects of the export restraint for the years in which the constraint had the strongest effect (1983, 1984, and 1987). In years in which quotas did not bind, the equilibrium outcome is equivalent to that under free trade.[61] This is a direct consequence of the "no spillovers" assumption which was discussed in Section 2.3. The implications of relaxing this assumption are discussed in Krishna (1989). To quantify the impact of quotas on sales, prices, and quality mix of domestic and foreign firms, I solve the model under two different assumptions, quotas vs. free trade, and compare the outcomes.

Effects on Sales and Market Shares: The effects of the export restraint on sales and market shares, as implied by the model simulations, are summarized in Table VI.

In 1983 and 1984 the quotas lead to a drop in Japanese sales of passenger cars of about 300,000 units a year. This decline in Japanese imports does not,

[60] The result that the quota constraint became binding again in 1987 is puzzling. I attribute this unlikely finding to the unsatisfactory treatment of vehicle models that are produced both domestically and abroad, such as the Honda Accord, Toyota Camry, etc. The domestic production of foreign brand names increased significantly in 1987. Since I treat these models as Japanese rather than American products, I include them in the quota constraint. Thus I overestimate the impact of quotas on foreign production. While this effect is small in years preceding 1987, it seems to matter in 1987.

[61] Table V indicates that the constraint was binding in 1985 and 1986; the Lagrange multipliers are, however, significantly lower for these years. I therefore exclude 1985 and 1986 from the simulations; the reported results should characterize the general pattern of quota effects.

however, benefit American producers to the full extent; American sales captured on average only 54% of the lost Japanese sales. This is the result of two effects: First, the quota leads to substitution towards other imports, mainly European cars, which increase by 18% on average. Second, the restraint leads to a small decline in total sales; as a consequence of higher prices some consumers substitute towards cheaper, used automobiles.[62] A disaggregate analysis of the quota effects on two different consumer groups classified on the basis of their income shows that the majority of consumers switching to used cars belongs to low income classes, earning less than $75,000 per year, and are less than 30 years old. As I discuss below, this differential impact of the quota on income classes affects the quality decisions of automobile producers.

Price Effects: In general, quotas raise prices. The price increase is most pronounced in Japanese passenger cars subject to quotas, which experience an average increase of 14% each year during 1983–84.[63] The prices of domestic vehicles and other imports also rise, but less (0.5–0.9% per year). This disproportionate increase of Japanese import prices changes the relative prices of small vs. large automobiles. This occurs because Japanese dominate subcompacts and compacts, while Americans and Germans are most strongly represented in mid-sized/large cars and luxury automobiles respectively. In addition, quotas affect the relative prices of cars subject to quotas; the prices of the relatively cheap Japanese subcompacts rise by more than the prices of the relatively expensive compacts. As noted in the next subsection, this change in relative prices affects the composition of auto sales.

Effects on Quality: Recent studies in imperfectly competitive markets show that quotas lead to a quality upgrading of foreign imports under a fairly general set of assumptions.[64] The effect comes from the cost side (Feenstra (1988)), or from the demand side (Krishna (1987, 1990a)). From an empirical perspective, the first step towards examining the impact of quotas on quality is to operationalize the term "quality upgrading."

[62] This second effect is limited because the coefficient on the inclusive value term at the new vs. used stage of the estimation is quite small; new and used cars appear to be almost different products from the perspective of consumers, and the choice is determined more by financial ability than by prices.

[63] The computation of the quota effects on wholesale prices assumes that dealer markups for Japanese cars are not affected by the quota constraint. This is clearly an abstraction as there is strong evidence that during the early 1980's, dealers of Japanese imports increased their markups. The dealer response to the VER has serious implications for the calculation of the quota impact on national welfare as it determines who captures the quota rents; constant dealer markups imply that the rents are captured by the Japanese producers while an increase in dealer markups suggests that the quotas benefit primarily domestic dealers. However, the objective is not to compute national welfare, but to assess the impact on prices, production, and market shares, so we abstract from this issue.

[64] See Falvey (1979), Rodriguez (1979), Krishna (1987, 1990a), Feenstra (1988), Das and Donnefeld (1987, 1989). Only Chen (1991) finds that in a repeated oligopoly setup quotas can lead to quality downgrading, if firms collude and the quota is just binding at its free trade equilibrium level.

TABLE VII
PERCENT CHANGE IN MARKET SEGMENTS (1983)

Class	Domestic	Foreign
Subcompact	1.9	−18.0
Compact	2.5	−15.3
Intermediate	4.2	7.5
Standard	3.3	—
Luxury	3.0	4.4
Sports	4.2	7.6
Trucks	5.0	10.1
Vans	0.3	0.8
Other	3.1	4.0

I define "quality upgrading" as a movement towards market segments that include more expensive cars. In terms of Japanese imports this implies a movement from relatively cheap subcompacts towards higher priced compacts. This compositional effect is easy to quantify as the nested structure of the automobile choice process allows for the choice between market segments. This approach underestimates the total effect of the quotas on quality change (as it ignores the introduction of new models and options), but outlines the trends in the industry.

Table VII reports the computed change in market segment shares that results from imposing an export restraint on Japanese auto sales. Two trends clearly emerge. First, the decrease in Japanese subcompact sales is larger than the corresponding decrease of compact sales. The share of the relatively more expensive compacts in the total Japanese imports of passenger cars thus increases. Second, the share of higher priced intermediate, standard, and luxury automobiles in both the American and the foreign production rises. Thus the overall "quality" of automobile sales increases.

What is the source of this compositional shift? The answer lies in the demand side of the model;[65] the shift towards higher priced market segments seems to be the result of two effects. First, the majority of consumers dropping out of the market belong to low income classes; these consumers used to purchase relatively inexpensive subcompacts and compacts, so that their absence from the market induces a shift towards larger automobile classes. More importantly, quotas change the relative prices of market segments so that within each consumer group, as defined by income, there is substitution towards higher priced automobile classes.

[65] Of course, profit maximization implies that under quantity constraints, suppliers have an incentive to shift production towards products with the highest markups. The question is whether the demand side of the model supports such a compositional shift. In our model, quality upgrading emerges as an equilibrium phenomenon; when the export restraint is imposed, prices change so that at the new equilibrium, relatively expensive cars have higher markups.

TABLE VIII
EQUIVALENT TARIFF LEVELS

Year	Tariff on Japanese Products	General Tariff
1983	64%	65%
1984	62%	62%
1987	55%	57%

6.1.3. *Comparison to an Equivalent Tariff*

A tariff on foreign products can take two forms. It can be imposed on Japanese products alone or be applied to all imports. For completeness, I consider both cases, although existing GATT rules should make the first option less likely. In both cases it is assumed that the government's objective is to limit Japanese sales in the United States to their VER level. To compute the equivalent tariff, I eliminate the Lagrange multiplier from the Japanese suppliers' problem, and modify the profit function to take tariffs into account.[66] The model is solved for the price and tariff levels that satisfy both the first order conditions of the profit maximizing producers, and the constraint that Japanese passenger car sales do not exceed the VER level. By comparing the equilibrium outcome to that with a quota restriction, I determine the differential effects of quotas and tariffs on sales, price, and quality.

Tariff on Japanese Imports: The equivalent tariff levels for the years 1983, 1984, and 1987 are depicted in Table VIII. The high tariff levels are due to the low degree of tariff pass-through on Japanese import prices; a tariff increase of 64% raises Japanese import prices by only 22%, so that huge tariff increases are necessary to reduce Japanese imports to the VER level.

General Tariff on Imports: The third column of Table VIII reports the computed equivalent tariff levels for the case of a general tariff on foreign sales. The general tariff required to reduce Japanese sales to the VER level is higher than the corresponding tariff on Japanese products alone. This somewhat surprising result is attributable to the different pass-through patterns between Japanese and other, primarily German, imports. While the tariff pass-through coefficients for Japanese imports are small, pass-through is almost complete in

[66] The foreign producer facing a tariff solves then the problem:

$$\max_{p_{it}^w} E_i \Pi_t^f = \left\{ \sum_{i=1}^{n_{ft}} \left(e_t p_{it}^w / (1+TR) - c_{it} \right) q_{it} - F_{ft}(X_{ft}) \right\}.$$

The variable TR denoting the ad valorem tariff is treated as an unknown and solved for during the computation of the market equilibrium.

the case of German imports.[67] This implies that a general tariff increases prices of other imports by more than prices of Japanese cars so that consumers with a preference for foreign automobiles have fewer substitution possibilities. In particular I find that the 64% tariff on foreign automobiles in 1983 raises Japanese import prices by only 22% as opposed to 52–65% for German cars. Therefore a higher tariff is required to reduce Japanese imports to the desired level.

As a consequence of the large price increase of other imports induced by the tariff, the import share drops significantly. In 1983 for example, imports subject to a general tariff account for only 24% of total sales, 3% lower than under a quota. A general tariff also differs from a quota with respect to implications about the composition of auto sales. A tariff does not affect the relative price of Japanese subcompacts vs. compacts, but it increases the relative price of foreign, primarily German, luxury cars by a disproportionate amount. At the same time the relative price of domestically produced large automobiles drops. The net effect of this change in relative prices is a quality downgrading of imports, but an overall quality upgrading of auto purchases.

In summary, the impact of the VER on domestic production—and therefore domestic employment—was rather limited. In contrast, the price effects of the quota constraint were significant. The prices of new automobiles increased slightly, reducing purchases of new cars, while the relative prices of higher priced cars decreased, inducing a shift towards higher quality imports. Both these effects are more likely to have benefited producers than consumers. If the primary goal of the VER was to increase domestic employment rather than profits, the effectiveness of quotas seems doubtful. Interestingly, with imperfect competition we reach the same conclusion as traditional trade models based on perfectly competitive markets: Tariffs are superior to quotas in promoting national interests.

6.2. *Exchange Rate Pass-Through in the Automobile Industry*

It has been observed that the U.S. dollar prices of imported goods are often insensitive to exchange rate changes. Such price inertia results in differences in the relative prices of internationally traded goods and has important implications for both economic theory and policy. On the theoretical side, this phenomenon, often referred to as "pricing to market," offers evidence of the importance of imperfect competition and dynamic adjustment in international trade. From a policy standpoint the main concern is the impact of a dollar depreciation on the trade balance and inflation.

Recent studies of exchange rate pass-through have shown that "pricing to market" is not a global phenomenon but it is confined to markets for differentiated products, such as the automobile industry and heavy machinery. Consequently, explanations of the phenomenon focus on imperfect competition.

[67] For a more detailed discussion of these issues see the next section.

Theoretical work can be classified into two broad categories: Static models that emphasize market behavior and price elasticities of demand as determinants of pass-through effects, and dynamic models in which expectations about the exchange rate process in conjunction with demand and/or supply dynamics are crucial.[68]

The automobile industry has been the most prominent example of lack of exchange rate pass-through during the 1980's. During this period the dollar experienced dramatic swings which were not reflected in the import prices of foreign automobiles. In this section I seek an explanation for this phenomenon. In particular, I pose two questions. First, "What are the implications of the model with respect to exchange rate pass-through? Suppose the dollar appreciates (depreciates) by 20%; what would the model predict absent quota restrictions and quality change?" In the model producers maximize profits myopically, so dynamic factors are not an explanation of pass-through effects. The results are driven by price elasticity patterns in conjunction with the oligopolistic behavior of automobile producers.

The second question focuses explicitly on 1983–87. During these years automobile prices are not only affected by exchange rate changes, but also by quota restrictions and the change in characteristics of existing vehicle types. Therefore, exchange rate pass-through effects cannot be addressed unless the latter two effects are taken into consideration. To this end, I apply the empirical model to this period, incorporating quota restrictions and quality change, posing the question: "Can the model reproduce the price patterns observed during 1983–87?"

The results from the first exercise are summarized in Table IX. To isolate exchange rate pass-through effects from other factors affecting automobile prices, I keep vehicle characteristics at their 1983 level and simulate the effect of a 20% change of the exchange rate on prices, without and with a quota. The pass-through effects implied by these simulations exhibit three striking features:

1. Exchange rate pass-through on import prices is asymmetric. The effects on prices are larger when the dollar depreciates and import prices rise than when the dollar appreciates.

2. The pass-through coefficient for Japanese cars is small (between 15 and 30%). In contrast, the German pass-through coefficients are much larger (65% in the case of a dollar appreciation and between 95 and 102% for a dollar depreciation). These results are similar to those with a general tariff pass-through, and indicative of the symmetry between exchange rate changes and tariffs.

3. In the presence of a quota Japanese import prices are insensitive to exchange rate movements.

[68] Models in the first category include Gagnon and Knetter (1995), Knetter (1989), and Marston (1990). Representative studies of the second category are Giovannini (1988) and Froot and Klemperer (1988). An overview is provided in Krugman (1987).

TABLE IX

PASS-THROUGH EFFECTS IMPLIED BY THE MODEL

	Without Quota		With Quota	
	\$ + 20%	\$ − 20%	\$ + 20%	\$ − 20%
Jap. Subcompact	−3.1	5.0	−0.3	0.2
Compact	−3.6	6.0	−0.2	0.4
Trucks	−3.9	4.9	−4.7	5.1
Ger. Intermediate	−14.0	24.2	−12.0	24.0
Luxury	−15.1	20.3	−11.2	22.2
Sports	−12.1	16.1	−12.0	21.3

As mentioned above, the driving force is the price elasticities of demand. The model suggests that price elasticities for Japanese and German cars differ. Specifically, the pass-through effects suggest that the price elasticity of demand for Japanese imports is increasing in price at a decreasing rate; when prices increase—as a consequence of an exchange rate depreciation—the price elasticity increases too, so that the pass-through on prices is less than complete. Similarly, when prices decrease, the price elasticity of demand falls, but it falls by less than it increases in the case of a dollar depreciation, so that the pass-through effects are larger. The price elasticity of demand of German cars on the other hand, seems to exhibit an inverse *U*-shape around the equilibrium. When prices decrease, the price elasticity falls. When prices increase, the price elasticity of demand is fairly constant or in certain cases falling in price. Note that the only difference between German and Japanese imports in our model lies in the market segmentation. Both sets of producers are assumed to maximize profits myopically; differences in the markup behavior cannot be attributed to differences in strategic behavior or time horizons. Germans produce primarily for the luxury car market, while Japanese dominate the small car market. The results suggest that the level and variability of the price elasticities of demand in these two segments differ; in fact, a more disaggregate analysis of exchange rate pass-through shows that small German cars (such as the Volkswagen) exhibit the same pass-through behavior as Japanese models in the same market segment.[69]

Next, I apply the model to 1983–87. Price movements across years are the result of three components: (i) quota restrictions, (ii) exchange rate changes, and (iii) quality change of vehicle makes. To isolate each of those factors, I first compute the equilibrium in each period holding two of the three components constant. The results are displayed in Figures 2 and 3. For domestic, Japanese, and German cars a constant upgrading of vehicle characteristics exercises an upward pressure on prices throughout 1983–87. In the case of Japanese imports this upward pressure is temporarily mitigated by the relaxation of the quota in

[69] The different pass-through behavior of Japanese and German cars is also documented in Gagnon and Knetter (1995). They obtain the same results applying a different methodology and using aggregate data on export unit values rather than wholesale prices.

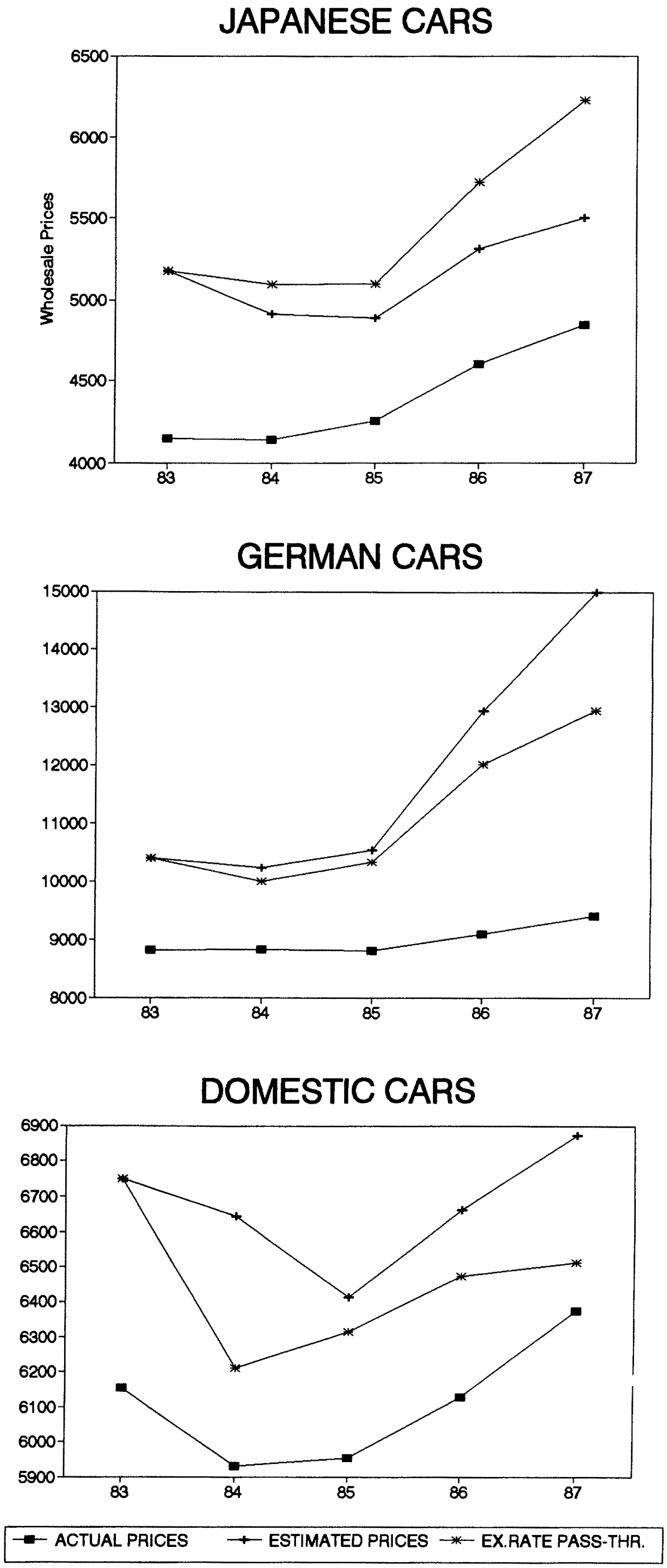

FIGURE 2.—Exchange rate pass-through.

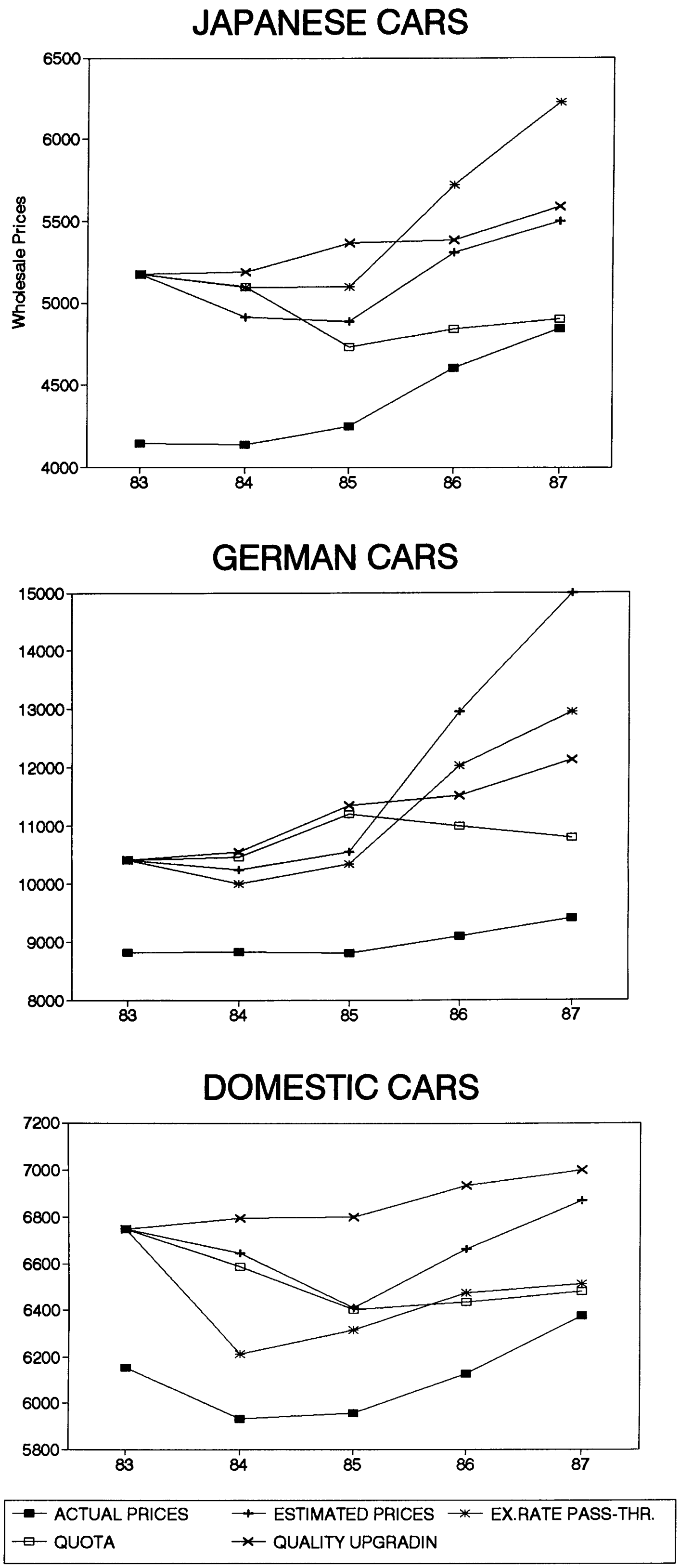

FIGURE 3.—Actual vs. estimated prices.

1985–86. The exchange rate pass-through effects are consistent with the trends reported above. In the case of Japanese imports, the effects are masked by the quota in the first two years.

Finally, I let all three components interact, to determine the prices predicted by the model. Figure 2 depicts actual and estimated prices for 1983–87. The model is successful in predicting the price movement of domestic and Japanese cars; this is also true of German cars in the first two years, when the dollar was strong. After 1985, the model predicts a significant increase in German import prices as a consequence of a dramatic dollar depreciation which is not matched by the data. In fact, the prices of German imports remained fairly constant during 1986 and 1987.

Two conclusions can be drawn. First, exchange rate pass-through cannot be analyzed without considering the impact of trade restrictions and quality change on import prices. Second, the static model is useful in predicting actual prices when the dollar appreciates, but not as useful when it depreciates. An explanation for this asymmetry is that the model ignores the influence of demand dynamics on profit maximization. The empirical results from the automobile choice model indicate that past purchases alter the current behavior of households. It is likely that producers take this effect into account, so that they do not raise their prices fully, when the dollar depreciates—especially when the change in the exchange rate is considered temporary. Extending the model to a dynamic optimization framework should help explain the pricing behavior of German producers during eras of dollar depreciation.

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APPENDIX A: DATA

List of Variables Used In The Estimation

(A) *Household Characteristics*:

AGE	Age of Household Head
EDUC	1 if Attended College
FEMALE	0: Male, 1: Female
INCOM	Household Income after Taxes
ASSET	Total Assets (Checking/Savings Accounts + U.S. Bonds + Stocks)
FAMSIZE	Family Size
PERSLT18	Number of Persons under 18
BIGCITY	1 if more than 1.25 Million Population Size
ASIAN	1 if Asian
MINOR	1 if Black or Hispanic
BLUEC	1 if Blue Collar
UNEMPL	1 if Unemployed

NE	1 if Northeast
NC	1 if Northcentral
WE	1 if West
COCCUP	1 if Household Head Changed Occupation during the Previous Year
CARSTOCK	Number of Cars Owned before New Vehicle was Purchased or before Household was Interviewed
NOCAR	1 if no Car Owned before
AVAGE	Average Age of the Existing Stock of Cars
AGENEW	Age of the Newest Car in the Stock before Purchase was made
A11	1 if $0 \leqslant$ AVAGE < 5 and $0 \leqslant$ AGENEW < 5
A21	1 if $5 \leqslant$ AVAGE < 10 and $0 \leqslant$ AGENEW < 5
A22	1 if $5 \leqslant$ AVAGE < 10 and $5 \leqslant$ AGENEW < 10
A31	1 if $10 \leqslant$ AVAGE and $0 \leqslant$ AGENEW < 5
A32	1 if $10 \leqslant$ AVAGE and $5 \leqslant$ AGENEW < 10
A33	1 if $10 \leqslant$ AVAGE and $10 \leqslant$ AGENEW

(B) *Vehicle Characteristics*:

LENGTH	
LENGWID	Square Root of (Length $\times$ Width)
LENGWIDF	Lengwid $\times$ Famsize
WEIGHT	
HP	Horsepower
HPD	Horsepower/Displacement (Measure of engine power and acceleration)
HPDYOUNG	Horsepower/Displacement if Household Head is less than 30
CYL	Number of Cylinders
FUELC	1/Miles per Gallon (city estimate) $\times$ Regional Gasoline Price (incl. taxes). The Gasoline Price is for Unleaded Regular, taken from the Statistical Abstract.
TRANS	1 if Car comes with Automatic Transmission
PS	1 if Car has Power Steering
AIRC	1 if Car has Airconditioning

When household has purchased a model before:

PP11	Price if Income $\leqslant$ 75,000
PP21	Price if Income > 75,000
PP1	Price (No distinction by income class. Used in the demand estimation for luxury and sports cars.)

When household has NOT purchased a model before:

PP10	Price if Income $\leqslant$ 75,000
PP20	Price if Income > 75,000
PP0	Price (No distinction by income class. Used in the demand estimation for luxury and sports cars.)

Brand Dummies	
COST	Marginal Cost
CC1-CC6	Dummies corresponding to Classes 1 to 6
CCLUX	1 if Car is Luxury or Sports (CCL = CC5 + CC6)
CCO	1 if Vehicle is Pick-up Truck, Van or Utility Vehicle
TRUCK	1 if Vehicle is Pick-up Truck
QUOT1-5	1 if Car is Subject to Quotas (Japanese passenger cars); the Numbers 1-5 correspond to the Years 1983–87
T1TOYOT–T5TOYOT	Year dummies for Toyota; the Numbers 3-7 correspond to the Years 1983–87
T1MAZDA–T5MAZDA	Year Dummies for Mazda
T1NISSA–T5NISSA	Year Dummies for Nissan
Q1TOYOT–Q5TOYOT	Year Dummies for Toyota $\times$ Dummy for Passenger Cars; Produced by Toyota (the latter are subiect to the VER)
Q1MAZDA–Q5MAZDA	Year Dummies for Mazda $\times$ Dummy for Passenger Cars
Q1NISSA–Q5NISSA	Year Dummies for Nissan $\times$ Dummy for Passenger Cars

(C) *Other*:

D83–D87	Year Dummies
D1–D19	Dummies corresponding to the Interview Period of each Household. For example, D1 refers to households interviewed between 83:2 and 84:1, D2 to the ones interviewed between 83:3 and 84:2, and so on.
MACY	Regional Disposable Personal Income per Capita (annual, Source: Statistical Abstract)
UNEMPLR	Regional Unemployment Rate (annual, Source: BLS, "Geographic Profile of Employment and Unemployment")
AUTOFINT	Average Interest Rate for (New and Used) Car Loans (annual, Source: Federal Reserve Board, "Annual Statistical Digest")
INCL11–INCL92	Inclusive Values for each Vehicle Class at the Last Node (e.g. INCL31 is the inclusive value for intermediate domestic cars, INCL52 is the inclusive value for luxury foreign cars, etc.)
CINCL1-9	Inclusive Values for each Market Segment at the Class Choice Node
NINCL	Inclusive Value for New Cars at the New/Used Node
BINCL	Inclusive Value for Buying a Car at the Buy/Not Buy Node

TABLE A1

CES HOUSEHOLD CHARACTERISTICS
(Sample Size: 20,571. Years covered: 1983–87)

Characteristics	Means	Standard Deviations
Age of Household Head	43.6	14.7
Income ($/year, in 82 dollars)	21,104	14,231
Family Size	2.67	1.44
Number of Earners	1.52	0.50
Cars/Household	1.57	1.12
Percent w/College Education	48	30
Ethnic Composition (%)		
Caucasian	88	29
Black/Hispanic	9	24
Asian	3	14
Geographic Composition (%)		
Northeast	20	42
North Central	25	43
West	26	40
South	29	40

TABLE A2

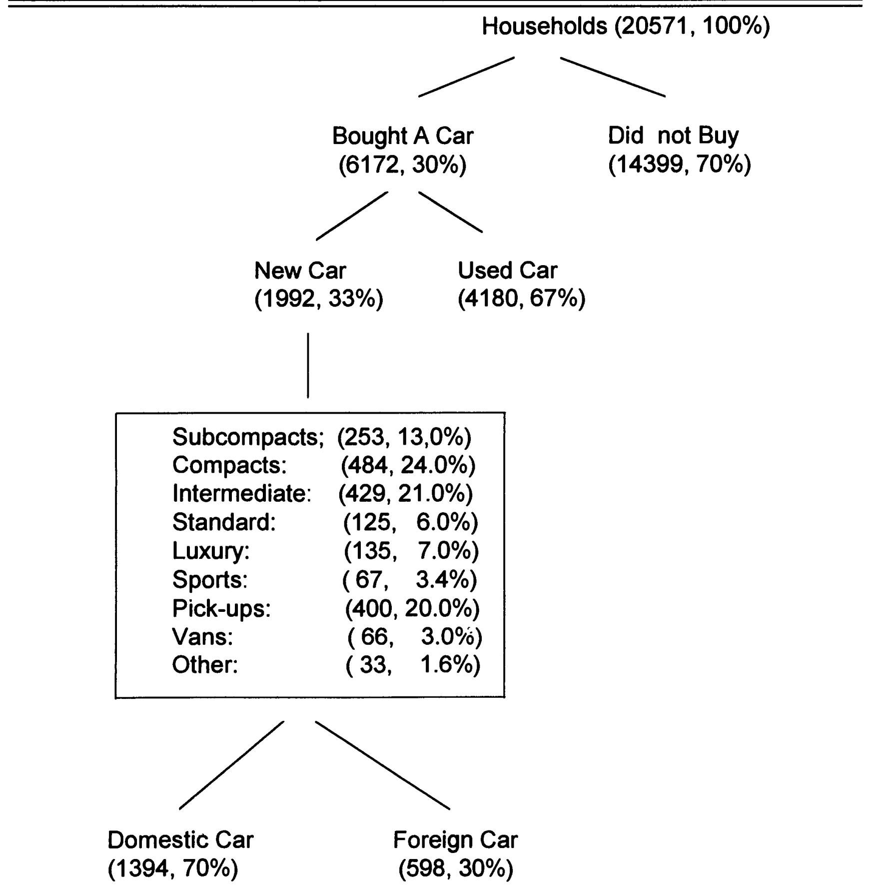
IMPORT PURCHASES IN CES SURVEY[a]

Year	Quantity of New Cars	Import Shares		
		Total	Japan	Other
1983	126	0.25	0.20	0.05
1984	404	0.33	0.25	0.08
1985	477	0.24	0.21	0.03
1986	534	0.33	0.26	0.07
1987	451	0.35	0.29	0.06

[a] The numbers in this table refer to an unweighted sample.

TABLE A3

CAR PURCHASES OF CES HOUSEHOLDS[a]



[a] The figures in parentheses refer to number and percentage of households respectively. The sample period is 1983–87. Approximately 9,000 households with missing or invalid responses were eliminated from the sample.

TABLE A4

NUMBER OF ALTERNATIVES BY CLASS[a]

Class	Origin	# of Models	Class	Origin	# of Models
1. Subcompacts	Domestic	16	6. Sports	Domestic	6
	Foreign	28		Foreign	7
2. Compacts	Domestic	14	7. Pick-ups	Domestic	30
	Foreign	19		Foreign	7
3. Intermediate	Domestic	30	8. Vans	Domestic	14
	Foreign	4		Foreign	2
4. Standard	Domestic	17	9. Other	Domestic	8
	Foreign	0		Foreign	2
5. Luxury	Domestic	14			
	Foreign	10			

[a] The number of models in a class is an average over 1983–87.

TABLE A5

MEANS OF VEHICLE CHARACTERISTICS BY CLASS[a]

Class	Ori	Price	Leng	Wid	HP	Wei	Cyl	MPG
1. Subcompact	Dom	9504	174.4	67.4	84.5	2.5	4.1	26.4
		(2126)	(7.5)	(2.9)	(13.1)	(0.3)	(0.3)	(6.5)
	For	10390	163.8	64.1	79.4	2.1	4.0	27.1
		(2674)	(7.2)	(1.6)	(9.8)	(0.2)	(0.0)	(3.6)
2. Compact	Dom	9577	174.1	66.3	86.3	2.4	4.1	24.0
		(2374)	(7.1)	(1.7)	(13.3)	(0.2)	(0.3)	(3.2)
	For	11284	170.4	65.1	87.6	2.3	4.3	25.4
		(2814)	(7.5)	(1.1)	(23.5)	(0.3)	(0.6)	(4.0)
3. Intermed.	Dom	11933	191.5	70.7	102.7	2.9	4.9	19.8
		(3101)	(9.1)	(2.0)	(13.6)	(0.3)	(1.1)	(2.4)
	For	16585	169.3	69.7	103.8	2.9	4.5	18.5
		(5301)	(35.1)	(1.1)	(7.1)	(0.2)	(0.4)	(1.7)
4. Standard	Dom	13782	204.5	73.9	124.7	3.3	6.2	18.4
		(2658)	(10.0)	(2.1)	(14.3)	(0.3)	(0.7)	(1.4)
5. Luxury	Dom	20524	205.1	72.8	132.1	3.7	7.2	17.4
		(4996)	(14.2)	(3.5)	(15.8)	(0.5)	(1.2)	(0.8)
	For	27615	190.8	67.8	126.8	3.1	4.8	17.5
		(10446)	(7.2)	(1.8)	(18.6)	(0.5)	(0.7)	(3.2)
6. Sports	Dom	14754	186.0	70.8	148.6	3.1	6.3	19.9
		(5203)	(10.2)	(1.0)	(45.6)	(0.6)	(1.4)	(2.9)
	For	17849	172.2	66.5	136.6	2.7	4.8	19.8
		(7454)	(4.5)	(1.2)	(33.5)	(0.3)	(0.9)	(2.1)
7. Pick-up	Dom	12078	193.0	75.6	132.6	6.0	6.4	16.5
		(2318)	(11.5)	(4.4)	(22.7)	(1.0)	(1.2)	(2.4)
	For	8705	174.6	64.1	98.2	4.4	4.0	23.0
		(1897)	(2.0)	(0.9)	(8.7)	(0.3)	(0.0)	(1.4)
8. Van	Dom	14742	191.6	78.0	123.4	5.1	5.9	17.4
		(4153)	(14.8)	(2.9)	(22.6)	(0.7)	(1.3)	(2.5)
	For	15453	191.6	77.9	123.5	5.2	5.2	17.0
		(4444)	(19.1)	(3.0)	(30.7)	(0.2)	(1.4)	(2.0)
9. Other	Dom	12709	181.1	73.7	118.2	5.7	5.5	18.7
		(3205)	(6.5)	(1.3)	(10.7)	(0.5)	(0.6)	(4.6)
	For	8993	146.5	45.1	77.6	3.2	4.4	21.0
		(2219)	(21.3)	(27.9)	(25.1)	(1.5)	(0.7)	(3.0)

[a] The table contains sample means over 1983–87, with standard deviations reported in parentheses. Vehicle characteristics are based on data reported in the Automotive News Market Data Book. Prices are dollar transaction prices based on the purchases of the CES households.

APPENDIX B

Results from Demand Estimation

TABLE B1

Model Choice: Small Cars
Number of Observations: 707
Log of Likelihood Function: −517.9

Variable	Parameter Estimate	Standard Error
PP10	−4.747	0.862
PP20	−4.501	0.356
PP11	−2.927	0.328
PP21	−2.755	1.277
TRANS	3.516	0.225
PS	0.615	0.202
AIRC	5.777	0.255
HPD	−0.018	0.588
HPDYOUNG	−0.203	0.903
FUELC	−7.143	0.740
+15 Brand Dummies		
(All of them highly significant)		

TABLE B2

Model Choice: Big Cars
Number of Observations: 980
Log of Likelihood Function: −414.5

Variable	Parameter Estimate	Standard Error
PP10	−4.445	0.602
PP20	−3.745	0.332
PP11	−3.076	0.649
PP21	−2.171	0.396
TRANS	0.877	0.281
PS	5.525	0.364
AIRC	8.956	0.429
HPD	3.580	0.864
HPDYOUNG	0.275	1.760
FUELC	−1.381	0.744
+16 Brand Dummies		
(5 of them significant at the 10% level)		

TABLE B3

Model Choice: Luxury and Sports Cars
Number of Observations: 185
Log of Likelihood Function: −334.7

Variable	Parameter Estimate	Standard Error
PP0	−1.223	0.174
PP1	−0.517	0.220
TRANS	1.693	0.296
PS	−1.585	0.621
AIRC	3.468	0.529
HPD	0.174	1.162
HPDYOUNG	0.514	2.176
LENGWID	5.030	5.218
LENGWIDF	−1.344	1.707
FUELC	0.231	0.931
+10 Brand Dummies		
(3 of them significant at the 10% level)		

TABLE B4

FOREIGN VS. DOMESTIC[a]
Number of Observations: 1867
Log of Likelihood Function: −413.9
0: Domestic; 1: Foreign

Variable	Parameter Estimate	Standard Error
INCL1	0.891	0.024
INCL2	0.988	0.023
INCL3	0.199	0.100
C1	−0.165	0.499
AGE1	−1.193	0.340
EDUC1	0.791	0.197
NE1	0.127	0.243
NC1	−0.435	0.261
WE1	0.460	0.246
ASIAN1	0.584	0.652
BLUEC1	−0.381	0.257
INCOM1	0.347	0.180
D841	0.255	0.359
D851	−0.199	0.367
D861	0.508	0.365
D871	1.743	0.371
CC21	0.147	0.269
CC31	−3.367	0.421
CCLUX1	−0.063	0.297
CCO1	−0.799	0.330

[a] All standard errors in this and following tables are corrected using the recursive formulas in McFadden (1981).

TABLE B5

CLASS CHOICE
Number of Observations: 1992
Log of Likelihood Function: −2115.1
1–9: Class 1–Class 9

Variable	Parameter Estimate	Standard Error
CINCL	0.944	0.024
C2	1.122	0.363
AGE2	−0.363	0.424
INCOM2	0.037	0.208
FAMSIZE2	−0.234	0.118
PERSLT182	0.180	0.170
C3	−10.793	0.469
AGE3	2.365	0.393
INCOM3	0.146	0.209
FAMSIZE3	−0.299	0.107
PERSLT183	0.448	0.156
C4	−17.199	0.672
AGE4	2.891	0.489
INCOM4	0.404	0.278
FAMSIZE4	−0.674	0.153
PERSLT184	0.795	0.225
C5	−5.027	0.506
AGE5	2.972	0.486
INCOM5	1.017	0.222
FAMSIZE5	−0.569	0.145
PERSLT185	0.855	0.203
C6	−3.190	0.519
AGE6	−0.136	0.592
INCOM6	0.419	0.307
FAMSIZE6	−0.110	0.165
PERSLT186	−0.112	0.247
C7	−5.870	0.437
AGE7	0.493	0.449
INCOM7	−0.081	0.241
FAMSIZE7	0.068	0.108
PERSLT187	0.067	0.161
C8	−8.965	0.978
AGE8	2.751	0.890
INCOM8	0.419	0.447
FAMSIZE8	−0.485	0.286
PERSLT188	1.165	0.372
C9	−5.317	1.072
AGE9	−0.691	1.358
INCOM9	1.028	0.437
FAMSIZE9	−0.438	0.387
PERSLT189	0.781	0.508

TABLE B6

NEW VS. USED
Number of Observations: 6172
Log of Likelihood Function: −3278.6
0: Used; 1: New

Variable	Parameter Estimate	Standard Error
C1	0.917	0.879
NINCL1	0.011	0.006
AGE1	0.795	0.122
INCOM1	0.632	0.082
ASSET1	0.343	0.070
BLUEC1	−0.438	0.077
EDUC1	0.578	0.074
FAMSIZE1	−0.109	0.021
MINOR1	−0.510	0.127
UNEMPL1	−0.268	0.106
NOCAR1	0.392	0.119
A111	1.119	0.114
A211	0.674	0.128
A221	0.445	0.117
A311	0.053	0.289
A321	−0.165	0.160
UNEMPLR1	−0.263	0.055
MACY1	−1.247	0.417
D841	−0.038	0.156
D851	0.431	0.162
D861	0.912	0.168
D871	1.152	0.200

TABLE B7

BUY VS. NOT BUY
Number of Observations: 20571
Log of Likelihood Function: −6578.5
0: Not Buy; 1: Buy

Variable	Parameter Estimate	Standard Error
C1	39.565	4.098
AGE1	−0.910	0.087
EDUC1	−0.306	0.054
INCOM1	0.487	0.063
ASSET1	0.055	0.043
UNEMPL1	−0.325	0.074
ASIAN1	−0.294	0.145
MINOR1	−0.302	0.079
FEMALE1	−0.360	0.05
BIGCITY1	−0.090	0.046
NE1	9.436	0.542
NC1	3.959	0.325
WE1	7.055	0.499
NOCAR1	2.274	0.101
A111	−0.476	0.072
A211	−0.365	0.083
A221	−0.344	0.070
A311	−0.387	0.196
A321	0.015	0.098
UNEMPLR1	0.145	0.105
MACY1	−38.731	2.744
AUTOFIN1	−0.132	0.052
D2-D19 Dummies (All of them highly significant)		

APPENDIX C

Specification Testing

(1) *Testing the IIA Property*

Tables C1 and C2 report the results from testing for violations of the IIA property at the last node of the tree using the Hausman-McFadden statistic. Two alternative specifications are considered (Figure C1): One in which the model choice is conditioned on both market segment and origin (Specification B), and one in which the last stage is conditioned only on market segment (Specification A). In both cases, the subsamples comprising the restricted choice sets were selected at random.

TABLE C1

TESTING THE IIA PROPERTY FOR SPECIFICATION A

Small Cars		Large Cars		Luxury Cars	
DoF	χ^2	DoF	χ^2	DoF	χ^2
25	49.82 (p-Value 0.002)	26	66.75 (p-Value 0.000)	20	126.74 (p-Value: 0.000)

TABLE C2

TESTING THE IIA PROPERTY FOR SPECIFICATION B

Small Cars		Large Cars		Luxury Cars	
DoF	χ^2	DoF	χ^2	DoF	χ^2
25	35.64 (p-Value 0.077)	26	41.45 (p-Value 0.027)	20	8.63 (p-Value: 0.986)

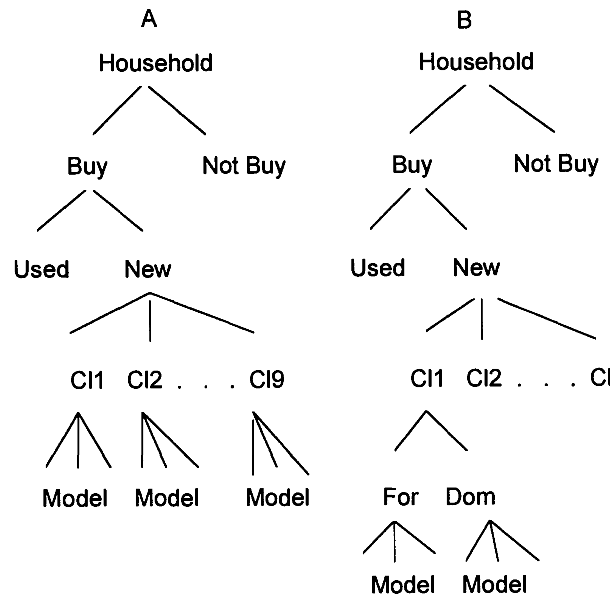


FIGURE C1

(2) *χ^2-Tests for the Sample Period (1983–87)*

In the following tests, I group households according to three characteristics: education (consumers who attended college versus consumers who did not), age (less than 30 years old, between 30 and 45, and above 45), and income (under \$25,000 per year, between \$25,000 and \$75,000, and above \$75,000). Depending on the interaction of these characteristics, I consider 3 (based on age or income), 9 (based on both age and income), or 18 (based on age, income, and education) alternative consumer groupings.

Vehicles are grouped according to newness, market segment, origin, and brand. The following notation will be used: B denotes 2 product cells (buy vs. not buy), N also denotes 2 product cells (new vs. used), C corresponds to 9 market segments, CFD corresponds to 17 vehicle cells defined by both market segment and origin, FD corresponds to 2 cells (foreign vs. domestic), and *Brand* stands for 6 car cells defined as GM, Chrysler, Ford, Toyota, Honda, and Other. In the unconditional tests, three alternative vehicle groupings are used: (i) $NB/N/U$ denoting 3 cells (Not Buy, New, and Used), (ii) $NB/U/C$ denoting 11 choice categories (Not Buy, Used, and 9 market segments if a new car was bought), and (iii) $NB/U/CFD$ corresponding to 19 groups (Not Buy, Used, and 17 Vehicle Classes if a new car was bought).

(a) *Unconditional Tests*

TABLE C3

χ^2-TESTS BASED ON 3 CONSUMER GROUPS

No. of Cells (DoF)	9(4)	33(20)	57(36)
Product Cells Defined By →	$NB/N/U$	$NB/U/C$	$NB/U/CFD$
Consumer Cells Defined By ↓			
Age	6.4	29.7	92.9
Income	15.1	59.3	106.6

TABLE C4

χ^2-Tests Based on 9 Consumer Groups

No. of Cells (DoF)	27(16)	99(80)	171(144)
Product Cells Defined By →	*NB/N/U*	*NB/U/C*	*NB/U/CFD*
Consumer Cells Defined By ↓			
Age and Income	50.4	132.3	200.6

(b) *Tests Conditional on the Purchase of a New Car*

TABLE C5

χ^2-Tests Based on 3 Consumer Groups

No. of Cells (DoF)	51(32)	6(2)	18(10)
Product Cells Defined By →	*CFD*	*FD*	*BRAND*
Consumer Cells Defined By ↓			
Age	39.0	1.13	19.5
Income	43.8	2.18	17.2

TABLE C6

χ^2-Tests Based on 9 Consumer Groups

No. of Cells (DoF)	153(128)	18(8)	54(40)
Product Cells Defined By →	*CFD*	*FD*	*BRAND*
Consumer Cells Defined By ↓			
Age and Income	162.6	10.4	57.2

TABLE C7

χ^2-Tests Based on 18 Consumer Groups

No. of Cells (DoF)	306(272)	36(17)	108(85)
Product Cells Defined By →	*CFD*	*FD*	*BRAND*
Consumer Cells Defined By ↓			
Age, Income, and Education	211.0	21.8	127.1

(c) *Tests Conditional on the Previous Stage Choice*

TABLE C8

χ^2-Tests Based on 3 Consumer Groups

No. of Cells (DoF)	6(2)	6(2)	27(16)	48(16)
Product Cells Defined By →	*B*	*N*	*C*	*FDC*
Consumer Cells Defined By ↓				
Age	4.91	3.43	12.5	1.03
Income	10.5	13.9	27.7	1.74

TABLE C9

χ^2-TESTS BASED ON 9 CONSUMER GROUPS

No. of Cells (DoF)	18(8)	18(8)	81(64)	144(64)
Product Cells Defined By →	*B*	*N*	*C*	*FDC*
Consumer Cells Defined By ↓				
Age and Income	20.5	29.4	64.1	2.3

TABLE C10

χ^2-TESTS BASED ON 18 CONSUMER GROUPS

No. of Cells (DoF)	36(17)	36(17)	162(136)	288(136)
Product Cells Defined By →	*B*	*N*	*C*	*FDC*
Consumer Cells Defined By ↓				
Age, Income, and Education	28.5	48.1	137.1	4.02

(3) *Out-of-Sample Predictions*

TABLE C11

AGGREGATE MARKET SHARES FOR 1989 AND 1990

	Predicted			Actual		
Year	Car Sales	Imports	% Import	Car Sales	Imports	% Import
1989	6543211	2034938	31.1	9713125	2698274	27.8
1990	6699120	2130320	31.8	9295732	2452999	26.4
Year	Truck Sales	Imports	% Import	Truck Sales	Imports	% Import
1989	4925778	980229	19.9	4779192	723871	15.1
1990	3100232	585943	18.9	4591077	755025	16.4
Year	Class	Cl. Share	% Import	Class	Cl. Share[a]	% Import
1989	1	24.4	63.0	1	22.7	58.2
1989	2	30.1	30.3	2	35.0	23.9
1989	3	23.4	6.4	3	21.9	10.5
1989	4	10.3	0.0	4	9.8	0.0
1989	5	11.7	33.1	5	10.5	34.3

[a] These figures are taken from Ward's Automotive Yearbook.

APPENDIX D

Results from the Cost Estimation

TABLE D1

AMERICAN CARS
Method of Estimation = OLS
Dependent Variable = Cost
Number of Observations = 723
R-Squared = .39

Variable	Parameter Estimate	Standard Error
CONST	3016.040	2141.700
LENGTH	5.516	13.355
WEIGHT	112.694	154.925
CYL	26.207	118.208
HP	11.090	5.724
TRANS	361.135	450.688
PS	740.327	332.998
AIRC	1986.890	509.919
CC1	−2262.860	448.552
CC2	−2085.670	478.650
CC3	−2570.130	478.533
CC4	−3834.170	532.365
CC5	−2861.230	1083.680
CC6	−4990.660	570.242
TRUCK	−2013.490	259.782
D84	−3.716	257.808
D85	118.250	292.342
D86	−42.242	296.495
D87	−165.991	285.044

Note: Standard errors are heteroskedastic-consistent estimates.

TABLE D2

GERMAN CARS
Method of Estimation = OLS
Dependent Variable = Cost
Number of Observations = 133
R-Squared = .66

Variable	Parameter Estimate	Standard Error
CONST	−13822.200	6036.100
LENGTH	38.370	34.490
WEIGHT	−1539.810	1175.560
CYL	2737.140	1303.370
HP	135.348	43.608
TRANS	16480.100	2671.830
PS	5147.300	2447.320
AIRC	−4238.310	2836.990
D84	1735.190	1775.930
D85	2972.010	1726.320
D86	−999.772	1575.090
D87	−4907.460	1420.190

Note: Standard errors are heteroskedastic-consistent estimates.

TABLE D3

JAPANESE CARS
Method of Estimation = OLS
Dependent Variable = Cost
Number of Observations = 222
R-Squared = .30

Variable	Parameter Estimate	Standard Error
CONST	−1148240.000	596084.000
LENGTH	3177.790	3328.110
WEIGHT	−103769.000	36389.700
CYL	334971.000	132377.000
HP	1527.310	3411.440
TRANS	54811.700	184056.000
PS	−21558.200	82308.900
AIRC	−497155.000	337027.000
D84	100497.000	109688.000
D85	63957.300	76327.100
D86	48273.500	106592.000
D87	−88715.800	75887.700
QUOT1	207534.000	86663.900
QUOT2	230561.000	101806.000
QUOT3	421010.000	115716.000
QUOT4	187203.000	103244.000
QUOT5	193255.000	87291.100

Note: Standard errors are heteroskedastic-consistent estimates.

TABLE D4

JAPANESE CARS
Method of Estimation = OLS
Dependent Variable = Cost
Number of Observations = 222
R-Squared = .47

Variable	Parameter Estimate	Standard Error
CONST	−1497810.000	603410.000
LENGTH	7232.560	3757.670
WEIGHT	−112227.000	40697.400
CYL	280737.000	131296.000
HP	91.826	3550.050
TRANS	326131.000	163916.000
PS	101449.000	88804.300
AIRC	−397198.000	339172.000
D84	80792.700	70610.700
D85	238261.000	105406.000
D86	71392.100	80988.500
D87	−8503.150	89439.400
QUOT1	434518.000	106417.000
QUOT2	220553.000	96286.200
QUOT3	423753.000	143306.000
QUOT4	144704.000	92127.000
QUOT5	199344.000	100760.000
T3TOYOT	378224.000	244803.000
T3MAZDA	34873.900	60761.500
T3NISSA	−120263.000	60761.500
T4TOYOT	261803.000	237694.000
T4MAZDA	−155209.000	60584.400
T4NISSA	−52169.800	60584.400
T5TOYOT	−169618.000	150008.000
T5MAZDA	−232215.000	122987.000
T5NISSA	−242494.000	110377.000
T6TOYOT	262393.000	264573.000
T6MAZDA	−230532.000	73719.800
T6NISSA	−13932.000	72467.600
T7TOYOT	29855.500	161302.000
T7MAZDA	−131221.000	96942.200
T7NISSA	−266175.000	112279.000
Q3TOYOT	−727425.000	268397.000
Q3MAZDA	−331858.000	117139.000
Q3NISSA	−385040.000	128700.000
Q4TOYOT	−329236.000	261584.000
Q4MAZDA	367411.000	173777.000
Q4NISSA	22354.800	127046.000
Q5TOYOT	−280133.000	204998.000
Q5MAZDA	328104.000	308640.000
Q5NISSA	−286652.000	202806.000
Q6TOYOT	−436399.000	299896.000
Q6MAZDA	546206.000	176814.000
Q6NISSA	−98065.500	212803.000
Q7TOYOT	−260711.000	179677.000
Q7MAZDA	143702.000	193391.000

Note: Standard errors are heteroskedastic-consistent estimates.

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