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DISCUSSION PAPER NO:  8

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WARRANTY, QUALITY, AND PRICE IN THE U.S. AUTOMOBILE MARKET

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Dennis C. Glennon*
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I: INTRODUCTION

Cooper and Ross (1985) note that the U.S. automobile market provides an interesting application of the quality and warranty literature, in that there appears to be an inverse relationship between these two product characteristics. Notably, warranties on domestic cars typically are more extensive than those on imported cars, while imported cars typically have lower complaint rates. Indeed, in 1989, domestic manufacturers offered a mean powertrain warranty of 65.14 months and 62,680 miles compared with the importers’ 38.5 months and 43,500 miles. At the same time, domestic cars represent 95.8% of the cars having “poor” complaint experience, 75.9% of the “average” category, and only 20% of the “good” category, when all cars were trichotomized by the ratio of complaints (registered with the National Highway and Traffic Safety Administration) to total sales of each model. Presumably, most complaints arise as a result of product failure in one sense or another, supporting the presumption that imported cars are, by and large, more durable than American cars.

At first glance, the negative cross-sectional relationship between warranties and product quality may seem counter-intuitive. One might expect the more durable product to be warranted more extensively, due to lower servicing costs, ceteris paribus. Spence (1977) argued that more-extensive warranties would be used to ‘signal’ greater durability, but Priest (1981) found that warranty duration was not systematically related to product durability and tended to be limited to substantially less than the product’s useful life. Emons (1989) and others have argued that one explanation for the limitation of warranty duration might be the inability of firms to screen consumers who use the product with different intensities. This application of the screening literature assumes quality to be exogenously determined but recognises that there is a potential for a tradeoff between lower quality (or durability) and higher warranty. In a similar vein, Gal-Or (1989) develops a signalling model of oligopolistic markets which recognises that while warranties can serve as signals of quality, there is the potential for a negative relationship between warranty and quality when the latter is determined exogenously.
The possible negative relationship between warranty coverage and product quality is identified by Cooper and Ross, Emons, and Gal-Or as being of further theoretical and practical interest, and is the focus of the current paper. An extension of the model developed by Cooper and Ross (1985) is proposed, and an empirical test is conducted of the model’s implications. Essentially, the Cooper and Ross model, which endogenizes both quality and warranty, is extended to make price dependent on quality and to include the role of consumer preferences. This is in contrast to Emons (1989) and Gal-Or (1989), who assume quality to be exogenous. We thus provide a clear extension of previous theoretical work, as well as a thorough empirical analysis of the warranty and quality choice in the American automobile market.

II. THE RELATIONSHIP BETWEEN WARRANTY AND QUALITY

It is well known that warranties constitute an insurance policy for the buyer against the financial risk of potential future repair costs. To compete for a given customer, the domestic manufacturers may need to offer a better warranty to provide the customer with better insurance against the financial risk associated with a breakdown, since there appears to be a higher probability that the domestic cars, in general, will break down. However, financial costs are not the only costs of a product breakdown. There are also psychic and opportunity costs associated with taking the product to be repaired, with waiting, missing appointments, and so on. The more extensive dealership networks of the domestic manufacturers may serve to reduce these psychic and opportunity costs for buyers of domestic cars, and thus render the domestic cars more competitive (than they otherwise would be) with the more durable imports. Without extensive dealership networks, the imports seem to choose the strategy of building more durable products for buyers who demonstrate a preference for higher quality as a result of their aversion to the potential psychic and opportunity costs of product failure.

The development of the theoretical model follows that of Cooper and Ross (1985), which is also well expounded in Philips (1988). They consider a contract between a particular buyer and a particular seller for the purchase/sale of a single unit of the product. There is a stated price, $p$, of the product, and a probability, $H$, that
the product works. The probability of the product working is a function of the quality level, \( q \), chosen by the seller and the level of effort, \( e \), expended by the buyer on maintenance and monitoring of the product's condition. The buyer's utility is expressed by Cooper and Ross as:

\[
U(e,q,p,s) = (y - p)w + \Pi z + (1-\Pi)s - g(e)
\]

where \( y \) is income, \( y-p \) represents the value of all other goods, and \( w \) converts this value to utility (Cooper and Ross assume \( w = 1 \)); \( z \) is the value to the consumer of the product if it works; and \( s \) is a measure of the degree of warranty protection in the contract. The function \( g(e) \) measures the consumer's disutility of effort. Note that only \( p \) and \( s \) are observable to both parties, while \( q \) is observable by the seller and \( e \) is observable by the buyer. The firm's expected profits are:

\[
V(e,q,p,s) = p - C(q) - (1-\Pi)sz.
\]

The analysis developed by Cooper and Ross, which endogenizes quality, \( q \), and warranty, \( s \), finds that there is a possible theoretical explanation for observed negative and positive correlations between the two. As they point out (1985, pp. 111-112):

"Buyers with higher costs of effort will seek out sellers willing to carry more of the burden of preventing breakdowns by choosing a higher level of \( q \). These incentives are accommodated through the selection of a higher level of \( s \). When some sellers have a cost disadvantage in providing warranty protection, they may opt to reduce their warranty offerings and raise \( q \) (so that they have to pay off on the warranty less often)."

This is exactly what appears to be occurring in the U.S. automobile market, although in that market a better understanding can be achieved if prices are also made a function of quality. Consequently, we extend the model as follows. Let the buyer's utility function be:

\[
U(e,q,s) = (y - p(q))w + \Pi z + (1-\Pi)s - g(e)
\]

and the firm's expected profits be of the form:

\[
V(e,q,s) = p(q) - C(q) - (1-\Pi)(sz+x).
\]
The primary differences between this specification and the earlier one are twofold: price is now positively related to quality; and the cost of providing warranty protection is now also a function of \( x \), where \( x \) is a cost of covering the warranty that is borne by the firm.\(^2\) In other words, \( x \) can be seen as the cost of a warranty service network which, in this context, differs between foreign and domestic producers.

The first order conditions yield

\[
\begin{align*}
H_r (1-s)z &= g_r \quad (3') \\
H_q (sz+x) + p_q &= C_q \quad (4')
\end{align*}
\]

Here, \( H_r = \partial H_r / \partial e \), and so on, and these imply that the level of effort and quality provided by the consumer and producer respectively are determined when the marginal returns of each are equated to their marginal cost. Thus the analysis is essentially two-stage in nature: the first order conditions provide information on the initial equilibrium conditions, and this information can then be used when maximizing a joint profit function to determine the optimal level of warranty protection.

Following Cooper and Ross, the Nash equilibrium in a non-cooperative game is represented by the values of \( e \) and \( q \) which simultaneously solve the reaction functions \((3')\) and \((4')\). The joint maximization of equations \((3')\) and \((4')\) is then used to determine the optimal warranty level, \( s \). In other words, the equilibrium value of effort on the part of the consumer, \( e = e(s) \), is determined using equation \((3')\) for a given value of \( s \), based upon the consumer's current conjecture about \( q \). Similarly, the equilibrium value of quality, \( q = q(s) \), is determined by the seller, using equation \((4')\), for a value of \( s \) based upon a specific conjecture about \( e \). The equilibrium value of the warranty, \( s \), is then determined by the maximization of the joint profit function:

\[
\max_s \bar{L} = Hz - g(e) - C(q) - (1-H)x + (1-w) p(q) + wy \tag{5}
\]

subject to the equilibrium value of effort and quality, \( e = e(s) \) and \( q = q(s) \). This, when differentiated with respect to \( s \) and combined with equations \((3')\) and \((4')\), yields:

\[
q_s H_q z (1-s) - w p_q q_s + e_s H_r (sz+x) = 0. \tag{6}
\]

Solving equation \((6)\) for \( s \) yields

\[
s = \left( q_s H_q z - w p_q q_s + e_s H_r x \right) / z \left( q_s H_q - e_s H_r \right). \tag{6'}
\]
In order to analyse the comparative statics of the model we specify the special case where \( \Pi(e,q) \) is linear, \( s \in (0,1) \), and the other functions have the assumed properties outlined above. Specifically:

\[
\Pi(e,q) = \alpha e + \beta q
\]

\( \Pi_e = \alpha, \Pi_q = \beta \) \hspace{1cm} (7)

\[
C(q) = \gamma q^2
\]

\( \gamma > 0 \) \hspace{1cm} (8)

\[
g(e) = \delta e^2
\]

\( \delta > 0 \) \hspace{1cm} (9)

\[
p(q) = \tau q
\]

\( \tau > 0 \) \hspace{1cm} (10)

In the second stage, the substitution of equations (7)-(10) into equation (3') result in the equilibrium level of effort (for a given value of \( s \)):

\[
e = \alpha (1-s) z / 2 \delta.
\]

Similarly, equation (4') yields the optimal quality (for a given value of \( s \)):

\[
q = (\beta (sz+x) + \tau) / 2 \gamma.
\]

The optimal warranty is then derived using the equilibrium value from equation (6) and the implicit assumption from equations (7)-(10) that \( \Pi_{eq} > 0 \). That is, substituting equations (7)-(12) into equation (6') yields:

\[
s = (f' \delta z - \alpha \delta x - w \tau / \delta) / z (f' \delta + \alpha \delta).
\]

This allows us to observe that the optimal warranty will fall as \( x \), the cost of covering the warranty borne by the producer, increases, since:

\[
\partial s / \partial x = - \alpha \delta / z (f' \delta + \alpha \delta) < 0.
\]

Moreover, the impact of an increase in \( x \) on the quality of the good can be derived from equations (12) and (13). Note that an increase in \( x \) results in an increase in \( q \) since:

\[
\partial q / \partial x = \beta' \delta / 2 \gamma (f' \delta + \alpha \delta) > 0.
\]

The impact of an increase in a firm's cost of providing quality (\( \gamma \)) is also relatively straightforward to derive from equations (12) and (13). Such an increase unambiguously decreases the optimal quality a firm is willing to incorporate into its product, but has an ambiguous impact on the optimal warranty. Specifically:

\[
\partial s / \partial \gamma = - \alpha \beta' \delta (f (x+z) - w \tau) / z (f' \delta + \alpha \delta)^2.
\]

It can be shown using equation (13), that the utility maximizing level of quality, for a given level of \( e \) and \( s \), occurs when:

\[
\beta sz = \beta z - w \tau.
\]

(17)
Substituting equation (17) into (16) and noting from equation (4') that the profit maximizing level of quality is given by $\beta(sz+x) = C_q - p_q$, it can be shown that $\partial s/\partial y > 0$ iff $C_q - p_q < 0$.

In other words, the optimal warranty decreases if the marginal cost of providing quality, $C_q$, is greater than the marginal revenue, $p_q$, as the profit maximizing firm attempts to shift the cost of maintenance onto the consumer in the form of an increase in consumer effort, $e$ (see equation (11)). This attempt will not be successful however, if the consumer has a strong preference for quality, as represented by the willingness to pay a premium for higher quality ($p_q > 0$). If the premium for quality is sufficiently high, the firm may find it more profitable to raise the warranty as a compensation for lower quality. Reinforcing this view is the result, from equation (13), that an increase in consumers' preferences for quality has a negative impact on the optimal warranty level. That is:

$$\partial s/\partial \tau = -\beta \delta / \epsilon (\beta \delta + \alpha \gamma) < 0.$$  \hspace{1cm} (18)

The results outlined in equation (14), (15) and (16) are especially interesting when applied to the U.S. auto industry. It is generally argued that domestic producers have a cost advantage in providing warranty service relative to foreign producers ($x_f < x_d$), reflecting in large part economies of scale in product service that are probably achievable with larger dealership networks, while foreign producers generally have a comparative advantage in producing quality ($\gamma_f < \gamma_d$). Taken together, $x_f > x_d$ and $\gamma_f < \gamma_d$ suggest that foreign producers should indeed provide more quality; however, the amount of warranty protection provided by foreign producers is ambiguous, a priori. Specifically, the higher cost of providing warranty service on the part of foreign producers would have a negative impact on warranty protection offered by them, whereas the lower cost of producing quality might increase warranty protection. The role of consumers is clearly important here: if $p_q > C_q$ then the impact of a lower production cost, $\gamma$ on the optimal warranty would reinforce the impact of higher $x$. Foreign producers would indeed provide more quality and lower warranty, but only to the extent that consumers are willing to pay for it.

The theory developed here provides some insight into the automobile industry, and potentially explains the observations made in the introduction. However, since
the relationship between warranty, $s$, and quality, $q$, is clearly dependent on consumer preferences and the cost of developing a network to provide service, the extent of the tradeoff is an empirical issue. Thus, the following section develops an empirical model and uses readily available data to determine the direction of the empirical relationship.

III. EMPIRICAL ANALYSIS

There are several empirical questions which need to be answered. The first is whether the relationship between warranty and quality in the U.S. auto market is negative or positive. The second is whether the observed relationship is due to differences in the cost of providing a network and/or to differences in consumer preferences for quality. The final empirical question is to determine the sensitivity of price to quality.

Information is readily available to car buyers in the plethora of car buyer's guides that are available at minimal cost. Since these guides represent the data available to consumers about quality, warranty, price, and other vehicle characteristics, they provide the ideal data base with which to address the empirical issues raised above. Three major car buyers' guides were used to glean information on car characteristics and price. The variables used, their means and sources are described in the Appendix. The key variables of interest are price, quality and warranty. While the first of these is readily available there were several competing measures of quality and warranty provided in each of the car guides. Since these tended to be very similar (e.g., both a complaint index, and index of durability were provided in two of the car guides), factor analysis was used to generate a single measure of each of these variables. One of the guides did provide direct measure of the cost of repair, but since there was no measure of the cost of providing a network, $x$, the proxy used was whether or not the vehicle was imported.

Relatively complete data were collected on 124 cars. After deleting the foreign designed and/or manufactured cars that are sold by the domestic producers, the data set contained information on 111 cars. The simple correlation between warranty and quality for this set was negative (-.52) and significantly different from zero, with an $F$ test of 37.04.
There did appear to be a systematically different relationship between quality and warranty for domestics and imports. A brief glance at Figure 1 reveals that, in general, domestic cars are clustered in the high warranty, low quality quadrant, with the reverse being true for imported cars. Table 1, which reports the results of a t-test performed to compare the means of each group confirms the visual evidence: the mean quality for domestic cars is well below average (-.73) and significantly different from the mean for imports (.71). Similarly the mean warranty for domestics (.58) is significantly higher than that for imports (-.53). Clearly, the relationship between warranty and quality may indeed vary according to, or even be attributable to, other factors, such as the cost of providing a network and/or differences in consumer tastes.

It is clear from the theoretical development that warranty and quality are simultaneously determined; that the former is also affected by the cost of establishing a network; and that the latter is affected by the cost of providing quality. There is also the possibility that other characteristics, such as the size of the car, could affect the degree of warranty protection, since larger and heavier cars are likely to be more expensive to repair. Thus the empirical specification of the theoretical model from equations (12) and (13) and the above discussion is:

\[
WARR = b_0 + b_1 \text{QUAL} + b_2 \text{IMP} + b_3 \text{SIZE} \tag{19}
\]
\[
\text{QUAL} = c_0 + c_1 \text{WARR} + c_2 \text{IMP} + c_3 \text{COST} \tag{20}
\]

where all variables are as defined in the appendix. Note that IMP is used as the proxy for \(x\), the cost of providing warranty service; COST controls for the durability of the vehicles; \(b_2 = -\alpha^2\gamma(\beta'\delta + \alpha^2\gamma); c_1 = \beta z/2\gamma\) and \(c_2 = \beta/2\gamma\). The interpretation of the coefficient on \(\text{QUAL}\), \(b_1\), is not as straightforward. As indicated in the text above, it depends on the impact of production costs relative to that of consumer preferences. The sign of this term must be determined empirically. Graphical analysis did reveal that the data were linearly related, as assumed in the model specification.

The price specification is similar to that of Lancaster (1971) in that it is essentially a regression of price on characteristics:

\[
\text{PRICE} = h(\text{SIZE, FUELECON, STRUCT1, STRUCT2, QUAL})
\]

These variables are documented in the appendix. Due to multicollinearity among
some of the characteristics, such as number of doors, coupe, and automatic, factor analysis was used to create STRUCT1 and STRUCT2, which embody such structural characteristics. Factor analysis was also used to generate the SIZE and FUELECON variables.

The results of the simultaneous estimation procedure are reported in Table 2, and do confirm the theoretical analysis. Specifically, the results suggest that the relationship between quality and warranty is indeed determined by the cost of establishing a network and providing quality, as evidenced by the negative and significant sign on IMP in the warranty equation, and the positive and significant sign on IMP in the quality equation. The observed simple inverse relationship between warranty and quality which was demonstrated in Table 1 now becomes insignificant in both equations: the effect of quality on warranty is insignificant, as is the effect of warranty on quality. These results are robust in terms of sign and (except for the coefficient on QUAL in the price equation) in terms of magnitude under OLS, 2SLS, and 3SLS estimation procedures. The robustness also held when outliers (such as the Hyundai and BMW cars) were deleted. The reported R² statistics, which lose their traditional meaning in a GLS estimation, are relatively weak but did range from 0.46 to 0.65 in the OLS estimation. Thus the goodness of fit was acceptable for a cross-section regression of this nature.

Although data on consumer preferences toward quality cannot be gathered, the coefficient on quality in the price equation does indicate that consumers are willing to pay substantially more for higher quality, again substantiating the theoretical analysis that if \( p_q \) is sufficiently great, there is a potential advantage to some producers in providing increased quality rather than increased warranty protection.

IV. SUMMARY

This study has extended the theory of warranty and quality choice by producers and consumers by endogenizing the joint price, warranty and quality decision, and by introducing consumer preferences for quality. Consumers seeking their preferred combination of price, quality and warranty, and producers seeking their preferred combination of cost, quality and warranty, interact to determine the optimal price/
quality/warranty combination for each firm. Given that firms may incur different costs in the provision of quality and warranty, and that consumers may have different preferences toward quality, it was shown theoretically that profit-maximizing firms may offer greater warranty and lower quality if they hold a comparative advantage in the provision of warranty service, and vice-versa for firms holding the comparative advantage in the provision of product durability.

Similarly, consumers with a relatively strong aversion to the inconvenience and dangers associated with product failure (that is, a relatively strong preference for quality) and/or a relatively weak aversion to the financial risks associated with product breakdown, would maximize their utility by choosing products with greater quality and lower warranties. Conversely, those with relatively low preference for quality and relatively high aversion to financial risk, would prefer products of lower quality and greater warranty protection, ceteris paribus.

The model was supported empirically by data from the United States automobile market. Thus, the negative relationship between the quality and warranty offerings of domestic and imported cars can plausibly be ascribed to the differences in producer costs and consumer preferences.
FOOTNOTES

1. Data sources are noted in the Appendix. It is notable that the great majority of the imported brands (19 of 24) have the same limits on both their basic warranty (against manufacturers' defects) as on their drivetrain warranty, whereas 9 out of 14 domestic brands had substantially shorter basic warranties (typically 12 months/12,000 miles) as compared with their drivetrain warranty. Most domestic manufacturers, however, also offered an extended basic warranty at additional cost.

2. Cooper and Ross extend their model with the latter variation, but not the former.

3. As $s$ changes the joint non-cooperative game solution to equations (11) and (12) are re-evaluated. As Cooper and Ross show, the joint solution depends on the value of $s$.

4. From equation (15) and a manipulation of equations (12) and (13).

5. From equations (14), (16), and (17).

6. During 1989 the use of "price incentives" meant that actual transaction prices were significantly lower than list prices in many cases. However, this practice was largely restricted to domestic cars, which tend to be less expensive, as a group, than imports in any case. Conversely, some imports in short supply were reputedly sold at prices higher than their list prices. Fortunately the measurement error here is 'in the right direction.' Thus, we expect that any result achieved using list prices would be even stronger if actual transaction prices were obtainable.

7. The rationale for using factor analysis is that essentially all such measures are attempting to measure the same common factor, for example quality. Factor analysis revealed that the competing measures were, indeed, highly correlated and that a common factor underlay the competing measures. It should be noted that the variables thus generated have a mean of zero and a standard deviation of 1.
TABLE 1:  t-Test for differences in Quality and Warranty

<table>
<thead>
<tr>
<th></th>
<th>Mean Quality</th>
<th>Mean Warranty</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestics</td>
<td>-0.73</td>
<td>0.58</td>
<td>53</td>
</tr>
<tr>
<td>Imports</td>
<td>0.71</td>
<td>-0.53</td>
<td>58</td>
</tr>
<tr>
<td>t-statistics</td>
<td>10.47*</td>
<td>7.01*</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at the 1% level.
<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>PRICE</th>
<th>WARR</th>
<th>QUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE</td>
<td>5,888.10</td>
<td>-0.02</td>
<td>(6.19)*</td>
</tr>
<tr>
<td>FUELECON</td>
<td>549.93</td>
<td>(0.54)</td>
<td></td>
</tr>
<tr>
<td>STRUCT1</td>
<td>542.01</td>
<td>(1.01)</td>
<td></td>
</tr>
<tr>
<td>STRUCT2</td>
<td>111.25</td>
<td>(0.22)</td>
<td></td>
</tr>
<tr>
<td>IMP</td>
<td>-2.63</td>
<td>2.84</td>
<td>(-3.34)*</td>
</tr>
<tr>
<td>COST</td>
<td>0.20</td>
<td>(1.59)</td>
<td></td>
</tr>
<tr>
<td>WARR</td>
<td>0.97</td>
<td>(1.58)</td>
<td></td>
</tr>
<tr>
<td>QUAL</td>
<td>3,252.70</td>
<td>0.76</td>
<td>(4.66)*</td>
</tr>
<tr>
<td>R²</td>
<td>0.51</td>
<td>0.19</td>
<td>0.06</td>
</tr>
</tbody>
</table>

* Significant at the 1% level.

Note: System $R^2 = 0.99$, and the number of usable observations was 79.
## APPENDIX

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRICE</td>
<td>Retail list price</td>
<td>A</td>
<td>$19,344</td>
</tr>
<tr>
<td>IMP</td>
<td>1 if imported, 0 if domestic</td>
<td>A</td>
<td>0.52</td>
</tr>
</tbody>
</table>
| COMP     | Complaint index  
1 = high complaints  
2 = moderate complaints  
3 = low complaints | A | 2.12 |
| TROUBLE  | Trouble index  
1 = low; 5 = high | C | 2.85 |
| COST     | Cost index  
1 = low; 5 = high | C | 3.00 |
| WARRANTY | Warranty index  
(higher is better) | B | 831.48 |
| MONTHS   | Duration of basic warranty in months | B | 46.70 |
| MILES    | Basic warranty miles covered (thousands) | B | 49.64 |
| WBASE    | Wheelbase (inches) | A | 103.16 |
| HORSES   | Horsepower (bhp) | A | 142.11 |
| WEIGHT   | Curb weight (lbs) | A | 2,849.37 |
| D2       | 1 if 2-doors, 0 if not | A | 0.14 |
| D3       | 1 if 3-doors, 0 if not | A | 0.16 |
| D4       | 1 if 4-doors, 0 if not | A | 0.62 |
| COUPÉ    | 1 if coupe, 0 if not | A | 0.27 |
| AUTO     | 1 if automatic, 0 if not | A | 0.33 |
| EPA _CITY_ | EPA city (mpg) | B | 20.96 |
| EPA _HIGHWAY_ | EPA highway (mpg) | B | 28.21 |
APPENDIX (continued)

Factor Analysis

<table>
<thead>
<tr>
<th>Factor</th>
<th>Constructed from</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE</td>
<td>WBASE, HORSES, WEIGHT</td>
</tr>
<tr>
<td>STRUCT1, STRUCT2</td>
<td>D2, D3, D4, COUPE, AUTO</td>
</tr>
<tr>
<td>FUELECON</td>
<td>EPA II, EPALO</td>
</tr>
<tr>
<td>QUAL</td>
<td>COMP, TROUBLE</td>
</tr>
<tr>
<td>WARR</td>
<td>WARRANTY, MONTHS, MILES</td>
</tr>
</tbody>
</table>

Data Sources

C: Consumer Reports, April 1989.
REFERENCES


Figure 1
Price, Quality and Warranty

balloon is imported cars
prism is domestic cars