Lemons in the Used Car Market: An Empirical Investigation

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Abstract

This paper uses a modified version of the Bond (1982) lemon model to test the hypothesis that there is no difference in the average maintenance expenditures required for cars acquired used and those acquired new. The author used tobit and logit models to deal with the censoring problem in the data and applied a sensitivity analysis to check the robustness of the coefficients. The data for this study were collected from "The Panel Study of Income Dynamics (PSID)" from the University of Michigan. The results showed no evidence that cars acquired used required more maintenance expenditures than those of a similar age acquired new. The paper further examines the possible impacts of leasing and Certified Pre-Owned programs on the information mechanism and average quality of traded cars. The study found that these institutions have substantially improved the information mechanism between buyers and sellers, which, in turn, has helped reduce adverse selection and improve the average quality of traded cars in the used car market.

I. Introduction

Leasing in the automobile industry has been growing rapidly in the last decade. For example, consumer leasing as a percentage of the number of cars acquired was 9.3 percent in 1992 and increased to 20 percent in 2002[1]. Most car leases are two to three years long, and studies show that only 25 percent of lessees keep their cars at maturity (see Hendel and Lizzeri [2002]), implying that lessees hold onto their cars for shorter periods than car buyers. In fact, many off-leased cars are still under a manufacturer's warranty at the time they are returned, indicating that off-leased used cars can be of better quality than purchased cars. Certified Pre-Owned (CPO) programs originated due to the large number of off-leased vehicles in the market, and most of these vehicles have lower mileage and are considered good quality cars. As a result, manufacturers began to refurbish these vehicles with a guarantee, a trend that has been growing rapidly.

In his seminal paper on the lemons market (the average quality of traded and non-traded cars is not the same), Akerlof (1970) suggested two possible outcomes because of asymmetric information between the buyer and seller of a used car. First, because of asymmetric information between buyers and sellers of used cars: "the bad cars tend to drive out the good" (Akerlof, 1970). Second, private institutions can provide information to buyers about the quality of a product. These institutions can improve the functioning of a market but may not be able to eliminate market failure caused by asymmetric information.

Since earlier empirical studies on the subject are inconclusive as some of them have found little evidence of adverse selection and with these changes in the automotive industry and more recent data set might lead to a different answer. So, the motivation for doing the study is the fact that this is a different market segment now because of leasing and CPO and a different type of data set is being used. Hence, the first question to

[1] For details, see Automotive News, CNW Marketing/Research, and The Used Car Market Report 2003 by Manheim Auctions.

examine in this paper is this: Does the lemons hypothesis still hold in the current used car market? To examine this question, the hypothesis of no difference in the average maintenance expenditures required for cars that were acquired used and those that were acquired new was tested. To do this, the Panel Study of Income Dynamics (PSID) data set was used, which has two advantages over the data set used by Bond's (1982). First, it provides actual maintenance expenditure incurred on a car rather than a probability of maintenance expenditure. Second, it has some household characteristics such as income, age of household, and number of cars in the household. Thus, this study provides a useful complement to existing empirical results.

The second question is as follows: What impact do leasing and CPO have on the used car market, and to what extent do they help mitigate the consequences of adverse selection in the used car market? To investigate that, the hypothesis that the average maintenance expenditures for leased cars are not different from those for purchased cars was tested. The alternative hypothesis is that the average maintenance expenditures required for leased cars are lower than those for purchased cars. If a null hypothesis is rejected, that implies that the quality of leased cars is better than that of purchased cars. Also, the null hypothesis of no difference in the average maintenance expenditures required for CPO cars and other used cars was tested. CPO cars should have lower maintenance expenditures than other used cars since they are considered to be of higher quality than other used cars.

II. Literature Review

The seminal paper on the lemons market was by Akerlof (1970). He showed that in the used car market, sellers know the quality of their cars, but buyers are unable to discern lemons from good cars, which reduce volume of trade as the bad cars tend to drive out the good from the market.

Using data from the Truck Inventory and Use Survey of the Census of Transportation to test the lemons hypothesis (whether the average quality of traded and non-traded pickup trucks is the same), Bond (1982) estimated a binomial logit model with frequency of maintenance as a dependent variable, while mileage, age of car, and "traded" were independent variables. He found no support for the hypothesis. Lacko (1986) found some evidence of adverse selection by comparing the quality of cars purchased from friends and those purchased through newspaper ads. He found that cars purchased from friends and relatives required less maintenance expenditure than cars purchased through newspaper ads. Genesove (1993) examined prices of cars sold and selling propensity by New Car Dealers (NCDs) and Used Car Dealers (UCDs) at wholesale auctions and found that NCDs received premium over UCDs for only 1984 model cars implying that NCDs have better quality cars. Both the dealers received the same price for model years 1987 and 1988. In short, Genesove found weak evidence of adverse selection. In conformity to earlier studies, Sultan and Miah (2007) showed that non-CPO cars required more maintenance expenditures than CPO cars of a similar age. Sultan (2007) also found no evidence of lemons hypothesis. Pratt and Hoffer (1986) investigated whether the quality certification and the used vehicle disclosure laws required by certain states were effective or not. They found no evidence that the mandated disclosure requirements in certain states were effective in increasing the number of good quality trucks traded in the market. Role of leasing in a market with asymmetric information was examined by Gilligan (2004), and he found evidence that leasing mitigates the consequences of asymmetric information about the quality uncertainty of used durable goods. Further evidence was provided by Aizcorbe and Starr-McCluer (1997) and Starkey (1997), and they found that the higher income consumers

prefer leasing to buying. Desai and Purohit (1998), using auction data for a popular car model, found that off-lease cars sell at a premium or, that the price decline over time is slower than for purchased cars, implying that off-leased cars are of higher average quality than other used cars.

III. Data Description

This empirical analysis drew bi-annual survey data from sections V and X of "The Panel Study of Income Dynamics[2] (PSID)" from the University of Michigan. The data about vehicles were taken from section V, while data on maintenance expenditures were taken from section X. These sections have been a part of the survey since 1999. The sample covered a total of 36,757 cars for the years 1999 and 2001. Households not owning a car were not included.

Table 1 summarizes the statistics. It shows that the proportion of new cars that required maintenance expenditures was 18 percent in 1999 and 19 percent in 2001. The proportion of used cars that required maintenance expenditures was 29 percent for both years. This means cars acquired used required more maintenance expenditures than cars acquired new. Of leased cars, 3 percent required maintenance expenditures in 1999 and 2001, while 14 percent of purchased cars required maintenance expenditures in 1999 and 16 percent in 2001, implying that differential in maintenance expenditures could be associated with age of a car. The proportion of used dealer cars that required maintenance expenditures was 6 percent in 1999 and 4 percent in 2001. Among other used cars, only 11 percent required maintenance expenditures in 1999, and the same percentage required maintenance expenditures in 2001. This also shows that used dealer cars required less maintenance expenditure than other used cars.

Descriptive statistics for the data are presented in Table 2. It shows the variables included in the model and their respective means, standard deviations, maxima, and minima. It also shows that average monthly maintenance expenditures for the first car in the household are $56 for cars purchased new and $97 for used cars. The average maintenance expenditure per month for the second car is $31 for cars purchased new and $83 for used. Note the maintenance expenditure for the second car is lower than that for the first car because of lower usage of second car in the household as they are older cars. The average age of the household's first car is 1.54 years for cars purchased new and 4.60 years for cars purchased used. The average age of the second car is 1.46 years for cars purchased new and 4.29 years for cars purchased used but they have large age variance. The ages of all cars ranged from 1 to 20 years. The variable NUMBER OF CARS represents number of cars in the household and ranges from 1 to 10, with a mean of 2.06. It ranges from 1 to 8 for new cars, with a mean of 0.95, while it ranges from 1 to 8 for households with used cars, with a mean of 1.13. Mean values for the variables TRADED1, LEASE1 and CPO1 were 0.57, 0.07 and 0.09, respectively. The maintenance expenditure data is aggregated for each household.

IV. Model and the Methodology

I used the following model, which is based on Bond (1982):

$$m_i = \beta_o + \beta_1 (TRADED)_i + \beta_2 (LEASE)_i + \beta_3 (CPO)_i + \beta_4 (AGEC)_i + \beta_5 (NUMBERC) + \beta_6 (SYEAR) + \varepsilon \quad (1)$$

$i = 1, 2$; 1 for 1st car and 2 for 2nd car.

[2] For details, see the website: http://psidonline.isr.umich.edu/

where m_i = maintenance expenditure incurred on a car; TRADED is a dummy variable equaling 1 if the car was acquired used and 0 otherwise; LEASE is a dummy variable equaling 1 if the car was leased and 0 otherwise; CPO is a dummy variable equaling 1 if the car was a CPO and obtained from the dealer and 0 otherwise; AGEC represents age of a car; NUMBERC represents number of cars; and SYEAR is a dummy variable equaling 1 if the survey year was 2001. Used dealer cars is a proxy for CPO cars, which are bought directly from used car dealers under the CPO program. Bond (1982) estimated a model with a probability of maintenance as a dependent variable and age of a truck, mileage, and "traded" as independent variables.

Bond (1982) tested the lemon hypothesis (whether the average quality of traded and non-traded pickup trucks is the same) and found no evidence of the hypothesis. To test the lemons hypothesis, I used the amount of maintenance expenditure as a measure of car quality. That is, a car requiring more than average expenditure on maintenance was considered a lemon, whereas a car requiring less than average expenditure was a good car. The presence of a positive and significant value of the coefficient of TRADED, β_1, indicates that a traded car is likely to have more maintenance expenditure than a non-traded car, all else being equal. The presence of a negative and significant value of β_1 indicates that a traded car is likely to have less maintenance expenditure than a non-traded car. If β_1 is insignificant, then there is no significant difference in the maintenance expenditures between a car acquired new and one acquired used. I expect β_1 to be not significantly different from zero.

The second question considered involves the impact that leasing and CPO have on the used car market. The coefficient of LEASE, β_2, should be negative and significant. The presence of a positive and significant value of β_3 indicates that a CPO car is likely to have more maintenance expenditure than other used cars (or a non-CPO). Therefore, I expect the coefficient on CPO, β_3, to be negative and significant.

I estimated the above model by using the Tobit model rather than OLS; justification for this is as follows. In the survey population, there are two types of car owners: those who spend nothing on the maintenance of their cars, and those who spend on the maintenance of their cars. If we estimate the model using OLS, because of the large number (proportion) of zero maintenance, the estimates will be biased and inconsistent since there is no guarantee that E (ε) will be necessarily zero. As shown in Table 1, approximately half the cars in the sample did not require any maintenance expenditure. To deal with this censoring, I estimated a Tobit model. The Tobit model assumes that the structure of the error term as $\varepsilon \sim N(0, \sigma^2)$, where σ^2 is the variance of the error term. Moreover, the R^2 measure for Tobit (sampling correlation $(\hat{y}_i, y_i)^2$) is higher than OLS [see Wooldridge (1991)]. Therefore, I used the Tobit model.

There is a common notion that as a car gets older, the more maintenance expenditure it requires. Akerlof's (1970) lemons model gives no specific guidance about how long it would take a car owner to become aware that his/her car is a lemon. Among the older cars, many lemons may already have been scrapped. Many newer cars may still have warranty, so age of a car must be controlled for to test the hypothesis.

INCOME and AGE OF HOUSEHOLD variables are also added to see the robustness of my results. They are also expected to affect the maintenance expenditure incurred on a car. I expect income to be positively related to the maintenance expenditures as higher income people consume more to get good service from their cars. Age of household can go either way.

I estimated three versions of the model. First, I estimated the model without INCOME and AGE OF HOUSEHOLD variables, second, I estimated the model adding

AGE OF HOUSEHOLD and AGE OF HOUSEHOLD SQUARED to the model; and third, I added both INCOME and AGE OF HOUSEHOLD and squared these two variables in the model. The variables INCOME SQUARED and AGE SQUARED were added to see the non-linearity effects between these variables and the dependent variable. This procedure allowed me to better understand the effect of these variables on the estimates of TRADED, LEASE, and CPO.

V. Discussion of the Results

First, I compared the result of the logit model with Bond's (1982) results in Table 3. Columns 1 – 4 show his results, and columns 5 – 6 show my results. Out of four repair types[3], he found the estimates for only one type as significant for age group 1 – 5 and one for age group 6 – 10. For all other repair types and age groups, he found that the estimates of TRADED are insignificant. Column 5 of Table 3 shows that the estimated coefficient of $\beta_1 = 0.0250$ ($z = 0.90$) is positive and insignificant at either the 5% or 10% level, as expected, implying that the maintenance expenditure is not significantly different for both types of cars – acquired new and acquired used. Column 6 of the table shows the result by adding INCOME and AGE OF HOUSEHOLD variables to the basic model. As displayed in column 6 of Table 3, the estimated coefficient of TRADED is $\beta_1 = 0.020$ ($z = 0.72$) for the first car, which is insignificant. Bond (1982) found that for older cars the coefficient is significant (see column 3 in table 3). I also found $\beta_1 = 0.077$ ($z = 2.82$) for the second car. Thus, the estimated coefficient of TRADED is significant for the second car[4]. The likely reason is that most of the second cars in the sample are older as indicated by larger age variance. Hence, my results support the earlier studies including Bond (1982).

I present the result of the Tobit model in Table 4. Column 1 shows that the estimated coefficient of TRADED is $\beta_1 = 0.012$ ($z = 1.19$) for the first car. It remains insignificant even after adding INCOME, AGE OF HOUSEHOLD and squared of these two variables as explanatory variables to the basic model as shown in columns 2 and 3. Thus, the coefficient estimate of TRADED has the expected positive sign and is insignificant. Therefore, maintenance expenditure is not significantly different for cars acquired new and those acquired used.

As shown in column 2 of Table 4, the estimated coefficient of LEASE is $\beta_2 = -0.033$ ($z = 1.85$) and the estimated coefficient of CPO is $\beta_3 = -0.027$ ($z = 1.80$). The estimated coefficients of LEASE and CPO have an expected negative sign and are significant at the 5% level of significance, implying that the average maintenance expenditures for CPO cars and leased cars are lower than maintenance expenditures for non-CPO and purchased cars. By adding AGE OF HOUSEHOLD and AGE OF HOUSEHOLD SQUARED variables, as displayed in column 2 of Table 4, the estimated coefficient $\beta_2 = - 0.033$ ($z = 1.85$) for the first car and $\beta_2 = 0.020$ ($z = 0.74$) for the second car, and the estimated coefficient $\beta_3 = - 0.027$ ($z = 1.80$) for the first car and $\beta_3 = 0.001$ ($z = 0.04$) for second car. The estimated coefficients of LEASE and CPO are negative and significant at the 5% level of significance for the first car but insignificant for the second car. Again, the likely reason is the presence of older cars and larger age variance of the second car in the sample.

Next, I estimated the model by adding INCOME, AGE OF HOUSEHOLD, and the square of these two variables as explanatory variables and found that the estimated coefficients of LEASE and CPO were significant. This indicates that the average

[3] Bond (1982) used four repair types, and they are engine, transmission, brakes, and rear axle.
[4] Second car in the household.

maintenance expenditure is significantly different for leased and purchased cars and for CPO and non-CPO cars.

I tested the hypothesis of the stability of parameters between the two years and found the F-statistic to be 0.791, with a p-value of 0.21. Thus, the stability hypothesis cannot be rejected at the 10% level of significance, implying a strong likelihood that pooling the data across the two years is legitimate. Therefore, I present the results from the combined data only. I ignored the dependence issue arising from repeat samples of households over the years because they are less than 1 percent.

VI. Sensitivity Analysis

I examined whether the estimates are robust to alternative model specifications. In general, the parameter estimates are robust. In particular, the estimated coefficient for the variable TRADED remains positive and insignificant, while the estimated coefficients for the variables LEASE and CPO remain negative and significant for the first car.

First, I estimated the model using OLS[5] with different specification choices and found the results very similar to the baseline results from Tobit, where the baseline results are displayed in column 2 of Table 4.

Second, I estimated the Tobit and OLS[6] models using a different expenditure data set. I selected observations with only one car in the household and with positive maintenance expenditure incurred on a car for both the years. For 2001[7], the results showed that the coefficient estimate of TRADED, LEASE and CPO are similar to the baseline estimate. For 1999, the coefficient estimate of TRADED is statistically insignificant but estimates of LEASE and CPO become insignificant. The likely reason for this is biasness as some of the variables are omitted.

VII. Conclusion

The first purpose of this paper was to examine the difference in the quality between cars acquired used and those acquired new. I measured the quality of the car by using maintenance expenditures incurred on a car and used a new panel dataset published by the University of Michigan. I found that cars acquired new required the same maintenance expenditures as those acquired used, all else being equal, implying that cars acquired used are of same quality as cars acquired new of a similar age. If cars acquired used were of lower quality, they would have required more maintenance expenditure. This result is consistent with earlier empirical testing by Bond (1982), Lacko (1986), and Genesove (1993).

The second purpose of this paper was to examine the consequences of leasing and CPO on the adverse selection and the average quality of traded cars in the market. I found that purchased cars required more maintenance expenditure than those that were leased, indicating that used cars that are off-leased are of better quality than other used cars, all else being equal. This result is consistent with earlier empirical results by Gilligan (2004) and Desai and Purohit (1998). Also, I found that CPO cars require less maintenance expenditure than non-CPO cars, all else being equal.

[5] These results are not reported to save the space but are available on request from the author.
[6] Again, I did not report these results here to save the space.
[7] Again, results are not reported to save the space.

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Table 1: Summary Statistics

Variable	1999	2001	Combined
Total Cars	17,902	18,855	36,757
Cars acquired used (%)	58	58	58
Proportion requiring maintenance			
All cars (%)	47	48	47.5
New cars (%)	18	19	18.5
Leased cars (%)	3	3	3
Purchased cars (%)	14	16	15
Received as gift - new (%)	1	0	0.5
Used cars (%)	29	29	29
Used Dealer Cars (%)	6	4	5
Other Used Cars (%)	11	11	11
Received as gift – used (%)	5	6	5.5
Others* (%)	7	8	7.5

*includes leased used cars, company cars and etc.

Table 2: Descriptive Statistics

Variable	Mean		Maximum.		Minimum		Std Deviation	
	New	Used	New	Used	New	Used	New	Used
AGEC1 (age of first car)	1.54	4.60	20.00	20.00	1.00	1.00	2.59	5.07
AGEC2 (age of second car)	1.46	4.29	20.00	20.00	1.00	1.00	3.33	5.80
LEASE1 (first car lease)	0.07	----	1.00	----	0.00	----	0.26	----
LEASE2 (second car lease)	0.02	----	1.00	----	0.00	----	0.15	----
MEXP1(000 dollars) (maintenance expenditure on first car)	0.056	0.097	6.200	5.200	0.00	0.00	0.241	0.302
MEXP2 (000 dollars) (maintenance expenditure on second car)	0.031	0.083	4.000	6.200	0.00	0.00	0.187	0.289
NUMBERC1 (number of cars)	0.95	1.13	8.00	8.00	1.00	1.00	1.30	1.23
NUMBERC2 (number of cars)	0.57	1.20	7.00	8.00	1.00	1.00	1.15	1.40
TRADED1 (new or used car)	---	0.57	----	1.00	----	0.00	----	0.49
TRADED2 (new or used car)	----	0.47	----	1.00	----	0.00	-----	0.49
CPO1 (Used Dealer Car)	----	0.09	----	1.00	----	0.00	----	0.28
CPO2 (Used Dealer Car)	----	0.04	----	1.00	----	0.00	----	0.20

Table 3: Comparison with Bond's Results
Dependent Variable: Maintenance Expenditure

Independent Variable	Bond's Results – Repair Type				Estimated Coefficient (Logit) – Comb. Data	
	Engine (1)	Transmission (2)	Rear Axle (3)	Brakes (4)	(5)	(6)
Constant	----	----	----	----	-0.84*** (14.9)	-0.63*** (8.65)
TRADED (age 1 – 5)	-0.03 (0.33)	-0.19** (1.72)	0.02 (0.13)	-0.26 *** (2.88)	---	----
TRADED (age 6 – 10)	0.12 (1.2)	-0.09 (0.64)	-0.18** (1.80)	0.06 (0.31)	----	----
TRADED (1st car)	----	----	----	----	0.0250 (0.90)	0.0203 (0.72)
TRADED (2nd car)	----	-----	----	----	0.079** (2.90)	0.077** (2.82)
AGE of 1st Car	----	----	----	----	0.04*** (8.16)	0.04*** (8.16)
AGE of 2nd Car	----	----	----	----	-0.0009 (0.22)	0.0003 (0.07)
NUMBER OF CARS	----	----	----	----	0.19*** (12.10)	0.20*** (12.57)
INCOME	----	----	----	----	----	0.057** (1.84)
AGE OF HOUSEHOLD	----	----	----	----	----	-0.06*** (120.0)

*** Denotes significance at 1 percent level;
** Denotes significance at 5 percent level; and
* Denotes significance at 1 percent level. Z-statistics are in parentheses. Columns 1 - 4 report estimates of Bond (1982). Column 5 reports logit estimates, and column 6 reports logit estimates with INCOME and AGE OF HOUSEHOLD as additional explanatory variables.

Table 4: Tobit Estimates (Combined Data)
Dependent Variable: Maintenance Expenditure

Independent Variable	Estimated Coefficient (1)	(2)	(3)
Constant	-0.5032***	-0.6598***	-0.6744***
	(23.95)	(12.92)	(13.21)
TRADED (1st car)	0.0123	0.0090	0.0142
	(1.19)	(0.87)	(1.36)
TRADED (2nd car)	0.0220**	0.0200**	0.0231**
	(2.31)	(2.08)	(2.40)
LEASED (1st car)	-0.0308**	-0.033**	-0.0377**
	(1.74)	(1.85)	(2.11)
LEASED (2nd car)	0.0205	0.0201	0.0214
	(0.76)	(0.74)	(0.79)
CPO1 (1st car)	-0.0275**	-0.0278**	-0.0277**
	(1.80)	(1.80)	(1.80)
CPO2 (2nd car)	0.0009	0.0011	0.0016
	(0.04)	(0.04)	(0.07)
AGE of 1st Car	0.0162***	0.0162***	0.0173***
	(9.52)	(9.52)	(10.17)
AGE of 2nd Car	0.0019	0.0025**	0.0039***
	(1.35)	(1.66)	(2.60)
NUMBER OF CARS	0.0845***	0.0839***	0.0838***
	(19.20)	(19.06)	(19.04)
SURVEY YEAR	0.0780***	0.0799***	0.1214***
	(8.21)	(8.41)	(10.28)
INCOME	-----		0.0079***
			(2.63)
$INCOME^2$	-----		7.50E-05
			(0.057)
AGE OF HOUSEHOLD	------	0.0899***	0.0589***
		(4.49)	(2.85)
$AGE\ OF\ HOUSEHOLD^2$	------	-0.0116***	0.0084***
		(5.52)	(3.81)
R^2	0.015	0.017	0.019

$\bar{Z}$-statiscs are in parentheses.
*** Denotes significance at 1 percent level;
** denotes significance at 5 percent level; and
* Denotes significance at 10 percent level.
Column 1 reports Tobit estimates, and columns 2 and 3 report Tobit estimates with additional explanatory variables.