The Market for "Lemons" Reconsidered: A Model of the Used Car Market with Asymmetric Information

By JAE-CHEOL KIM*

The purpose of this paper is to analyze the working of the used car market, a market suffering severe informational asymmetry, by generalizing in two respects works of George Akerlof (1970) and Charles Wilson (1980) in the Walrasian paradigm.[1]

First, although Akerlof correctly points out a possible market failure in the used car market, his description of it overlooks the ability of each agent to freely choose whether to be a buyer or a seller. In other words, in the used car market, unlike other markets with informational asymmetry—the insurance market and the labor market—an agent can change his position from buyer to seller, or vice versa, with little or no transaction cost. Instead, Akerlof (and Wilson) arbitrarily divides the agents in the market into two groups, buyers and sellers, where, for example, an agent in the buyer group is supposed to buy only a used car. This is unnecessarily restrictive. It is possible that, if the price of used cars goes up, a used car buyer may want to shift his demand from a used car to a new car, and as a result he will be a used car seller.

Second, my model treats the quality of used cars as an endogenous variable in contrast with the Akerlof-Wilson model where each seller is exogenously endowed with a car of given quality. However, it is well recognized that the quality of a car depends not only on purely stochastic elements as perceived by Akerlof and Wilson, but also on its owner through endogenous factors such as maintenance, driving habits, and the like. This paper places more emphasis on the latter by assuming that the quality of a car is a function of the maintenance level.

Throughout the analysis, however, I will preserve the informational structure of Akerlof and Wilson by assuming that no activities of information acquisition and transmission (i.e., signaling, warranty, or search) are allowed. As a result, potential buyers make their decision based only on the average quality of used cars.

The basic model is constructed in Section I as follows. A car lasts two periods; it is new in the first and used in the second. There are many types of agents in the market and each agent can buy either a new car or a used car depending on his (or her) preference structure. The buyer may also refrain from buying a car. If he buys a new car, he chooses a level of maintenance for it, which determines a service flow. The service flow of a used car (the quality of a used car) depends on maintenance in the previous period when the car was new, but not on that in the current period. An owner of a new car can either sell or keep it after one period when it becomes used.

In Section II, given this setting, I characterize an equilibrium in the used car market, examining two contrasting cases depending on the underlying structure. An interesting result obtained in the first case is that the Akerlof's Lemons Principle need not hold in the used car market. Akerlof originally asserts that the lowest quality car will drive out cars of higher qualities. Yet the situation is not that extreme. Even in Akerlof's example, a nontrivial equilibrium could be shown to exist by slightly changing the assumed parameters. (Wilson shows this in a more general framework.) Then, the principle can be reinterpreted as saying that the

*Department of Economics, Amherst Campus, State University of New York, Buffalo, NY 14260. I thank many for their helpful comments, but am especially indebted to James Friedman, David Gordon, and Dave Weimer, and the anonymous referees who made valuable suggestions on an earlier version of this paper.

[1] Wilson provides two more conventions used to set the price in addition to the Walrasian convention for the analysis of market equilibrium with asymmetric information.

average quality of nontraded cars is higher than that of traded cars. Recently, Eric Bond (1982) tests this hypothesis for the pickup truck market and rejects it. His finding is that there is no significant difference in quality between traded and nontraded trucks. This paper provides a theoretical support to this finding by showing that either quality can be higher than the other. However, this is not because there is a mechanism to reduce or eliminate asymmetry in information as Bond himself conjectures. Rather, this is because there may be some people who value car service so highly that they maintain their cars exceptionally well when they are new in order to keep the service flow at a very high level. This leaves good used cars after one period. However, they will sell their good used cars and buy new cars in order to continue receiving the very high service flow associated with new cars. Also in Section II, the second case is considered. Although the case appears to be very similar to the Akerlof-Wilson model in many respects, a significant discrepancy is shown to exist. The concluding section summarizes the results and suggests areas for further research.

I. The Basic Model

Consider the used car market with many types of agents and asymmetric information. A buyer of a used car can observe only the average quality of used cars while a seller knows the quality of his own car. Let x be an index denoting the quality of a car, measuring its overall efficiency in terms of factors such as driving performance, the number of breakdowns including the resulting inconvenience and cost of repair, comfort, and so on. A unique feature of the model is that the quality of a car is endogenous, varying with a level of maintenance, m, which represents the expenditure on a car for any preventive purpose such as regular checkups.

When a car is new, its quality, $x_n(m)$, is a continuously differentiable, increasing and strictly concave function of the maintenance level; $x_n'(m)>0$ and $x_n''(m)<0$. However, it is assumed that maintenance on a used car has no effect on quality. Rather, the quality of a used car is solely determined by the maintenance level in the previous period when the car was new. Let $x_u(m)$ be the quality of a used car where m is the maintenance level applied in the previous period. Also assume that $x_u'(m)>0$ and $x_u''(m)<0$. Finally, for analytic simplicity, it is assumed that $x_u(\infty)<x_n(0)$, that is, any used car is lower in quality than any new car. Each agent is characterized by a real number t distributed on $T=[\underline{t},\bar{t}]$ with a density function $w(t)>0$ where $\underline{t}>0$. A type-t agent tries to maximize two-period expected utility and has the following von Neumann-Morgenstern one-period utility function, being risk neutral with respect to quality:

$$U(x,e:t)=tx-e, \tag{1}$$

where e is the expenditure on a car.[2] The ownership of no car is equivalent to owning a car of zero quality. If an agent buys a used car, his expected utility is a linear function of the average quality of used cars offered in the market. Finally, let P_n, P_u and β be the price of new cars, the price of used cars and a discount parameter, respectively.

Now let us consider the optimum behavior of a type-t agent. Assume that at the beginning of the first period, he has no car. Given this state of "having no car," he faces four possible choices: 1) buy a new car, maintain it and in the second period sell it; 2) buy a new car, maintain and keep it for both periods; 3) buy a used car and sell it in the second period; and 4) do not buy a car. It is simple to calculate the two-period utility, $S_2(t)$, if option 2) is taken,

$$S_2(t)=-P_n+Z_2(t), \tag{2}$$

where $Z_2(t)=tx_n(m_2(t))+\beta tx_u(m_2(t))-m_2(t)$ is the two-period net service from a

[2] The utility function in a general context can be defined as $U(x,c:t)=tx+c$, where c is consumption other than car service. Then, letting y be per period income, $c=y-e$. It can be easily seen that income level has no effect on optimal decision in this simple model if each agent receives the same rate of income, irrespective of agent type. Thus, without losing generality, we may set y equal to zero, which gives the utility function in equation (1).

car when adopting option 2 for which $m_2(t)$ is the optimum maintenance. If he chooses options 1, 3, or 4, he goes back to the starting state of having no car after one period. Therefore, if an option is optimal for him in the second period, so must it be in the first period. This means that we only have to consider stationary policies taking the same option in each period.

Let $Z_1(t) = (1+\beta)(tx_n(m_1(t)) - m_1(t))$ and $Z_3(t) = (1+\beta)tx_u^e$ be the two-period net service when adopting options 1 and 3, respectively, where $m_1(t)$ is the optimum maintenance for option 1 and x_u^e is the expected average quality of used cars in the market. It is assumed that each agent has the same expectations about the average quality. Letting $S_i(t)$ be the two-period utility, a type-t agent can obtain when taking option i, $(i=1,3,4)$,

$$(3)\quad S_1(t) = (-P_n + \beta P_u)(1+\beta) + Z_1(t),$$

$$S_3(t) = -P_u(1+\beta) + Z_3(t),$$

$$S_4(t) = 0.$$

Let $V(t)$ be the maximum two-period utility of a type-t agent. Then, from the above discussion, $V(t)$ is an envelope of the $S_i(t)$'s; that is,

$$(4)\quad V(t) = \max\{S_i(t),\ i=1,2,3,4\}.$$

Now the simple nature of the problem immediately implies the following properties. First, noting that S_i's depend on P_n, P_u, and x_u^e, let us define T_i using the above equation as follows:

$$(5)\quad T_i \equiv T_i(P_n, P_u, x_u^e) = \{t: V(t) = S_i(t)\}, \qquad i=1,2,3,4.$$

Then T_i is a set of agent types who maximize utility by adopting option i, $i=1,2,3,4$. There may be an interval of t over which two or more S_i's coincide. For analytic simplicity, but without sacrificing essentials, I will assume away this possibility.[3] Also, if some t belongs to more than one T_i, then I include it in T_i with the smallest index. An agent in T_1 buys a new car in each period and sells it after one period. Therefore, T_1 is a set of used car sellers. Similarly, T_3 is a set of used car buyers. Each agent in T_2 buys a new car and keeps it for both periods so that he is an owner of a nontraded used car. T_4 is a set of agents who do not buy cars.

Second, $m_1(t)$ maximizes $tx_n(m) - m$ while $m_2(t)$ maximizes $tx_n(m) + \beta tx_u(m) - m$. Assuming interior solutions, $m_1(t)$ and $m_2(t)$ are found from $tx_n'(m) = 1$ and $tx_n'(m) + \beta tx_u'(m) = 1$, respectively. Also from the assumption of strict concavity, it is easy to see that $m_1'(t) > 0$, $m_2'(t) > 0$, and $m_2(t) > m_1(t)$ for all t. Since t represents the marginal rate of substitution of a type-t agent, I conclude that agents with higher preferences for car service select higher maintenance levels. Moreover, agents would also select higher maintenance levels for new cars if they anticipate using them in the second period.

Finally, assuming that the set of used car sellers who adopt the maintenance policy $m_1(t)$ is not empty, the average quality of traded used cars, $Ex_u(T_1)$ is given by

$$(6)\quad Ex_u(T_1) = \int_{T_1} x_u(m_1(t))w(t)\,dt / W(T_1)$$

where $W(T_1) = \int_{T_1} w(t)\,dt$ is the total supply of used cars by agents in T_1. The average quality of nontraded used cars can be similarly calculated for agents who keep new cars two periods (option 2). The only difference is that $m_2(t)$ is used for the calculation instead of $m_1(t)$.

II. Equilibrium in the Used Car Market

An equilibrium in the used car market can be defined as follows:

DEFINITION: *The used car market is in equilibrium, given P_n, if there exist x_u^e and P_u such that* (a) $x_u^e = Ex_u(T_1)$ *where* $T_1 \neq 0$, *and* (b) $W(T_1) = W(T_3)$.

[3] It is not difficult to incorporate such a possibility in the model by slightly modifying the definition of an equilibrium presented below. However, this would add no more significant result but complications. Moreover, such a case does not arise in two special cases on which I will concentrate later.

Condition (a) says that the expectations about the average quality of traded used cars must be correct. Condition (b) is the usual market-clearing condition in the Walrasian paradigm. Since $T_1 \neq 0$, there must be a positive level of trade in the market. A quick glance at the conditions reveals that the nature of equilibrium depends heavily on the shapes of the S_i curves, especially on their slopes, which are given below.

$$(7)\quad \partial S_1/\partial t = \partial Z_1/\partial t = (1+\beta)x_n(m_1(t)) > 0$$

$$\partial S_2/\partial t = \partial Z_2/\partial t = x_n(m_2(t)) + \beta x_u(m_2(t)) > 0$$

$$\partial S_3/\partial t = \partial Z_3/\partial t = (1+\beta)x_u^e > 0$$

$$\partial S_4/\partial t = 0$$

$$\partial^2 S_1/\partial t^2 = (1+\beta)x_n'(m_1(t))m_1'(t) > 0$$

$$\partial^2 S_2/\partial t^2 = \{x_n'(m_2(t)) + \beta x_u'(m_2(t))\}m_2'(t) > 0$$

$$\partial^2 S_3/\partial t^2 = \partial^2 S_4/\partial t^2 = 0.$$

First note that the S_i's ($i=1,2,3,$) are all increasing functions of t. Second, S_1 and S_2 are increasing at increasing rates while S_3 increases linearly. Third, S_1 is always steeper than S_3 because of the assumption that $x_n(0) > x_u(\infty)$. Fourth, it is not obvious whether or not S_2 is steeper than S_1 and S_3.

The last observation opens up an interesting possibility that there are different types of equilibrium depending on the set of agent types and the shape of $x_n(m)$ and $x_u(m)$. In this paper, I consider two special cases of interest: Case 1: S_2 is steeper than S_3 but flatter than S_1; and Case 2: S_2 is the steepest. These complete orderings make the analysis simple because the S_i curves intersect each other at most once. Even though I will be mainly concerned with the first case, the second case is equally interesting because it turns out to be very similar to the Akerlof-Wilson model in nature.

A

Case 1: $\partial S_1/\partial t > \partial S_2/\partial t > \partial S_3/\partial t$.

Case 1 is worth considering for several reasons. First, if $x_n(\infty)$ is bounded from above and t is sufficiently large, the above assumption is automatically satisfied, because as t grows, $x_n(m_2(t)) - x_n(m_1(t)$ becomes arbitrarily small while $x_n(m_1(t)) - x_u(m_2(t))$ is bounded away from some positive number so that S_1 will eventually be steeper than S_2 (see equation (7)). The same kind of reasoning can be applied to show that S_2 is steeper than S_3 for a sufficiently large t. Second, if the technology of $x_n(m)$ and $x_u(m)$ is of an exponential form, for which some numerical examples are constructed later on, it can be shown that S_1 is always steeper than S_2, which is in turn steeper than S_3. Finally and most importantly, this formulation gives us an interesting counterexample to Akerlof's Lemons Principle.

A possible equilibrium situation is drawn in Figure 1, assuming that all the T_i's are nonempty. Let t_1 be the marginal agents who are indifferent between options 1 and 2. Similarly, t_2 and t_4 are the marginal agents who are indifferent between options 2 and 3, and options 3 and 4, respectively. Then,

$$(5')\qquad T_1 = [t_1, \bar{t}], \qquad T_2 = [t_2, t_1),$$
$$T_3 = [t_4, t_2); \quad T_4 = [\underline{t}, t_4).$$

From Figure 1, the following immediate observations can be made. Agents with higher preferences for car service (in T_1 and T_2) buy new cars and agents with lower preferences (in T_3) buy used cars. Among the agents buying new cars, agents with higher preferences (in T_1) are used car sellers and those with lower preferences (in T_2) are used car keepers.

It can be seen that, in equilibrium, used cars of various qualities are traded in the market. Agents with used cars of above average quality are also willing to sell their cars. In other words, as noted earlier, when an agent chooses the optimum maintenance level, he is only concerned with the net service from a car and not with the used car price,

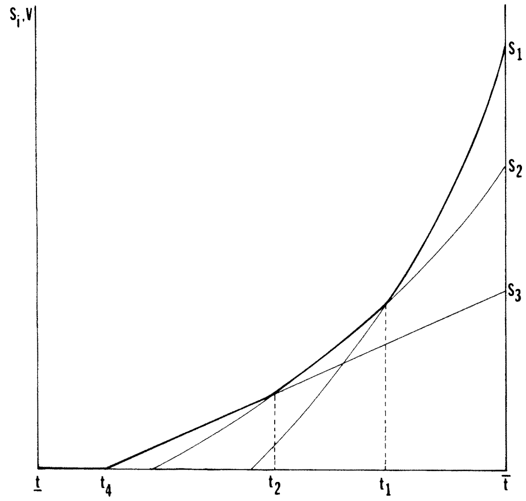

FIGURE 1

which is beyond his control under asymmetric information. That is, the fact that he receives a lower price than he possibly deserves is already taken into account in his decision process. Another direct result follows from the diagram.

PROPOSITION 1: *The average quality of nontraded used cars can be either higher or lower than that of traded used cars.*

This is because even though, for given t, $m_2(t) > m_1(t)$ so that $x_u(m_2(t)) > x_u(m_1(t))$, T_1 consists of agents with higher t's selecting higher maintenance levels for a given option as discussed in Section I. As a result, either one of them could be higher than the other. In some cases, the average quality of traded cars will be higher than that of nontraded cars, thus contradicting the Lemons Principle. A numerical example is provided below.

Numerical Example: Suppose that $x_n(m) = 2 - \exp(-m/2)$ and $x_u(m) = (1 - \exp(-m/2))/2$. Also t is distributed on $[7,8]$ such that $w(t) = .5$ for $7.65 < t < 7.90$, and equals 1 otherwise. If $P_n = 13.00$, then equilibrium t_i's are given by $t_1 = 7.76$, $t_2 = 7.56$, $t_4 = 7.39$, and $P_u = 2.76$. The average quality of nontraded cars is .44 while that of traded cars is .37, confirming the Lemons Principle. However, as expected, the result is very sensitive to the distribution of agent types (and also the technology). In particular, suppose the lower margin of a set of t over which $w(t) = .5$ increases slightly. Then the average quality of nontrade cars will be reduced with all other equilibrium values remaining unchanged. For example, if the lower margin goes up to 7.71 from 7.65, the average quality of nontrade cars drops to .32, becoming less than that of traded cars.

Now let us investigate the nature of equilibrium shown in Figure 1 more closely. In terms of t_i's $(i = 1,2,4)$, the equilibrium can be characterized as

$$Z_1(t_1) - Z_2(t_1) + \beta(-P_n + (1+\beta)P_u) = 0 \tag{8a}$$

$$Z_2(t_2) - Z_3(t_2) + (-P_n + (1+\beta)P_u) = 0 \tag{8b}$$

$$Z_3(t_4) - (1+\beta)P_u = 0 \tag{8c}$$

$$\int_{t_1}^{\bar{t}} w(t)\,dt = \int_{t_4}^{t_2} w(t)\,dt \tag{8d}$$

$$t > t_1 > t_2 > t_4 > \underline{t}. \tag{8e}$$

I first derive the demand and supply functions in the used car market from the above equation. For this, I totally differentiate (8a), (8b), and (8c) with respect to P_u. Using the slope conditions and the fact that an increase in t_1 raises the average quality of traded used cars, it can easily be shown that

$$\partial t_1/\partial P_u < 0, \quad \partial t_2/\partial P_u < 0, \quad \partial t_4/\partial P_u > 0. \tag{9}$$

Combined with the market-clearing condition equation (8d), the above equation says that the demand function is downward sloping while the supply function is upward sloping. Therefore,

PROPOSITION 2: *If there exists an equilibrium, it is unique.*

The reason why the demand and supply functions have the usual shape is the following. Suppose that the used car price goes up. This will make it more profitable than before to sell used cars, which will induce some agents who otherwise would be used car keepers to become used car sellers, lowering the average quality and increasing the supply of used cars. At the same time, an increase in the used car price and the resulting decrease in the average quality will depress the demand for used cars.

Before continuing, it seems worthwhile to investigate the structural difference between the present model and the Akerlof-Wilson model. In the Akerlof-Wilson model, sellers are identical except for the quality of cars they own. Then, given a used car price, owners of cars above some critical quality level do not want to offer their cars for sale in the market. So identical agents behave in different ways depending on the cars they own. By contrast, in this model, there are many different types of agents. All agents of the same type are assumed to behave in the same way, that is, take the same option so that the quality of a car is endogenously linked to the type of agent holding the car. This structural difference generates different outcomes in many ways. For example, in case of an increase in the used car price, the Akerlof-Wilson model predicts an opposite result that the quality will go up because owners of higher quality cars will be induced to sell.

There are a few more things to be noted. First, if $\underline{t} = \bar{t}$ (the agents are identical so that buyers get perfect information about the quality of used cars), a used car market cannot exist. This is because, in such a situation, for a used car market to exist, the typical agent must be indifferent between options 1 and 3. But this means that the typical agent in turn is indifferent between those options and the option of buying a new car, maintaining at the level of m_1, and keeping it for both periods. However, the latter, and therefore options 1 and 3, are obviously inferior to option 2, that constitutes a desired contradiction. As a result, in this case, the agents will keep their used cars because they cannot obtain gains from trade. This observation can be easily extended to a case where $\underline{t}$ and $\bar{t}$ are close to each other. That is, if the difference in consumer tastes is small enough, there may not exist an equilibrium in the used car market.

Second, the effect of an increase in the new car price is examined. For this, I totally differentiate equations (8a), (8b), (8c), and (8d) with respect to P_n. After tedious manipulation, we have

$$(10)\quad \partial t_1/\partial P_n > 0, \quad \partial t_2/\partial P_n > 0,$$

$$\partial t_4/\partial P_n > 0, \quad 1/(1+\beta) > \partial P_u/\partial P_n > 0.$$

A type-t_1 agent who was indifferent between options 1 and 2 will prefer option 2. This is because as the new car price goes up, the additional cost is $(1+\beta)(dP_n - \beta\, dP_u)$ which is greater than dP_n, the additional cost if he takes option 2, by the second last inequality of equation (10). An analogous argument can be made for agents of types t_2 and t_4. Therefore, as the price of new cars increases, the supply of and demand for used cars decrease and, as a result, the average quality of used cars rises. The used car price also rises, but by a relatively small amount. To see the effect on agents's welfare, note that the S_1 and S_2 curves shift downward. The S_3 curve becomes steeper because of an increase in the average quality. This observation combined with equation (10) indicates that $\partial S_3/\partial P_n$ may be positive for some t's around t_2, reflecting that the extra utility from the average quality increase exceeds the disutility from the used car price increase for those agents. Therefore, everyone is made worse off in the new equilibrium except possibly some used car buyers (around type-t_2 agents) who benefit from the increased average quality.

B

Case 2: $\partial S_2/\partial t > \partial S_1/\partial t$.

Case 2 is shown as a solid line in Figure 2 where $T_1 = [t_3, t_1)$, $T_2 = [t_1, \bar{t}]$, $T_3 = [t_4, t_3)$, and $T_4 = [\underline{t}, t_4)$. It is immediately seen that in this case the average quality of nontraded cars is definitely higher than that of traded

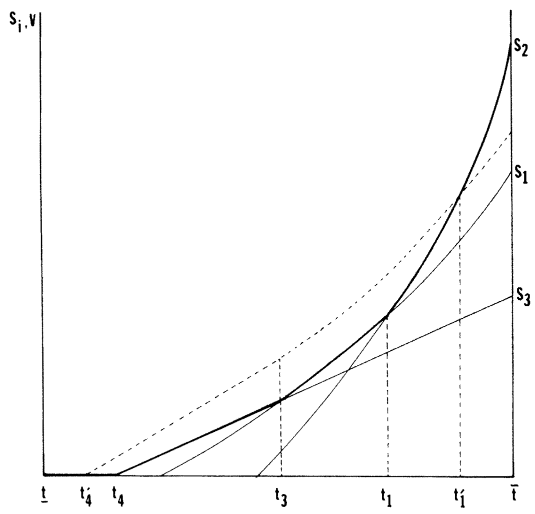

FIGURE 2

cars, thus supporting the Lemons Principle. Therefore, in this special case, the present model and the Akerlof-Wilson model give the same conclusion. However, there still exists a significant discrepancy between the two models, illustrated by the following example. Wilson argues that in the Walrasian paradigm, there may exist multiple equilibria, and in such a case an equilibrium with the highest used car price is Pareto superior. Multiple equilibria could also exist in Case 2 for the same reason given by Wilson. To see this point more closely, suppose that P_u increases. This will induce the agents with higher t's than t_1 to sell their cars, which will increase the average quality of traded cars. At the same time, this increase in P_u may attract some used car buyers to be used car sellers, which has a negative effect on the average quality. As Wilson argues, if the average quality happens to increase more rapidly than the used car price, there might be another equilibrium with a higher used car price.

If t_3 does not change in the new equilibrium (which may be interpreted as saying that sellers and buyers are separated as in Akerlof-Wilson model), then Wilson's argument can be applied in exactly the same way to conclude that the new equilibrium is Pareto superior. This possibility is shown in Figure 2 where a dotted line is an envelope of new S_1 and S_3 curves. The supply of used cars increases because $t_1' > t_1$. Then the demand should also increase, which implies that S_3 cuts S_4 before t_4 in the new equilibrium. Obviously, agents in $[t_4', t_1')$ are better off so that the new equilibrium is Pareto superior.

But, in general, it will be more reasonable to think that t_3 changes after the price change. Then, there might be an equilibrium with t_3 and t_4 moving to the right which clearly cannot be Pareto superior because some used car buyers will be driven out of the market due to the increase in P_u.

PROPOSITION 3: *In Case* 2, *the Lemons Principle holds. Moreover, there are possibly multiple equilibria. However, it is not generally possible to rank those equilibria by the Pareto criterion.*

III. Concluding Remarks

I have constructed a model of the used car market with asymmetric information where there are many types of agents in the market. Even though there could be many kinds of equilibrium depending on the underlying parameters, attention has been focused on two contrasting cases.

In Case 1, there exists a unique equilibrium given the new car price and the distribution of agent types. Furthermore, the Lemons Principle need not hold: average quality of traded used cars may be higher than that of nontraded cars. Case 2 closely resembles the Akerlof-Wilson model. Not only does the Lemons Principle hold in this case, but also multiple equilibria with different used car prices may emerge for the reason Wilson indicates. However, in this case, the ability of agents to change their positions costlessly makes it impossible to rank equilibria by the Pareto criterion in contrast with Wilson's argument.

In future research, it may be worthwhile to consider the situation where perfect information is available; that is, each agent may learn the quality of used cars by observing them. The importance of such a study may be seen by the following consideration. In reality, a potential buyer of a used car buys it either from an individual seller or from a used car dealer. In the first type of transaction, the buyer presumably obtains little information about the quality of the car, which fits the present model. On the other hand, if the buyer is engaged in the second type of transaction, he may obtain considerable information from the used car dealer, for example, in the form of a warranty, by paying a transaction cost. Perfect information may be accommodated by modifying the model so that an agent has perfect knowledge about the quality of a car if he pays some positive cost. It will be necessary to combine the two models so as to allow each agent to decide on what types of transactions he will make in order to explain why both types of transactions are popular in the real world.

REFERENCES

Akerlof, George A., "The Market for 'Lemons': Qualitative Uncertainty and the Market Mechanism," *Quarterly Journal of Economics*, August 1970, *84*, 488–500.

Bond, Eric W., "A Direct Test of the "Lemons" Model: The Market for Used Pickup Trucks," *American Economic Review*, September 1982, *72*, 836–40.

Wilson, Charles, "The Nature of Equilibrium in the Markets with Adverse Selection," *Bell Journal of Economics*, Spring 1980, *11*, 108–30.