The Role of Leasing under Adverse Selection

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¶We would like to thank Gene Grossman and Steve Tadelis. Alessandro Lizzeri would like to thank IDEI in Toulouse for hospitality while part of this research was completed. Financial support for this project by NSF grant SBR-9711355 is gratefully acknowledged.

Abstract

Leasing contracts are extensively used in durable goods markets. These contracts specify a rental rate and an option price at which the used good can be bought upon termination of the lease. This option price cannot be controlled when the car is sold. We show that in a world where quality is observable this additional control variable is ineffective. Under adverse selection instead, leasing contracts affect equilibrium allocations in a way that matches observed behavior in the car market. Consistent with the data, our model predicts that leased cars have a higher turnover and that off-lease used cars are of higher quality. Moreover, the model predicts that the recent increase in leasing can be explained by the observed increase in car durability. We show that leasing contracts can improve welfare but that they are imperfect tools. We also show that a producer with market power can benefit from leasing contracts for two reasons: market segmentation and better pricing of the option. Moreover, despite the fact that lessors could structure contracts to prevent adverse selection, we show that this is not in their interest.

JEL D82, L15

1 Introduction

Leasing contracts are extensively used in durable goods markets. A third of the capital equipment in US corporations is leased. In the automobile market the importance of leases has been growing up to the point where in 1996, one out of three new cars was leased. If one consumer leases and another buys, should we expect them to behave differently in secondary markets or are the two consumers simply financing a similar utilization of a durable good in a different way?[1]

Evidence from the car market, shows that buyers and lessees behave in a different manner. First, the turnover of leased cars is higher than that of sold cars. Second, off-lease used cars seem to be of better quality than pre-owned cars of the same vintage. Evidence of the first phenomenon is particularly strong. Lessees buy their cars at maturity only 25% of the time. Since most car leases have a two to three year duration, this means that a large fraction of leased cars are sold in the used market by the time they are three years old.[2] In 1996 42% of the so called premium used cars, which include two to four year old cars, were off-lease cars. But back in 1993 only one out of four new cars was leased. For leased cars to account for 42% of trades in 1996, while only being 25% of the stock in 1993, they must have a propensity to be traded within the first four years which is 117% larger than that of sold cars. Further evidence is provided by Sattler (1995) who reports that 56% of 1989 car models in his sample were held by their first owner five years later. Moreover, the average length of period that all new cars (leased and bought) are held before changing hands is almost 6 years. New car buyers hold on to their cars much longer than consumers who lease.

Evidence that off-lease cars are of better quality is a little weaker but still suggestive. In the automotive press it is a common finding. For instance, "[T]he industry-wide assumption [is] that the most desirable used vehicle is the consumer off-lease variety...."[3] Moreover, advertisements of used cars for sale often specify whether a car is off-lease. This would hardly be highlighted if the perception

[1] From now on, for concreteness, we will refer to cars. However, our model is applicable to other markets as well.

[2] Polk's analysis estimates 2.88 million off-lease vehicles returned to the used car market in 1997, 87 percent being two- and three-year-old vehicles. In fact, 1997 numbers show off-lease vehicles representing 65 percent of two-year-old vehicles on the market, and 57 percent of three-year-old vehicles. Source, Polk Corporation.

[3] Polk Corp, Press release 1996.

was that off-lease cars are no better than sold cars. Finally, Desai and Purohit (1997), using auction data for a popular car model, find that off-lease cars sell at a premium or, more precisely, that the price decline over time is slower than for sold cars.

The purpose of this paper is to study how the structure of leasing contracts affects market allocations, social welfare, and the profits of manufacturers, in a world where the user of the durable gains superior information about its quality.

A leasing contract, beyond specifying the rental payments for the good, also specifies the option price at which the used good can be bought at maturity. This option price can be set independently of the price in the used market and provides an additional control variable for the manufacturer. We show that in the absence of asymmetric information the structure of leasing contract is irrelevant: the equilibrium allocation and manufacturers profits are the same regardless of the option prices. We then introduce the possibility of adverse selection in the used market and show that leasing can play a significant role. The key ingredients of the model are the following.[4] Consumers are long lived and have heterogeneous valuations for quality. Cars are produced every period and depreciate. Consumers endogenously self-select between buying new or used cars.

We show that when leasing and selling contracts are available on the market, then higher valuation consumers prefer leasing. Thus, offering both contracts helps segment the market. Moreover, the percentage of off-lease cars that are returned at maturity is higher than the percentage of pre-owned cars that are traded in the used market. Furthermore, off-lease cars have higher average quality. These predictions of the model match the empirically observed differences in behavior between lessees and buyers. Interestingly, the popular press commonly prescribes leasing contracts to lower income households on the basis that they involve lower cash flows. Our model predicts the opposite: leasing is preferred by higher income households. This is in line evidence presented by Aizcorbe and Starr-McClure (1997) and Starkey (1997) who report that higher income individuals are more likely to lease.

We investigate the welfare effects of leasing contracts. We show that a social planner can use

[4]We build on the model of adverse selection in durable goods markets presented in Hendel and Lizzeri (1999b).

leasing contracts to ameliorate the welfare distortion caused by adverse selection. However, except for the case where there are only two types of consumers, no menu of leasing contracts can achieve even the second best allocation. Leasing contracts are good tools to control the keeping behavior of new car consumers and therefore to adjust the volume of trade in the used car market. However, they cannot deal with the distortion in the allocation of used goods among used good buyers: because of adverse selection it is not possible to match used car buyers with different valuations to the right qualities of used goods. Solving this distortion requires that finer information about the quality of the used goods be obtained from the first users. A menu of leasing contracts is not capable of doing this. We show that there exists a mechanism that completely solves the adverse selection problem; the first best allocation can be achieved by an incentive compatible, individually rational, and budget balanced mechanism. This is in contrast with familiar results from static adverse selection models where such efficient mechanisms do not exist.

We then consider the optimal choice of leasing contracts by a monopolist. We present an example with the striking feature that the manufacturer can raise the option price above the market clearing price in the used market and increase its profits without affecting the equilibrium allocation in the market. The reason the monopolist profits from increasing the option price reflects an important force that is present in a world with adverse selection. For consumers who purchase the good, the option of keeping the good is implicitly priced by the market clearing price in the used market. With adverse selection, this price reflects the fact that the traded used good is of lower quality than the good that is kept by the new car buyer. Thus, the new car buyer gets to keep a high quality good that is priced as if it were a low quality one. Leasing allows the manufacturer to raise the option price thereby reducing the competitive threat that the used good poses to the new good. We go on to show that this allows the manufacturer to profitably expand output.

Our model suggests that the increased popularity of leasing may be (partly) explained by the recent improvement in car durability. According to our model, incentives for manufacturers to offer leasing contracts are strengthened when the good becomes more durable. An increase in durability has two effects in our model: (1) It makes the used car market more important, thus increasing

the profits that manufacturers can obtain from leasing; (2) More interestingly, it implies that used cars are better substitutes for new cars, hence worsening the adverse selection problem, thereby expanding the role of leasing in dealing with this problem.

Given the ability to control behavior in the used market, and given the fact that adverse selection is generally a source of inefficiency, it is natural to ask why leasing contracts often include the option of buying the good at the end of the lease. If this option were very expensive, all used goods would be returned resulting in a pool of used cars that does not suffer from adverse selection. We show that allowing some lessees the option of keeping the used good is optimal for the manufacturer despite the fact that these lessees only return the worse quality cars. This is because leasing contracts allow a better segmentation of the market.

2 Related Literature

Several roles for leasing have been suggested in the durable goods literature. Bulow (1986) shows that leasing can be used by a monopolist to overcome the Coasian time inconsistency problem. Waldman (1996) and Hendel and Lizzeri (1999a) show that manufacturers may choose to lease because this gives them additional market power in the used market. These papers provide rationales for leasing but they make no predictions on how sold and leased units differ in the secondary market.

There is a large literature in finance that focuses on the valuation of leasing contracts. Most of this literature takes as given the structure of the leasing contract and obtains the equilibrium lease value and the rental rate for a wide variety of leasing contracts.[5] Smith and Wakeham (1985) provide the most extensive analysis of the determinants of corporate leasing policy. Their analysis is informal but very insightful. Some of the issues that they consider are the following: Repossessing an asset is easier for a lessor than for a secured debt holder in the event of bankruptcy. Thus, firms that have problems obtaining financing might be expected to lease. Sharpe and Nguyen (1995) present evidence that firms likely to face high financial contracting costs lease a higher proportion of their

[5]Examples are papers by Grenadier (1995, 1996) and McConnel and Schallheim (1983).

capital equipment. This is an implausible explanation for the car market because it is unlikely that it can account for the observed higher turnover of leased cars as opposed to sold cars.[6] Smith and Wakeham also argue that leasing might be favored if the lessees plan to use the equipment for less than its useful life and the lessor has a comparative advantage in disposing of the asset. However, they acknowledge that this transaction cost explanation for leasing is problematic since it requires that the comparative advantage of the manufacturer not be available under selling. Many manufacturers (including car manufacturers) however, allow dealers to accept trade-ins thereby making available to buyers the same advantage that is available to lessees. Smith and Wakeham also discuss the rationales for a number of common provisions in leasing contracts. The most relevant to our analysis is their discussion of options to purchase at the end of the lease. They argue that this provision serves to give an incentive to the user to take care of the asset.

Waldman (1999) is the only other paper that deals with leasing and adverse selection. The main difference with our paper is that he looks at a special case where the analysis is simplified. His analysis does not capture a number of effects that arise in a richer model. The main result of his analysis of adverse selection is that "leasing solves the adverse selection problem", i.e., leasing contracts offered by a competitive industry lead to efficient allocations. However, as we show in section 6, this is true *only* under the assumption of two types of consumers. We show that in general leasing contracts cannot even achieve the incentive efficient allocation.

There is also a difference in focus. While Waldman's empirical predictions come from moral hazard in maintenance, we ignore moral hazard and provide empirical implications which are solely a consequence of adverse selection. We will highlight the differences with his analysis at several points in the paper.

Laffont and Tirole (1996) study the problem of inducing the right amount of pollution and investment in pollution abatement. Despite the difference in the topic, their model has some similarity with the one that we study. They look at a two period problem where the second period private in-

[6]Because of the higher turnover, consumers who lease spend more money on average than consumers who buy. Thus, it is unlikely that lessees are those who have higher financial contracting costs.

formation is correlated with the first period private information and there is an investment in the first period. They show that the optimal mechanism involves an offer of two menus of option contracts depending on whether the agent decides to invest. In their model the allocation of pollution is not ex-post efficient, while in our model the allocation in the optimal incentive compatible mechanism is ex-post efficient. The main difference between the models is the existence of a second hand market, that is a crucial aspect of our model.

More broadly, from a technical perspective, this paper fits into the literature on multi-dimensional screening. This literature studies the properties of mechanisms in an environment where there is more than one dimension of private information of individuals. See Rochet and Stole (2000) for a survey of this literature.

3 The Model

3.1 Set-up

Consider a discrete time, infinite horizon economy. There is a unit mass of infinitely lived consumers who differ in their valuation for quality. This valuation is denoted by θ and distributed according to the cumulative distribution function F. With the exception of the example in section 7 and some of the discussion in section 6, we shall assume that F is strictly increasing and continuous on the interval $[\underline{\theta}, \overline{\theta}]$. The value of θ and consumers' trading histories are assumed to be unobservable so that trading is anonymous. A consumer of type θ who pays a (rental) price p_t for a good of quality q_t at time t obtains utility flow $\theta q_t - p_t$. All consumers demand at most one unit at any date, and have a discount factor δ.

Goods last two periods. We denote by v the quality of a new good and by w the quality of a used one. The quality of the used good is a random variable distributed between w_l and w_h according to the distribution G.[7] We assume that $w_h \leq v$ so that the used good depreciates for sure.[8]

[7] Whether v is also a random variable or not is immaterial we can think of v as the expectation of the quality of the new product.

[8] An equivalent assumption is that the quality of new goods improves over time at a constant rate.

Goods can be sold or leased. Only new goods are leased and the length of a lease is one period. There are potentially many leasing contracts. Each contract i is characterized by the rental price P_i^L and the price of keeping the good at the end of the lease (or option price) P_i^k. The price at which a new good is sold is denoted by P^n. A special case of a leasing contract is the selling contract. If the price of the option of keeping is set at zero ($P^k = 0$), the rental price P^L is in fact a selling price. All cars that are returned at the end of the lease are then sold on the used market.[9] A customer who consumes a new good at date t knows the realization of w at date $t+1$ for that unit of the good. A buyer who decides to buy a used good does not know the value of w for that good. Because of the presence of asymmetric information, the used cars that are returned by consumers who chose different contracts are different goods. The price of a used good that was leased under contract i is denoted by P_i^u.

We shall denote by y the flow of output of new goods. We focus on steady state equilibria. We will first fix the menu of leasing contracts to determine equilibrium behavior in the market. We then discuss the incentives for a manufacturer and a social planner to optimally choose output and the structure of contracts.

3.2 Discussion

We analyze the case where there is a variety of leasing contracts for two reasons. First, we must allow for the coexistence of leasing and selling contracts in order to capture the differences observed in the car market between the behavior of lessees and the behavior of buyers. In the buying/leasing case we believe it is realistic to assume that used car consumers can distinguish between the pre-owned and off-lease units. As discussed in the introduction the automotive press does highlight the differences between off-lease cars and pre-owned cars. Moreover, used car buyers can easily distinguish between the two types of used cars by checking the title of the car. The second reason is theoretical. We want to find out what allocations can be implemented through leasing contracts in order to understand

[9] Hendel and Lizzeri (1999a) show that a monopoly manufacturer may have an incentive to scrap some of the used units. We ignore this incentive to focus on the issues at hand.

their limitations. To this end, we want to allow for the richest possible menu of contracts.

We neglect the issue of moral hazard on the part of consumers. This is a potentially important phenomenon since the level of maintenance that is chosen by new car consumers may depend on the terms of the leasing contract. A lessee who is facing a high option price and therefore anticipates not exercising the option to buy at the end of the lease might take less good care of the car. We justify this neglect on three grounds. First, most cars are still under warranty by the time the lease expires. This reduces the disincentive to maintain. Second, as mentioned in the introduction, the common perception is that off-lease units are better quality cars. This is consistent with our analysis and suggests that, if there is a moral hazard problem, this is of secondary importance relative to the forces that we discuss.[10] The third reason we neglect moral hazard is that interesting phenomena arise even in a world with pure adverse selection; incorporating maintenance decisions by the consumer would add unnecessary complexity to our analysis.

Results in sections 4 and 5 describe equilibrium allocations in the market for used goods given some prices in the new good market. The characterization does not rely on any assumption on the market structure of the producers of the good. We deal with optimal behavior of the manufacturer in section 7 where we present a simple monopoly example and section 8 where we describe some features of the optimal menu of contracts under both monopoly and competition.

4 An Irrelevance Result

Before discussing adverse selection, we consider the case where there is no asymmetric information. This benchmark is useful for evaluating the impact of adverse selection on the optimal structure of leasing contracts. We show that in the absence of asymmetric information leasing affects neither the equilibrium allocation nor profits.

[10] Some readers may have an objection in the opposite direction; leasing could be a way to overcome the moral hazard problem. Manufacturers are in a better position to verify the quality of the car at the end of a lease. However, if this were true, it is not clear why manufacturer could not do this for sold cars that are traded in at dealers. In fact, some manufacturers do certify some "pre-owned cars."

If quality of the used cars is observable an allocation in the used market must specify which type consumes which quality. The function $\vartheta : [w_l, w_h] \to [\underline{\theta}, \overline{\theta}]$ specifies that a consumer of type $\vartheta(w)$ consumes a used good of quality w. Denote prices in the used market by a function $P^u : [w_l, w_h] \to \Re_+$ that describes the price of every quality of used good. Used markets must clear for every quality w.

We need to briefly describe the equilibrium under a selling contract.[11] Denote by θ_z the type such that $1 - F(\theta_z) \equiv z$. Thus, θ_z is the type such that there is a fraction z of consumers with higher valuation. In equilibrium, types in $[\underline{\theta}, \theta_{2y}]$ do not buy any cars, types in $[\theta_{2y}, \theta_y]$ buy used cars, with lower types consuming lower qualities, and types in $[\theta_y, \overline{\theta}]$ buy new cars at every date. Thus there is a hundred percent volume of trade in the used market (all used units change hands). A new good buyer at date t will be a new good buyer at all dates and therefore never holds on to a used good.

Market clearing in the used market for every quality requires that $F(\vartheta(w)) - F(\theta_{2y}) = yG(w)\ \forall w \in [w_l,\ w_h]$. Furthermore, optimal behavior by consumers implies that the function $\vartheta(\cdot)$ is increasing (higher types consume higher quality). Equilibrium prices under selling are

$$P^u(w) = \int_{w_l}^{w} \vartheta(s)ds + \theta_{2y} w_l \tag{1}$$

$$P^n = \theta_y(v - w_h) + P^u(w_h) + \delta \int_{w_l}^{w_h} P^u(w) dG(w) \tag{2}$$

The expression for $P^u(w)$ is obtained through self-selection conditions for used car consumers. The expression for P^n can be interpreted by observing that

$$P^n - P^u(w_h) = \theta_y(v - w^h) + \delta E(P^u(w))$$

Thus, the extra cost of buying a new car relative to the best available substitute (the highest quality used car) is equal to the extra quality of the new car $(v - w^h)$, evaluated by the marginal consumer of the new car θ_y, plus the expected discounted resale value of the used car $\delta E(P^u(w))$.

Denote now by $\hat{P}^L$ the *implied* rental price of a new car in a selling-only regime. By equation 2 $\hat{P}^L$ must satisfy:

$$\hat{P}^L = \theta_y(v - w_h) + P^u(w_h) \tag{3}$$

[11] For details see Hendel and Lizzeri (1999b) Section 3.2.

Suppose now that the manufacturer chooses to supply a given output y through leasing contracts instead of selling it. Under a leasing contract the manufacturer specifies a rental price P^L, and a function $P^k : [w_l, w_h] \to \Re_+$ which determines the future price of keeping a car of quality w.[12] Notice first that if the manufacturer sets $P^k(w) = P^u(w)$ then the equilibrium is the same as under selling and the rental price such that the demand for new equals y is $P^L = \hat{P}^L$ (see equation 3).

Can the manufacturer profit by setting $P^k(w)$ appropriately? The following proposition answers this question: the manufacturer's profits and the equilibrium allocation are unaffected by manipulating $P^k(\cdot)$. The only effect is that differences between $P^k(w)$ and $P^u(w)$ are capitalized into P^L.

Proposition 1 *(i) The equilibrium allocation and manufacturer profits are the same for any choice of the function P^k. Thus, leasing and selling lead to the same equilibrium allocation and profits.*

(ii) In equilibrium $P^u(w)$ satisfies equation 1 regardless of $P^k(w)$. P^L satisfies the following equation.

$$P^L = \hat{P}^L + \delta \int_{w_l}^{w_h} max\{P^u(w) - P^k(w), 0\} dG(w) \tag{4}$$

where $\hat{P}^L$ is given in equation 3 and $P^u(w)$ is given in Equation (1).

Proof:

Fix P^L as in Equation (4) and $P^u(w)$ as in Equation (1). Consider the following behavior by consumers. Consumers who were buyers of used cars of quality w under selling do the same under leasing. Consumers who purchased new cars under selling now lease new cars. Lessees always return cars of quality w such that $P^k(w) \geq P^u(w)$. If $P^k(w) < P^u(w)$, then the lessee purchases the car of quality w and immediately resells it on the used market.

With this postulated behavior by consumers, markets clear at every date. Furthermore, it is obvious that the value to consumers of pursuing such policies is the same as under selling. Thus, by

[12] Allowing for a whole menu of functions (i.e., several leasing contracts) would change nothing in the following arguments.

analogy with the case of selling, it cannot be optimal for any consumer to pursue policies that lead to any other consumption pattern than the one that has been postulated.

To obtain profits, from the previous analysis we get that in the used market the lessor sells cars of quality w at $P^u(w)$ when $P^u(w) < P^k(w)$ and at $P^k(w)$ when $P^u(w) > P^k(w)$. We thus obtain that profits for a lessor who produces y units and leases these units are:

$$\Pi = \frac{y}{1-\delta}(P^L + \delta(\int_{\{w:P^u(w)\leq P^k(w)\}} P^u(w)dG(w) + \int_{\{w:P^u(w)>P^k(w)\}} P^k(w)dG(w)))$$

Substituting into this expression P^L from equation 4 we obtain that profits are not affected by the structure of the leasing contract. *Q.E.D.*

The proposition shows that the ability of the manufacturer to manipulate the option price has no role in a world with symmetric information. The intuition for this is that, under observable quality, consumers find a way to exploit all the gains from trade. Equation 4 says that the rental price of the new good is adjusted upward from $\hat{P}^L$ to capitalize all the gains that lessees can make in the used market by keeping the car and immediately selling in the used market when $P^k < P^u$. Keeping decisions are unaffected by changing $P^k(\cdot)$: when $P^k(w) < P^u(w)$ the true cost of keeping is $P^u(w)$ and the effective price of consuming a used cars is unchanged; when $P^k(w) > P^u(w)$ consumers who did not plan to keep at P^u also do not keep at P^k, hence nobody pays a $P^k(w) > P^u(w)$. It is also clear that, given that the supply of used cars is unchanged, the equilibrium $P^u(\cdot)$ is unchanged and still satisfies equation 1. Thus, the equilibrium allocation is unchanged.

An important property of the equilibrium allocation with observable quality is that it is first best efficient. First, all types of consumers are matched with the right quality of the good. Moreover, it is easy to see that a competitive industry that produces the good at a marginal cost of c would produce the optimal quantity of the good. This is an important benchmark for our welfare results in section 6.

5 Adverse Selection

5.1 Consumer Behavior

We now assume that consumers of a new car know the quality w whereas used car buyers do not.

Let w_i^u denote consumers' beliefs about the average quality of used cars that were leased under contract i and were returned at the end of the lease. Rational consumers will always believe that $w_i^u \leq E(w)$. The average supplied quality, denoted by w_i^A, is determined by the keeping behavior of the lessees who chose contract i. In equilibrium expectations must be correct, i.e., $w_i^u = w_i^A$ for all contracts i.

Consumers take as given the following variables: $\{w_i^u, P_i^L, P_i^k, P_i^u\}_{i \in I}$.

The discounted utility of a consumer of type θ who buys a used car from leasing contract i every period is

$$V_i^u(\theta) = \frac{\theta w_i^u - P_i^u}{1-\delta}. \tag{5}$$

The determination of the utility of consumers who contemplate leasing is more complex since such consumers must decide what to do when the lease expires. They can exercise the option of keeping the used car by paying P_i^k or return the car at no cost and lease another new car. These decisions clearly depend on the private information of the consumer, namely the quality of the car w and the intensity of valuation for quality θ. It is easy to show that optimal behavior is characterized by a cut-off rule; if the quality of the car is lower than some level $x_i(\theta)$, a consumer of type θ will return the car, if the car is of higher quality the consumer will exercise the option.

We denote by $V_i^L(\theta)$ the discounted utility for a consumer who has no car, chooses to lease a new car, under contract i and then behaves optimally conditional on this choice.

$$V_i^L(\theta) = \theta v - P_i^L + \delta[G(x_i(\theta))V_i^L(\theta) + (1 - G(x_i(\theta)))(\theta E(w|w \geq x_i(\theta)) - P_i^k + \delta V_i^L(\theta))]$$

This expression has a simple interpretation. The first term ($\theta v - P_i^L$) is the flow of utility enjoyed during the lease period. In the next period there are two possible events: in the first event, the

quality of the car turns out to be below the cut-off (with probability $G(x_i(\theta))$) and the consumer starts a new lease, in which event he gets utility $V_i^L(\theta)$; in the second event, the quality is higher than the cut-off (with probability $1-G(x_i(\theta))$), and he enjoys a utility flow of $\theta E(w|w \geq x_i(\theta)) - P_i^k$, and in the next period he starts a new lease which will then yield a utility of $V_i^L(\theta)$.

To determine the value of $x_i(\theta)$, observe that the consumer must be indifferent between: (i) keeping the used good of quality $x_i(\theta)$ at a cost of P^k, and (ii) initiating a new lease right away. Option (i) yields a utility of $\theta x_i(\theta) - P_i^k + \delta V_i^L(\theta)$. Option (ii) yields a utility of $V_i^L(\theta)$. Therefore we have:

$$\theta x_i(\theta) - P_i^k = (1-\delta)V_i^L(\theta) \tag{6}$$

Proposition 2 *Given the choice of contract i, optimal behavior for consumers who lease is characterized by a continuous increasing function $x_i : [\theta_l, \theta_h] \to [w_l, w_h]$ such that a consumer of type θ keeps all used cars of quality above $x_i(\theta)$ and returns all those with quality below $x_i(\theta)$, where $x_i(\theta)$ is given by equation 6. Moreover,*

$$V_i^L(\theta) = \frac{\theta v + \delta(1-G(x_i(\theta)))(\theta E(w|w \geq x_i(\theta)) - P_i^k) - P_i^L}{1 - \delta G(x_i(\theta)) - \delta^2(1-G(x_i(\theta)))} \tag{7}$$

We omit the proof of this proposition since it can be obtained by a simple modification of the arguments in Hendel and Lizzeri (1999b), Proposition 3.

Because the cut-off function is increasing, higher types are less likely to exercise the option of keeping.[13]

We now want to determine how optimal behavior partitions the set of consumers as either (1) non-buyers, (2) buyers of used cars of type i, or (3) lessees of contract i. The next proposition describes this classification. All of the statements in the proposition are consequences of the following standard self selection result.

Lemma 3 *Suppose that consumers θ, θ' choose qualities q and q' with $q > q'$. Then $\theta > \theta'$.*

[13] If cars are sold instead of leased, equation 7 must be modified to take into account the fact that when the consumer buys the car, he does not pay anything if he decides to keep and he gets P^u if he decides to sell.

From now on we shall restrict attention to the case where $P_i^k \geq P_i^u$. This is without loss of generality since, whenever $P_i^u > P_i^k$, all lessees will exercise the option regardless of the realization of quality because there is an arbitrage opportunity. Their keeping behavior $x_i(\theta)$ would thus be determined by P_i^u. Denote by Θ_i^u the set of types who consume used cars of type i, Θ_i^n the set of types who choose to lease a new car according to contract i.

Proposition 4 *(i) Suppose that used cars of type i have higher quality than those of type j ($w_i^u > w_j^u$). Then, buyers of used cars of type i have higher valuation for quality: $\theta \in \Theta_i^u$ and $\theta' \in \Theta_j^u$ implies $\theta > \theta'$.*

(ii) Suppose that keeping a car of type i is more expensive ($P_i^k > P_j^k$). Then, consumers who choose to lease according to contract i have higher valuation for quality: $\theta \in \Theta_i^n$ and $\theta' \in \Theta_j^n$ implies $\theta > \theta'$.

(iii) New car consumers have higher valuations for quality than used car consumers: $\theta \in \Theta_i^n$ and $\theta' \in \Theta_j^u$ implies $\theta > \theta'$.

Proof: See Appendix. *Q.E.D.*

Remarks: Proposition 4 says that the set of consumers is partitioned into two classes of non overlapping intervals. In the first class are consumers with relatively low valuations. These buy used cars, with the lowest types buying used cars of low expected quality, and higher types buying used cars of higher expected quality. In the second class are consumers with relatively high valuation. These consumers are lessees, those with higher valuations choose contracts with higher option prices.

Because the environment facing a consumer is *stationary*, if a particular type of behavior is optimal for a consumer at date t it will be optimal at all future dates where the consumer faces the same choice. Thus, if contract i is best for a consumer of type θ at date t it will be optimal at all future dates.

5.2 Equilibrium

Equilibrium requires that supply equals demand in the used markets and in the new markets, and that expected quality w_i^u equals the average traded quality w_i^A for each type of car. As we explained in the introduction we still take as given the supply in the new market without specifying the market structure, we deal with optimal suppliers' behavior later. The appendix states precisely how aggregate demand, supply and average traded quality are determined from optimal individual behavior.[14] It is easy to adapt the proof in Theorem 7 of Hendel and Lizzeri (1999b) to show that an equilibrium exists.

For the case in which all units are sold, Hendel and Lizzeri (1999b, Section 4.3) showed that the volume of trade in the used market is always strictly between zero and one hundred percent. When $P^k > P^u$, keeping a used car becomes less appealing, implying that the volume of trade will always be positive in this case as well. It is clear though that P^k can be set so high as to discourage keeping altogether. Thus, under leasing we may have that the volume of trade is 100%. We will show later that this is not optimal for a manufacturer. The next Proposition compares the equilibrium properties of different leasing contracts.

Proposition 5 *Suppose that $P_i^k > P_j^k$. Then,*

(i) If any consumer chooses contract i, $P_i^L < P_j^L$.

(ii) $w_i^A > w_j^A$, and $G(x_i(\theta)) > G(x_j(\theta')) > 0$ $\forall \theta \in \Theta_i^n, \theta' \in \Theta_j^n$; average quality and volume of trade are higher for the contract with the higher option price.

Proof: Part (i) is immediate; if $P_j^L \leq P_i^L$ no consumer would choose contract i.

Part (ii) is a consequence of Proposition 2 and Proposition 4. We want to show that, if θ buys contract i and θ' buys contract j, $x_i(\theta) > x_j(\theta')$. By Proposition 4, $\theta > \theta'$. Because θ chose contract

[14]The determination of the equilibrium quantities is complicated by the need to account for the relative frequency with which different types of lessees keep their cars: as different types have different $x_i(\theta)$s. For example, if a consumer of type θ always kept the car he would lease (and consume new) only half as often as a consumer of type θ' who always returned his used car.

i, $V_i^L(\theta) \geq V_j^L(\theta)$. Thus, from equation 6, $x_i(\theta) > x_j(\theta)$. By proposition 2, $x_j(\theta) > x_j(\theta')$. Thus, $x_i(\theta) > x_j(\theta')$.

To prove that $G(x_j(\theta')) > 0 \; \forall \theta' \in \Theta_j^n$, observe that the lowest $x_j(\theta')$ can be is in the case where $P_j^k = 0$. But then contract j is a selling contract and this is an immediate consequence of the positive volume of trade result in Hendel and Lizzeri (1999b). This concludes the proof of (ii). *Q.E.D.*

5.3 Equilibrium Implications and Empirical Predictions

A special case of Proposition 5 is one where the only two options are a selling contract and a single leasing contract. The results of Proposition 5 are consistent with the observed phenomena in the used car market discussed earlier. As we discussed in the introduction, there is a common perception in the automotive press and among consumers that the average quality of "off-lease" used cars is higher. Moreover, the average age of "off-lease" used cars is much lower than the average age of non leased used cars that are sold in the used market for the first time. Thus, turnover is higher for leased cars. Proposition 5 part (ii) shows that these phenomena are consistent with equilibrium behavior in our model. Observe that the two phenomena are linked in our model: higher quality used cars go hand in hand with higher turnover in a world with adverse selection. There are two forces which contribute to the higher volume of trade of leased cars. The first is that if $P^k > P^u$, the cost of keeping a used car is higher for a leased car than for a purchased car.[15] The second is that leasing contracts attract higher types (Proposition 4 part (ii)), and these types keep less often for any contract by Proposition 2. In section 8.2 we solve for the optimal mix of selling and leasing contracts offered by a monopolist; we will see that it involves a P^k that is much higher than P^u.

For the simple case where there are only two contracts, a leasing and a selling contract, part (i) of Proposition 5 says that the rental rate P^L in the leasing contract is lower than the implicit rental rate in a selling contract. It may be puzzling that anybody would choose the selling contract if the rental rate is lower in the leasing contract. The reason some types choose to buy is that in the selling contract the price of the option of keeping is lower. In a world with adverse selection,

[15] Waldman (1999) reports that P^k is on average 14% higher than P^u.

consumers value this option because they can keep the high realizations of quality of the used car. One can then ask the opposite question: if the option is so valuable, why does anybody choose the leasing contract with the high option price? The two questions together can be rephrased to ask why neither contract dominates the other from the point of view of consumers. The reason is that different types of consumers value the option differently. High valuation consumers do not value the option very much since they are not likely to keep the car, and therefore choose the leasing contract. Low valuation consumers, on the other hand, value the option more because they are more likely to keep the car. Thus, the menu of contracts serves to segment the market since different contracts appeal to different types. We shall come back in sections 7 and 8.2 to the issue of how the pricing of the option affects equilibrium behavior of consumers and the profits of a manufacturer.

Observe that there is a natural relation between income and the valuation for quality θ since the latter can be interpreted as the marginal utility of income. This leads to another empirical implication of Proposition 4, namely that higher income individuals are more likely to lease. Notice that this contradicts the simple recipes suggested in buy vs. lease guides in the press which give the impression that leasing contracts should appeal to lower income households since they involve lower cash flows. However, Aizcorbe and Starr-McClure (1997) and Starkey (1997) report that higher income individuals are more likely to lease. Thus, these lease guides are not consistent with the data while the predictions of our model are.

6 Welfare

In this section we continue to ignore manufacturers' incentives to study what allocations can be achieved through leasing contracts and the limitations of these contracts. It turns out that leasing contracts are powerful instruments when only two types of consumers are present. In general, however, they have some serious limitations.

Proposition 6 *(i) If there are two types of consumers then the ex-post efficient allocation can be obtained through a single leasing contract.*

(ii) If there is more than one type of consumer buying used cars then the ex-post efficient allocation cannot be achieved through leasing contracts.

Proof: Part (i) is due to the fact that when there are only two types of consumers ex-post efficiency is solely an issue of volume of trade. Let θ_L and θ_H be the two types, with $\theta_L < \theta_H$. Given y, the ex-post efficient allocation requires that the high types consume the highest possible quality. Let μ be the measure of the set of high types. If $\mu \leq y$, the ex-post efficient allocation involves high types never keeping. This can be achieved by setting a very high P^k. If $\mu > y$, let x be the cut-off rule such that, if it is adopted by all high types, all high types consume new and no low type consumes new. There is a P^k that generates such keeping behavior by the high types as an optimal response. Thus, for any y it is possible to construct contracts that generate ex-post efficient allocations. It is then also possible to choose the efficient y.

To prove part (ii), denote by θ_1 and θ_2 two types of consumers such that $\theta_1 < \theta_2$ and both are used car consumers. Let w_1, w_2 denote the qualities consumed by the two types. If these qualities are the result of equilibrium with leasing contracts, we have that $w_1 = E(w|contract\ 1)$, $w_2 = E(w|contract\ 2)$ for some contracts 1 and 2 (possibly identical). The form these expected qualities take is $E(w|contract\ i) = E(w|w \leq x_i)$ for some x_i. Thus, there is an overlap in the support of the qualities consumed by the different types of consumers. This means that there is always a positive probability that low types of consumers end up consuming realizations of quality that are higher than the realizations of quality consumed by a consumer of type 2. This is a violation of ex-post efficiency. *Q.E.D.*

Waldman (1999) also shows that leasing can lead to first best allocations. Throughout his analysis of the pure adverse selection he assumes that there are only two types of consumers. Part (ii) of Proposition 6 shows that the assumption of two types is crucial; if there is more than one type of used car buyer it is impossible to achieve ex-post efficient allocations solely through leasing contracts. Leasing contracts are powerful tools in generating the "right" volume of trade in the used car market but they cannot solve the allocative distortion in the used market. This would require matching

different types of used car consumers to different quality used cars which cannot be done solely through the manipulation of option prices. Hence, leasing contracts cannot achieve the ex-post efficient allocation except in a very special case.

We now show that it is possible to achieve the first best outcome. Thus, leasing contracts are not even incentive efficient.

Proposition 7 *There exists an incentive compatible budget balanced mechanism that implements the first best allocation.*

Proof: The first best allocation is described in proposition 1. The social planner can implement this through the following mechanism. Use a leasing contract with a very high P^k so that nobody keeps and $P^L = \hat{P}^L$, from equation 3. When a consumer returns the car he must report the quality of the car. Since his utility does not depend on his report it is (weakly) incentive compatible for him to tell the truth. The allocation in the used market can be decentralized with the function $P^u(w)$ described in equation 1.

This replicates the first best allocation. Budget balance can easily be shown to hold for the optimal choice of output given a marginal cost c. This is because the revenues that are received by the social planner in the proposed mechanism are the same as the revenues in the world with observable quality. *Q.E.D.*

Remarks: (i) This result is in stark contrast with the familiar results from static adverse selection models where a mechanism with the desired properties does not exist. The contrast is due to the fact that in our model, at the time the new car consumer enters into the contract, he does not yet know the quality of the car. Thus, his payment does not depend on this information. Since the ex-post efficient allocation requires him to consume new goods every period, he should never keep the used good. Thus, extracting information about quality is not costly for the social planner.

(ii) Observe that there is a major difference between a leasing contract and the mechanism described in proposition 7. In a leasing contract there is no information transmission between the

lessee and the used car consumer beyond that inferred from equilibrium behavior. By proposition 6 the information transmitted via leasing contracts is much too coarse to lead to efficient allocations.

(iii) Proposition 7 raises the question of why this type of mechanism is not observed in reality. Clearly, the credible transmission of information is not sustainable in a world with profit motivated lessors; since $P^u(w)$ is an increasing function a lessor would have an incentive to overstate the quality of the used good.[16]

(iv) Hendel, Lizzeri, and Siniscalchi (2000) consider a related model and examine the possibility of achieving efficient outcomes with menus of leasing contracts conditional on the history of trades of a good. First best efficiency can be obtained in the limit when transactions can occur very quickly.

Suppose now that a social planner is constrained to using leasing contracts. What are the features of the best possible allocation that can be achieved with this tool? The final Proposition of this section shows an important characteristic of this allocation: a social planner that can only use leasing contracts would not want to "eliminate" the adverse selection problem, i.e., he would not want to generate full trade in the used market. Full trade is only optimal if quality can be allocated in the "right way" in the used market (as in Proposition 7).

Proposition 8 *If the social planner is constrained to using menus of leasing contracts, the allocation that maximizes consumer surplus never involves full trade in the second hand market.*

Proof: See the Appendix. *Q.E.D.*

The logic of this result is the following. As we saw in proposition 6, it is not possible to efficiently match the right used cars with the right types of consumers by only using leasing contracts. In this world, allowing some lessees to keep the high draws of the used good has good welfare consequences because it permits better matching of quality to types: it reduces the quality consumed by the lowest valuation consumers increasing the quality consumed by consumers with intermediate valuation.

[16]Moreover, notice such information is not contractible or verifiable, otherwise there would be no lemons problems to start with.

7 Leasing and Market Power: Option Pricing and Optimal Output.

We now discuss a simple example where the optimal solution for a monopoly manufacturer is particularly easy to characterize. We only present results and intuition; for details see Hendel and Lizzeri (1998). The point of the example is to show that the option of keeping the used good is mispriced in a selling contract. We explain the source of this mispricing and show how the optimal pricing of this option in a leasing contract enables the manufacturer to profitably expand output. To focus on the effects of asymmetric information we assume that the manufacturer commits to the terms of the contract.[17]

There are two types of consumers, those with low valuation $\theta_L = 1/3$ and those with high valuation $\theta_H = 1$. There is a mass of $1/2$ of each type of consumer. We also assume that the discount factor $\delta = .8$, and the quality of the new good $v = 2$, and that the distribution of quality of used goods G is uniform on $[1-s, 1+s]$ with $s \in [0,1]$. The parameter s represents the extent of asymmetric information; a low (high) s means that there is little (a lot of) uncertainty about the quality of a used car.

7.1 Selling vs. Leasing

We first fix output at $y = 1/3$, solve for the equilibrium under selling, and then solve for the optimal leasing contract. Fixing a particular y is a good starting point because the features of the solution will be very similar for all choices of y and the discussion is easier to follow for a fixed value of y. We will later obtain optimal output under both selling and leasing for the case of zero marginal cost.[18]

[17] Thus, we ignore the potential time consistency problem faced by a durable good monopolist. This would introduce an additional dimension in the differences between selling and leasing which would obscure the force that we want to highlight. Observe that when goods depreciate, the commitment outcome can be an equilibrium of the game where a monopolist cannot commit. See Bond and Samuelson (1987).

[18] An output of 1/3 would be optimal for some weakly convex cost function. However, output under leasing would be higher than under selling.

Selling The equilibrium has the following features: High types buy new cars and keep according to $x(\theta_H) = 1$, i.e. the high types keep a used car 50% of the time. A mass of 1/6 of low types buys used cars and the remaining mass of 1/3 of low types buys nothing.

It is easy to see that the market for used cars clears. As to the market for new cars, observe that, given that high types keep half the realization of used cars, at date t a mass of 1/6 of high types has a used car from the previous period and a mass of 1/3 of high types buys new. This adds up to 1/2 which is the mass of high types, hence the market clears at every date.

The average quality of used cars is $w^A = E(w|w \leq x(\theta_H)) = (1 - s + x(\theta_H))/2 = (2 - s)/2$. Setting $V^u(\theta_L) = 0$ yields $P^u = \theta_L w^A = (2 - s)/6$. At this price the low types are indifferent between buying used cars and buying nothing. Thus, it is optimal for some low types to buy used cars and some to buy nothing (in equilibrium, low types will have negative utility from buying new). The price of new cars is the one that makes the cut-off rule $x(\theta_H) = 1$ optimal given P^u. This yields $P^n = 1.6 - .1s$. Given these prices, it is easy to show that it is optimal for the high types to be new car buyers. Profits for the manufacturer are: $\Pi^S = P^n y = .53 - s/30$.

Leasing We now show that the manufacturer benefits from setting $P^k > P^u$ despite the fact that under the optimal leasing contract the equilibrium allocation is the same as under selling. The optimal contract here involves leasing only. Because there are only two types, more complicated menus serve no purpose.

We saw that, under selling, market clearing requires that P^n must be such that the high types keep according to $x(\theta_H) = 1$. An important feature of the equilibrium under selling is that $V^n(\theta_H) > V^u(\theta_H)$. Thus, high types strictly prefer buying new to buying used. In contrast, under symmetric information, prices are such that new car buyers are indifferent between the new good and the best alternative.

The reason for this wedge under adverse selection is the following: new car buyers must be indifferent between keeping a used car of quality $x(\theta_H)$ and selling it in order to buy a new car. But keeping a used car of quality $x(\theta_H)$ is strictly preferable to buying a used car of quality $w^A < x(\theta_H)$.

The cost of the option of keeping cars of quality above $x(\theta_H)$ is P^u which must equal $\theta_L w^A$ to clear the used market. This price is too low because it evaluates a *lower* quality good ($w^A < x(\theta_H)$) by a *lower* valuation consumer ($\theta_L < \theta_H$). This means that the option of keeping the used car is not fully priced for the high types. Thus, in a world with adverse selection, the competition for the new good is a used good that is priced too low. In contrast, when information is symmetric, the quality of the used good is observed in the market and therefore adequately priced. By raising the option price above the market clearing price in the used market ($P^k > P^u$) the manufacturer can better price the keeping option and extract more rents from the high valuation consumers.

The equilibrium is solved in a similar way to the one described for selling, the only difference is that now the manufacturer has two instruments (P^k and P^L) to affect keeping behavior. The following expression describes the market clearing P^L that corresponds to any given P^k, i.e., the set of (P^L, P^k) that make $x(\theta_H) = 1$.

$$P^L(P^k) = 1 + .2s + P^k \tag{8}$$

Expression 8 is remarkable; as the manufacturer increases P^k, one would expect that the rental price of the new good would have to fall to compensate for the fact that the option becomes less attractive. However, this reasoning does not take into account the fact that markets must clear. If a fall in P^L were to coincide with an increase in P^k, keeping a used car of any given quality would become less attractive relative to starting a new lease. We would then have excess demand for new cars.

Because leasing allows the manufacturer an additional tool to control keeping, P^k and P^L can be raised simultaneously until $V^L(\theta_H)$ and $V^u(\theta_H)$ are equalized. This yields $P^k = 1/3 + s/3$ and $P^L = 4/3 + .53s$. Profits for the manufacturer under this optimal leasing contract are $\Pi^L = .53 + .2s$. By comparing with profits under selling we see that $\Pi^L - \Pi^S = s/6$, which is positive for any non degenerate distribution of quality of the used good.

Profits under the optimal leasing contract increase in s, the opposite of what happened under

selling. In both cases the increase in s lowers P^u and increases the expected value of the cars kept by the high types. In the case of selling, the reduction in the used price makes keeping more appealing relative to buying, while in the case of leasing the cost of keeping is P^k, not P^u; leasing allows the manufacturer to control the pricing of the option, reducing the competitive threat that the used good poses to the new good.

7.2 The Choice of Optimal Output

So far we have restricted attention to the case where $y = 1/3$. We now derive the optimal output for different values of s under the assumption of zero marginal cost. The optimal output under leasing is $y = .5$ for all values of s while optimal output under selling depends on s; for low values of s optimal output is $y = .5$, for high values of s optimal output is $y = .25$. Thus, a monopolist who leases may produce more output than one who sells.

Selling We compute profits from selling $\Pi^S(y, s) = P^n y$. For any $s \leq .2$ profits are increasing in y until .5. Thus $y = .5$ is optimal for $s \leq .2$. $\Pi^S(.5, s) = .8 - .5s$. Since $\Pi^S(.25, s) = .7$, $y = .25$ is optimal for $s > .2$. At $s = .2$ the manufacturer is indifferent between the two values.

Let us first discuss the intuition for the fact that low output is optimal for high values of s whereas high output is optimal for low values of s. When $y = .25$, high types keep all the draws of quality of the used good and no low type buys the used good. The expected utility from keeping the used good for all realizations of quality is independent of s because the average quality is 1 for all s. Since in this case the condition that sets P^n is that the high types must have zero utility, P^n is independent of s. When $y = .5$, none of the high types keep any of the draws of the used good. For this to be optimal, from equation 6, we must have that

$$\theta_H x(\theta_H) - P^u = (1 - \delta)V^n(\theta_H) \tag{9}$$

Since market clearing requires that high types never keep, P^u is constant in s ($P^u = \theta_L E(w)$). However, $x(\theta_H) = 1 + s$ is increasing in s. Thus, the left hand side of equation 9 increases with s; as s increases, the higher types must be indifferent between buying a new car and keeping a higher

quality used car. Since the high type never keeps the used good, $(1-\delta)V^n(\theta_H) = \theta_H - P^n + \delta P^u$. Thus, for the right hand side of equation 9 to also increase with s, the price of the new good must drop. The competition from high quality used cars explains why $\Pi^s(1/2, s)$ declines in s, hence maximized at $s = 0$. To conclude, since P^n is independent of s for $y = .25$ but is declining in s for higher y's, then for low s a high output is optimal and for high s a low output is optimal.

Leasing As in the case of $y = 1/3$, by choosing P^k the manufacturer gets to price the option. In the region where $s > 0$ and $y > .25$ the manufacturer can extract rents from the high type by increasing P^k above P^u without changing the equilibrium allocation. Thus, by appropriately pricing the option, the manufacturer effectively eliminates the competition from high quality used goods. This implies that under leasing optimal output is $y = 0.5$ independent of s. Thus, leasing raises optimal output for manufacturers with high values of s and profits are $\Pi^L(0.5, s, P^{k^*}) = 0.8$, which is independent of s. These are the maximum attainable profits, which could only be achieved for $s = 0$ (no asymmetric information) under selling.

Remark: In the example that we have discussed, the gains from leasing come from the fact that under selling the utility that the high types receive from buying a new car is strictly higher than the utility they would get from buying a used car. In a world with a continuum of types there must always be a type who is indifferent between buying used and buying new. Does this mean that our example has nothing to say about a world with a continuum of types? The answer is no. In this world there are additional effects which influence the optimal pricing of the option in a leasing contract. However, something similar to what we uncovered in our two type example still exists. The identity of the marginal type depends on P^k. To see this, observe first that we could write down a continuous approximation of the two type example and the optimal solution would be very similar. Thus, the fact that the marginal type is indifferent between new and used in the continuous case does not affect the logic of our example. In a more general case the option of keeping may still be priced too low to induce the desired keeping behavior by lessees. It will no longer be possible to increase P^k and leave unchanged the equilibrium allocation because some types would stop leasing

and become used car buyers. However, this effect would be beneficial to the manufacturer because the marginal lessee would be higher.

8 Optimal Leasing Contracts

We now return to the case where the distribution of consumers valuations is strictly increasing and continuous.

8.1 Is Full Trade Optimal for Manufacturers?

It is puzzling that most leasing contracts incorporate the option of keeping the car at the expiration of the lease. After all, the very expression "adverse selection problem" suggests that leasing contracts with a prohibitive option price would benefit manufacturers because they get rid of adverse selection in the used market. If $P^k \geq \theta_y(w_h - E(w)) + \theta_{2y}E(w)$, then no lessee would ever exercise the option.

The following result shows that this reasoning is incomplete. It does not take into account the benefits of market segmentation.

Proposition 9 *The optimal menu of leasing contracts for a monopolist allows for a keeping option; not all consumers return all their cars at the expiration of the lease. This holds either if used cars consumers observe what leasing contract the used car comes from or if they do not.*

Proof: See the appendix *Q.E.D.*

The phenomenon presented in proposition 9 is due to the following force. As we saw in proposition 8, social surplus is increased by designing leasing contracts to reduce the volume of trade below 100%. The monopolist gets to capture some of this increase in surplus through a segmentation of the market. To see how this works, observe that, as P^k is reduced on one contract, some of the high quality used units are consumed by high types. While this reduces quality and the price in the used market, this reduction is more than compensated for by the fact that the option price of these units is much larger.[19]

[19]Proposition 9 does not say whether the optimal menu of leasing contracts would include selling contracts. However,

Remark The logic of the proof of proposition 9 does not depend on the assumption of a monopoly manufacturer. In fact, a subset of the proof is sufficient to show that 100% trade would never be an equilibrium under perfect competition.

8.2 Uniform Preferences: An Example

In this section we provide an example where preferences are uniformly distributed. The purpose of this section is to show the functioning of the model and to illustrate quantitatively the gains from leasing and from a mix of selling and leasing in an example with a continuous distribution of consumer valuations.[20]

By substituting the uniform distribution of quality in the expressions that define V^L and $x(\cdot)$ in Proposition 2 we get:

$$x(\theta) = 1 + \frac{P^k}{\theta} + s + \frac{2s}{\delta} - \frac{1}{\delta\theta}\sqrt{4\theta s\left(\delta\theta + \delta P^k + (1+\delta)\theta s - \delta\theta v + \delta P^L\right) + (\delta P^k)^2}$$

We assume that the support of the distribution of θ is $[0,1]$, while the support of the distribution of w is $[1-s, 1+s]$. We computed the equilibrium for $v = 2$, $\delta = 0.8$, $s = .5$ and different output levels y and keeping prices P^k. We then checked which output and keeping price maximizes profits for the lessor and compared to profits from selling. When selling the optimal output is $y = 0.31$, which leads to $P^u = 0.31$, $P^n = 1.35$, VOT (volume of trade) $= 56\%$, and profits are 0.41. When leasing the manufacturer produces almost the same output level, $y = 0.30$, but sets a $P^k = 0.65$ which leads to $P^u = 0.38$, $P^L = 1.08$, $VOT = 97\%$, and profits of 0.43.

Thus it pays for the manufacturer to set the option price above the market clearing price in the used market but below the price that would generate full trade. It is not in the manufacturer's interest to completely "solve" the adverse selection problem.

it would be very simple to obtain selling contracts being optimal if we introduced a cost for the lessor of administering leases. Alternatively, one could introduce a cost to the lessee of abiding by the lease agreement as in Waldman (1999).

[20] We computed the equilibrium by finding optimal behavior of each consumer for every set of prices and expected used quality. Then we aggregated behavior to define market demand and supply just as in the appendix. Finally we searched for the prices and quality that clear markets. We found equilibrium quantities by minimizing a norm of the excess demand function. The search was done using Matlab; codes are available upon request.

When the manufacturer leases and sells at the same time, the optimal solution is the following: $P^L = 1.083$, $P^k = 0.655$, and $P^n = 1.41$. At these prices the manufacturer leases 0.285 units with and sells 0.02 units. The volume of trade of the leased units is 97%. In contrast, the volume of trade of the sold units is only 31%. The average quality of the leased units is 30% higher than the average quality of the sold units. Prices in the used market are $P_1^u = 0.257$, $P_2^u = 0.388$; prices of off-lease cars are more than 50% higher than those of sold ones.

These numbers suggest that quantitatively important differences in the behavior of lessees and buyers can arise as the outcome of market segmentation by manufacturers in a world with adverse selection. These qualitative differences are in line with the phenomena described in the introduction, suggesting that these can be attributed to some extent to the forces discussed in this paper.

8.3 The Recent Increase in Leasing

In the context of the previous example we can address the phenomenon of the increase in leasing that has taken place in the past decade. The model predicts that the increase in leasing can be linked to an increase in durability. Durability of cars has increased in the past 15-20 years.[21] Improved durability has made used cars better substitutes for new ones.[22]

In the model durability is captured by the physical depreciation of the car, i.e., the decline in mean quality which takes place as the car ages. A slower depreciation of cars has two effects that make leasing more profitable.

(i) When cars become more durable, the used car becomes a closer substitute for the new car. Paradoxically, better durability leads to a worsening of the adverse selection problem. The reason

[21] Polk Corsp. has numerous studies reporting a dramatic increase in the longevity of cars in the last decades. Also Consumer reports.

[22] "Even among new-vehicle buyers, there has been a gradual increase in used vehicle shopping. In 1995, the number of new-vehicle buyers shopping used vehicles reached 2.4 million. The demand for nearly new vehicles will likely increase as the supply of off-lease vehicles grows. The study shows that this poses a growing threat to new vehicle sales ... The increasing consumer motivation to buy a used vehicle is a serious manufacturer issue, and may very well continue to be for at least the next decade." J.D. Power and Associates, press release October 7, 1996.

for this is simple. The steeper is depreciation, the larger the volume of trade in the used car market: high valuation consumers who typically consume new cars are less willing to hold on to used cars that are much worse than the new cars on the market thus they get rid even of the relatively good used cars, thereby reducing the adverse selection problem.

To confirm this intuition we computed the equilibrium for ratios of quality of new over average quality of the used ranging from 1.5 to 6. We found that the volume of trade in the used market increases as cars depreciate faster. The volume of trade rises from 42% to 83% as the quality ratio increases from 1.5 to 3. It reaches 94% of trade as the ratio doubles again. This shows that the impact of adverse selection increases with car durability.

Observe that the fact that the volume of trade in the used car market has increased in recent years does not contradict our explanation since observers claim that most of this increase comes from off-lease and fleet vehicles.

(ii) The second reason leasing becomes more important when durability increases is more straightforward. The allocation in the used market becomes more important since the used cars have higher quality.

To quantify the effect of the increase in durability on the gains from leasing, we compared the ratio of profits from leasing over the profits from selling for the different rates of depreciation. Table 1 presents the results. For high depreciation the gain is minimal (0.3%), while for a ratio of 1.5 the gain is about 3% of profits. The gain from leasing stems from overcoming the adverse selection problem which gets exacerbated as used cars become closer substitutes to new cars.

Our explanation is also consistent with the emergence of used car leases. This was a virtually non existent phenomenon until recently. This can be explained by the fact that the useful life of a used car was shorter and the dollar amounts involved (in terms of residual values) too small, to make it worthwhile to establish used car leases. The longer life of used cars makes such used car leases profitable. One would not expect used car leases to become as popular as new car leases however, because the size of the residual value is larger for new cars.

As is the case with many financial arrangements, it is hard to find a single factor that is responsible for the time series in automobile leasing. There are several additional potential explanations for this increase. A complementary explanation is provided by Waldman (1999) based on moral hazard in maintenance. Waldman cites Consumer Reports data showing that car reliability has improved in the last two decades. Reliability is measured by the decline in average number of complaints per car. He argues that this increase in reliability is likely to reduce the moral hazard problem thereby increasing the appeal of leasing.

Changes in tax laws also might bear some responsibility for this increase along with changes in income distribution and general economic conditions that favor consumer debt.[23]

9 Concluding Remarks

In this paper we have argued that there is an important link between adverse selection and leasing. We have shown that adverse selection may account for the higher turnover and slower price declines of off-lease vehicles relative to vehicles that were purchased. Furthermore, our model predicts that higher income individuals are more likely to lease. This is consistent with the evidence reported by Aizcorbe and Starr-McClure (1997) and Starkey (1997). We have also shown that manufacturers can gain by designing leasing contracts to segment the market and to better price the option of keeping the good.

The model provides an explanation for the recent increase in individual car leases; we show that the incentives for manufacturers to offer leasing contracts are positively related to the durability of cars. Thus, the increase in car durability that has taken place may have contributed to the rise in the popularity of leasing.

[23]For a discussion of fiscal reasons for leasing, see Aaron et al. (1987), Loewenstein and McLure (1988), Mc Lure (1988), and Sharpe and Nguyen. The 1986 tax reform repealed interest rate deductions eliminating the advantage of debt financed purchases. A micro study by Starkey (1997) reports that consumers with more debt have a higher propensity to lease. This suggests that after the tax reform leasing may have attracted former buyers who used to finance a purchase through debt.

10 Appendix

10.1 Aggregate Quantities

Let $\theta_i^1 = inf\{\theta \in \Theta_i^n\}$ and $\theta_i^2 = sup\{\theta \in \Theta_i^n\}$

The determination of the aggregate quantities is complicated by the need to account for the relative frequency with which different types of consumers are in the market. We state the formulas that can be derived by appropriate modifications of the calculations in Hendel and Lizzeri (1999b).

Proposition 10 *The quality traded in the used market is:*

$$w_i^A = \int_{\theta_i^1}^{\theta_i^2} E(w|w \leq x_i(\theta))dH_i(\theta) \tag{10}$$

Where

$$H_i(\theta) = \frac{\int_{\theta_i^1}^{\theta} \frac{G(x_i(s))}{[2-G(x_i(s))]}dF(s)}{\int_{\theta_i^1}^{\theta_i^2} \frac{G(x_i(s))}{[2-G(x_i(s))]}dF(s)}$$

denotes the distribution of consumer types who trade in the used car market at any given date.

Proposition 11 *Supply of used cars of type i is:*

$$y_{is}^u = \int_{\theta_i^1}^{\theta_i^2} \frac{G(x_i(\theta))}{[2 - G(x_i(\theta))]}dF(\theta) \tag{11}$$

Demand for used cars of type i is:

$$y_{id}^u = \mu(\Theta_i^u) \tag{12}$$

Demand in the market for new cars is:

$$y_{id}^n = \int_{\theta_i^1}^{\theta_i^2} \frac{1}{[2 - G(x_i(\theta))]}dF(\theta) \tag{13}$$

10.2 Proof of Proposition 4.

Proof: Part (i) is an immediate consequence of lemma 3.

Let us now prove part (ii). Assume that there are only two contracts, 1 and 2 with $P_1^k < P_2^k$. Suppose by way of contradiction that $\theta \in \Theta_2^n$, $\theta' \in \Theta_1^n$, and $\theta < \theta'$. Note first that $\Theta_i^n = \{\theta : V_i^L(\theta) > V_j^L(\theta), i \neq j, V_i^L(\theta) > V_h^u(\theta) > 0, \forall\, i, h\}$. Because the V functions are continuous, $V_2^L(\theta) - V_1^L(\theta)$ is

continuous. Therefore, it must be the case that for any ϵ, there exist α, β such that $\alpha \in \Theta_2^n$, $\beta \in \Theta_1^n$, and $\beta - \alpha < \epsilon$, with $\epsilon > 0$. By the continuity of $x_i(\theta)$, for α and β very close, $x_1(\alpha) \simeq x_1(\beta)$ and $x_2(\alpha) \simeq x_2(\beta)$. We can then conclude that, because $P_2^k > P_1^k$, by equation 6, $x_2(\alpha) > x_1(\beta)$. Since contract 2 is the contract chosen by type α and contract 1 is the contract chosen by type β, this implies that the actual cut-off rule given the optimal choice of contract involves type α keeping fewer realizations of the used good. But the average discounted quality consumed by a lessee who uses a cut-off rule x is

$$q(x) = \frac{v + \delta(1 - G(x))E(w|w \geq x)}{1 - \delta G(x) - \delta^2(1 - G(x))} \tag{14}$$

which is increasing in x. Since $\beta > \alpha$, an application of lemma 3 to types α and β, and qualities $q(x_1(\alpha))$ and $q(x_2(\beta))$ yields the desired contradiction.

When the number of contracts is bigger than 2 there is always a pair of contracts such that we can replicate the above exercise.

Part (iii) is again a consequence of lemma 3 plus the fact that the average discounted quality consumed by a lessee is higher than the average discounted quality consumed by a used car buyer for any i, j. To see this, observe that, because $v \geq w_h$, $q(x) > w_i^u/(1 - \delta)$, where $q(x)$ is defined in equation 14. *Q.E.D.*

10.3 Proof of Proposition 8

Proof: Suppose that the we start from an allocation with 100% trade. This implies that all types in $[\theta_{2y}, \theta_y]$ consume used goods every date and all types in $[\theta_y, \theta^h]$ consume new goods every date. Take the set of consumers with types between θ_y and $\theta_y + \epsilon$. Instead of forcing them to trade, allow them to keep the high realizations of quality of the used (this can be implemented with a leasing contract with a slightly lower option price than the one that generates no keeping). The resulting equilibrium allocation will involve some consumers with slightly lower valuation consuming new cars (types in $[\theta_y - \zeta, \theta_y)$). We thus have a transfer of quality from types in $[\theta_y, \theta_y + \epsilon)$ to types in $[\theta_y - \zeta, \theta_y)$. This is bad from the welfare perspective. However, the quality of the used good falls because types

in $[\theta_y - \zeta, \theta_y + \epsilon)$ keep some of the realizations of quality of the used good. Thus, there is also a transfer in quality from types in $[\theta_{2y}, \theta_y - \zeta)$ to types in $[\theta_y - \zeta, \theta_y)$. This transfer is good for welfare. In other words, types in $[\theta_y - \zeta, \theta_y)$ gain at the expense of types in $[\theta_y, \theta_y + \epsilon)$ and $[\theta_{2y}, \theta_y - \zeta)$. The welfare loss is negligible since types in $[\theta_y - \zeta, \theta_y)$ and types in $[\theta_y, \theta_y + \epsilon)$ are very close. The welfare gain however is substantial because types in $[\theta_y - \zeta, \theta_y)$ and those in $[\theta_{2y}, \theta_y - \zeta)$ are not close on average. Thus this type of deviation from full trade is beneficial. *Q.E.D.*

10.4 Proof of Proposition 9

Proof: Fix y. Let P^k, P^u, P^L be the equilibrium values that generate 100% trade. In equilibrium $P^u = \theta_{2y}E(w)$. The monopolist can change the contract in the following way. Keep the same y, offer one contract with $P_1^k = P^k, P_1^L = P^L$, and offer a second contract with P_2^k slightly smaller than P_1^k so that some people who lease will want to keep the used good. Observe that P_2^L is free to vary so that the market clears (recall that P_1^L is fixed). Denote by α the proportion of used cars off-lease 2 that are returned to the market, and w_2^A their mean quality. Denote by β the proportion of type-2 contracts out of all leases. There are 2 cases.

Case 1 Used car consumers cannot observe what leasing contract a used car is coming from. In this case, a used car buyer expects a quality

$$w^m = \frac{(1-\beta)E(w) + \alpha\beta w_2^A}{(1-\beta) + \alpha\beta}$$

hence the price of the used good is $P^m = \theta_{2y}w^m$. Total revenue in the used market is: $(((1-\beta) + \alpha\beta)P^m + \beta(1-\alpha)P_2^k)y$. That is, a proportion β of output is leased under contract two, among them $(1-\alpha)$ are kept at price P_2^k, while $\alpha\beta$ are returned. Overall $(1-\beta)+\alpha\beta$ are sold in the used market at P^m. Substituting P^m we get that total revenue from used units is: $R^m = y\{((1-\beta)E(w) + \alpha\beta w_2^A)\theta_{2y} + \beta(1-\alpha)P_2^k\}$.

We want to show that $R^m > y\theta_{2y}E(w)$ (total revenue under 100% trade). Dividing by y, subtracting $\theta_{2y}E(w)$ and then dividing by β on both sides we are left with:

$$\alpha w_2^A\theta_{2y} + (1-\alpha)P_2^k > E(w)\theta_{2y}$$

$E(w)$ by construction equals $\alpha w^A + (1-\alpha)w^K$, where w^K is the average quality of kept cars. After substituting in the last expression on the RHS and cancelling $\alpha w_2^A \theta_{2y}$ we are left with $P_2^k > \theta_{2y} w^{K\cdot}$. But, P_2^k can be made arbitrarily close to the price where nobody wants to keep, i.e., $P^k = \theta_y(w_h - E(w)) + \theta_{2y}E(w) > \theta_{2y}w_h > \theta_{2y}w^K$. Which ends the proof that used market revenue increases by introducing the new contract.

Moreover, by proposition 5 a second effect is also positive: $P_2^L \geq P_1^L$ since $P_1^k > P_2^k$. Hence, the introducing the second leasing contract is profitable for the manufacturer.

Case 2 Consumers observe what contracts the used cars come from. In this case used goods off different leases are priced differently. The proof of this case is similar to case (1) (see Hendel and Lizzeri (1998)). *Q.E.D.*

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Table 1

Ratio of qualities new/used	1.5	3	6
Volume of Trade	42%	83 %	94%
Extra Profits from Leasing	3%	2%	0.6%

Note: Simulation of the model in Section 8 for different depreciation rates of car quality.