The Role and Growth of New-Car Leasing: Theory and Evidence

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THEORY AND EVIDENCE

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ABSTRACT

An important change in the automobile market over the last few decades has been the substantial growth in new-car leasing. Building on recent theoretical research, we construct a model of the leasing decision in which leasing mitigates adverse selection and reduces transaction costs, but moral hazard limits its use. Also, in our model the prevalence of leasing is related to new-car reliability, so it suggests that the growth in leasing over time is at least partly due to improvements over time in new-car reliability. We use this model to derive a number of testable implications and then conduct an empirical analysis of the new-car and used-car markets to investigate whether the operation of these markets is consistent with the predictions of this theoretical approach. Our empirical results support the theoretical predictions of our model. In particular, we provide the first direct evidence that leasing mitigates adverse selection and our results also indicate that an important factor in the growth in new-car leasing has indeed been the growth in new-car reliability.
I. INTRODUCTION

One of the significant changes in the automobile market in the last few decades has been the growth in new-car leasing. In the early 1980s new-car leasing was basically non-existent in the US and this was followed by steady growth in the 1980s and 1990s reaching a peak around 2000 (CNW Marketing Research).\(^1\) As discussed below, previous arguments put forth to explain this growth do not do a good job of matching the data. This paper first builds a model of leasing that involves adverse selection, moral hazard, and transaction costs. We then use this model to explore theoretically and empirically both the role of leasing in the new-car market and why it has grown over time.

Numerous theories have been put forth for why firms lease. For example, a classic and popular theory in finance is that the decision is driven by tax considerations (see for example Myers, Dill, and Bautista (1976) and Franks and Hodges (1987)). The argument is that the tax code frequently taxes the same economic assets differently depending on whether they are owned by the users or leased, so the transaction is organized in the manner that minimizes the tax burden. Another classic theory from the industrial organization literature is that leasing solves a problem concerning limited commitment that arises in durable-goods-monopoly settings (see Coase (1972) and Bulow (1982) for early analyses of this problem). That is, because a durable-goods-monopoly seller in later periods does not internalize how its later actions affect the value of units previously sold, those later actions are frequently chosen in a manner that reduces the firm’s overall profitability. By leasing rather than selling, a firm avoids this problem.

Although these classic theories clearly explain the use of leasing in some settings, there are many settings in which these theories seem less important and, in particular, they do not seem like the correct arguments for understanding leasing in the new-car market and specifically why leasing has grown over time in that market. We discuss our reasons for saying this in detail in

\(^1\) In the 2000s in the US, the percentage of new-car transactions that were leases first fell and then rose again (see footnote 39 for a discussion). In Europe there has been a similar increase in leasing, although leasing continued to rise in Europe up to the late 2000s (Leaseurope). It is also of interest to note that lease percentages are similar in the US and Europe. For example, in the late 2000s approximately 25 percent of new cars were leased in both regions.
Section V. But briefly, the tax argument predicts growth in leasing in the US market after 1986, when US tax law became more favorable to leasing, and then a leveling off soon afterwards. The US time-series evidence, however, shows continued growth in leasing long after 1986. The limited commitment argument is also unlikely to be important for understanding new-car leasing for a variety of reasons, including insufficient market power in the new-car market to justify a monopoly explanation and that the limited commitment argument breaks down in the presence of replacement sales which are common in the automobile industry.

To better understand leasing in the new-car market and why it has grown over time we construct a theoretical model of the leasing decision that incorporates adverse selection, moral hazard, and transaction costs. In a series of papers, Hendel and Lizzeri (2002) and Johnson and Waldman (2003,2010) argue that adverse selection and moral hazard are important for understanding leasing in the automobile industry. On the one hand, the return to leasing a new car is that it reduces the adverse-selection problem in the used-car market first identified in Akerlof’s (1970) seminal analysis. The basic idea is that adverse selection means too few used cars are sold on the secondhand market, while leasing reduces the problem because appropriately setting the buyback price results in the percentage of cars returned to be close to or equal to the efficient level. On the other hand, because a leased car can be returned to the manufacturer at the end of the lease period, moral hazard causes maintenance expenditures on leased cars to be below socially-efficient levels.\(^2\) The idea that leasing can lead to moral hazard can be found in earlier papers such as Henderson and Ioannides (1983), Smith and Wakeman (1985), and Mann (1992), while empirical support for leasing leading to moral hazard can be found in Schneider’s (2010) investigation of the taxicab industry.

Another important recent perspective in the durable-goods literature is that transaction costs are important for understanding how often durable goods are sold on the secondhand

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\(^2\) The focus on moral hazard can be found in Johnson and Waldman (2003,2010). The 2010 paper also argues that moral hazard is important for purchased new cars due to asymmetric information in the secondhand market, but that is not part of the model considered here. See footnote 11 for a related discussion. Johnson and Waldman in both of their papers also argue that a second important cost of leasing is the cost to consumers of abiding by the standard restrictions found in lease contracts which is also part of the model considered here.
market and replaced. Transaction costs here refer to the time, bargaining, and search costs associated with buying and selling new and used durable units. Specifically, Gavazza (2011) considers a durable-goods model with transaction costs where these costs are assumed to be lower when units are leased rather than purchased. In his theoretical analysis, Gavazza shows that consumers that expect to trade more frequently typically choose to lease because of lower transaction costs and this, in turn, results in leased units trading more frequently. Gavazza finds support for the theory using data from the commercial aircraft industry.3

We begin by constructing a model that combines the two previously distinct approaches described above. That is, we develop a theoretical model of the automobile market characterized by adverse selection, moral hazard, and transaction costs, where following Gavazza we assume that the transaction costs associated with replacing a used car with a new car are lower for leased cars than owned cars. This model yields a number of testable implications concerning the operation of new- and used-car markets which are driven by the three main features of the model. For example, moral hazard suggests that maintenance should be lower for leased vehicles that the lessee plans on returning, while the model also predicts that model-vintages with high lease rates should show less evidence of adverse selection since in the model leasing is used to reduce the adverse-selection problem. We provide empirical tests of predictions from each of the main components of the model and in general our tests support these theoretical predictions.

There are two particular empirical findings that we would like to highlight. First, starting with Hendel and Lizzeri (2002) and Johnson and Waldman (2003), one argument concerning the leasing decision is that the leasing of new durable units can sometimes be used to reduce the degree of adverse selection in the used unit market. But as far as we know there are no prior tests of this argument. We empirically test for adverse selection in the used unit market and also whether leasing serves to reduce the degree of adverse selection as first argued in these earlier

3 Stolyarov (2002) also considers transaction costs in a durable-goods setting but does not focus on leasing.
papers. We find evidence consistent with adverse selection for cars purchased when new and that leasing reduces the problem. Also, as discussed in detail later, because we consider the possibility that leasing reduces adverse selection, our adverse selection tests are not subject to the same criticisms that have been made concerning earlier related tests of adverse selection in durable goods markets.

Second, the empirical analysis provides an explanation for the substantial growth in new-car leasing over the last few decades. Specifically, our theoretical model suggests that this growth is at least partly due to improvements in new-car reliability over this period. In our framework, the moral-hazard cost associated with leasing is smaller for more reliable new cars because maintenance is less important for these cars. Thus, as new cars have become more reliable over time, the percentage of new cars that are leased should have increased. We test this by examining whether within-car-model increases over time in the percentage of new cars that are leased correspond to increases in new-car reliability for that model. We find that car models with the largest improvements in reliability indeed had the largest increases in lease rate.

This paper contributes to a number of literatures. The first is the literature on reasons for leasing and empirical studies of leasing—in particular, in the automobile industry. As mentioned above, there are several possible rationales in addition to the ones we consider for why firms sometimes lease rather than sell their products. Our analysis indicates that, at least in the important case of new-car leasing, the evidence supports adverse selection, moral hazard, and transaction costs playing important roles. In Section V we discuss this literature in more detail.

The paper also contributes to the empirical literature on adverse selection in durable-goods markets. Early papers on the topic include Bond (1982,1984) which investigates repair rates for used pickup trucks and finds evidence of adverse selection only in the market for trucks that are over ten years old, and Genesove (1993) which finds weak evidence for adverse selection in an investigation that focuses on differences in behavior on the wholesale market between new-car and used-car dealers. More recently, Porter and Sattler (1999), Gilligan (2004), Emons and Sheldon (2009), Engers, Hartmann, and Stern (2009), and Peterson and Schneider
focus on tests of adverse selection that concern how the probability or volume of trade varies either across models or over time, where all but the first of these papers find evidence consistent with adverse selection. In terms of this literature, we conduct a number of related tests and find results consistent with adverse selection in the automobile market and with leasing reducing the problem.

II. THEORY AND TESTABLE IMPLICATIONS

This section presents a theory of leasing that combines adverse selection, moral hazard, and transaction costs. We start by presenting a model and then describe the nature of equilibrium and derive testable implications. Due to space considerations and in order to make the arguments concisely, we simplify the model in a number of ways such as having two consumer groups and two periods rather than $N$ groups and infinite periods.

A) The Model

There are two periods and two consumer groups, where group $j$, $j = 1, 2$, consists of a continuum of nonatomic consumers of mass $x_j$. In each period an individual drives either zero cars or one car, where individuals differ in their valuations per unit of car quality. Specifically, consumers in group $j$ have a valuation per unit of car quality equal to $v_j$, where $v_1 > v_2$. Given restrictions on the parameters imposed later, group-1 consumers are the individuals who purchase or lease new cars while group-2 consumers are the used-car drivers. Also, firms and all consumers are risk neutral and $\delta$ is the discount factor.

New cars can be purchased or leased for a single period, where a period-1 lease contract specifies both a lease price and a buyback price. A consumer who leases a new car in period 1 can purchase the car at the buyback price at the beginning of period 2 or return it to the

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4 Another recent paper on the topic is Adams, Hosken, and Newberry (2011) which finds no evidence of adverse selection among late-model used cars based on price depreciation patterns.
manufacturer in which case the firm sells the car on the secondhand market in period 2. Because period 2 is the last period, there is no possibility of buying back a car leased as new in period 2.

Each consumer incurs a cost of abiding by the standard restrictions found in lease contracts such as those concerning maximum mileage. Specifically, $z_i$ denotes the cost incurred by consumer $i$ in any period the consumer drives a leased car. Each consumer $i$ privately knows his or her own value for $z_i$ and the $z_i$’s are distributed within each consumer group according to the density function $h(z)$ and distribution function $H(z)$, where $h(z) > 0$ if $0 < z < Z$ and $h(z) = 0$ otherwise. Also, $Z$ is sufficiently large that new-car drivers with values for $z_i$ close to $Z$ choose to purchase rather than lease.\(^5\)

There is perfect competition in the production of cars and firms are all identical.\(^6\) There are no fixed costs of production while each firm has a constant marginal cost of production equal to $c$. When firms sell new cars, competition means the sale price equals $c$. When firms lease new cars, competition means that the contract maximizes the expected utility of the consumers who accept the contract subject to a zero-expected-profit constraint, i.e., all the surplus from such a contract accrues to the consumers entering into the contract. Following Hendel and Lizzeri (2002) and Johnson and Waldman (2003), we also assume that buyers on the secondhand market observe whether a car was purchased or leased in period 1.

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\(^5\) Standard lease contracts include various charges that translate into costs that are in addition to the standard monthly payment. These include charges for exceeding maximum mileage limits, charges for returning a vehicle prior to lease expiration, a required minimum level of insurance that can exceed the level a consumer would buy if he or she purchased the same car, and an inability to refinance to a lower interest rate which is typically allowed with car loans. Also, we introduce consumer heterogeneity concerning these costs since we believe such heterogeneity is quite realistic. For example, the costs of maximum mileage limits will vary from household to household depending on specific household characteristics such as distance from home to workplace. But note that results would be similar if we did not assume heterogeneity on this variable but instead assumed it for a different model variable such as the transaction cost associated with a consumer selling a used car on the secondhand market, which is a variable introduced below.

\(^6\) Clearly the automobile market is not perfectly competitive but oligopoly and monopolistically competitive models would be difficult to work with in terms of deriving the detailed predictions concerning lease rates, maintenance levels, and other outcome variables that we focus on. Further, we believe the automobile industry is more accurately modeled as perfectly competitive than as having multiple monopoly producers. Evidence that market power is limited, particularly in the US market which is the focus of our empirical analysis, is the low level of concentration (in 2011, seven producers in the US market had over an eight percent market share) and that profit margins for the major sellers in the US market during the last ten years were typically in the low single digits.
Consider consumer $i$ who purchases a new car in period 1. The new car is of quality $q^N$. Let $q^U$ be the car’s period-2 quality and $m$, $m = 0$ or 1, be the consumer’s period-1 maintenance choice, where $m = 1$ means the consumer performed maintenance and $m = 0$ means the consumer did not. Used car quality is given by $q^U = q$ if $m = 1$ and $q^U = q - \Delta$ if $m = 0$, where $q$ is the realization of a random variable and $\Delta$ is the amount that maintenance preserves car quality. The random variable $q$ is drawn from the distribution $F(q)$ with support $(\underline{q}, q^N)$, where $q - \Delta > 0$. We also assume that $\delta \Gamma \Delta > \kappa$, where $\kappa$ is the cost of performing maintenance. This last assumption means that investing in maintenance is efficient.

Now consider consumer $i$ who leases a new car in period 1. New-car quality is again $q^N$ while used-car quality is as before. Further, maintenance is still publicly observable, but the efficient level is not contractually enforceable due to high costs of legally challenging contract non-adherence. However, a sufficiently low maintenance level is legally contractible due to the reduced ambiguity about whether the observed maintenance level constitutes negligence. This type of minimum maintenance level is typically included in real-world lease contracts. One interpretation of our model is that $m = 0$ is this minimum maintenance level, but this maintenance level does not completely eliminate moral hazard because there is a higher maintenance level, $m = 1$, that is the efficient level.

There is a transaction cost, $\tau$, associated with selling a used car on the secondhand market when the car is pre-owned, i.e., purchased in period 1, while there is no transaction cost.

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7 Similarly, we are further implicitly assuming that, if we allowed a payment between the parties when a leased car is returned, that payment could not be made contingent in an enforceable way on whether the maintenance choice was efficient, again due to the costs of challenging contract non-adherence. Also, an alternative theoretical specification that would yield similar predictions concerning moral hazard (and identical predictions concerning other aspects of the model) is to assume that maintenance is not publicly observable for both leased and purchased new cars, each new-car driver’s maintenance choice is made prior to the individual observing used-car quality, and a subset of drivers always replace used cars because of a desire for “newness” where these consumers lease rather than purchase new cars to reduce transaction costs in the secondhand market. Similar to the results we derive in the next section, in this model there would be lower maintenance levels for leased new cars eventually returned rather than bought back, a similar relationship would not hold for purchased new cars, and maintenance would be lower for leased new cars eventually returned than for purchased new cars eventually sold.

8 We could formally model three maintenance levels (zero, a minimum maintenance level, and the efficient level) and associated costs of maintenance, but the qualitative nature of the results would be unchanged.
when the car is off-lease, i.e., leased in period 1. Without loss of generality, we assume this transaction cost is borne by the seller. We also assume $\tau < v_2(q - \Delta)$ which states that the transaction cost is sufficiently small that it is always better to sell a used car on the secondhand market rather than scrap the car. Note that the assumption that there is a higher transaction cost for selling a used car on the secondhand market that is pre-owned rather than off-lease follows Gavazza (2011) and is consistent with the existence of economies of scale associated with selling a used car on the secondhand market. That is, if there are such economies of scale, then a firm that leases new cars and sells multiple used cars on the secondhand market should have a lower per car transaction cost associated with selling its used cars than would a consumer who purchased a single new car and subsequently sells that single car on the secondhand market.\footnote{Results would be similar if we assumed a strictly positive but lower transaction cost associated with leasing.}

The timing of moves in the game is as follows. In period 1 there are three stages. First, at the beginning of period 1 each firm announces a new-car price, and when leasing is an option each firm also announces a lease price and a buyback price. Second, consumers make first-period purchasing and leasing decisions. Third, each consumer with a new car then privately observes the car’s value for $q$ and then chooses a maintenance level.

Period 2 is characterized by four stages. First, each consumer who leased a new car in period 1 either returns the car or purchases it at the buyback price. If the car is returned, then the manufacturer sells the car at the end of the period on the secondhand market at the price $p^{LU}$. Second, firms announce new-car purchase prices (because period 2 is the last period there is no return to leasing in period 2, so due to the leasing cost $z$, no cars are leased in period 2). Third, consumers make purchasing and leasing decisions. Fourth, both firms and consumers have the option of selling cars on a secondhand market where prices equate supply and demand.\footnote{One might argue that in the real world a consumer who trades-in a used car avoids the higher transaction costs. But in real-world markets the trade-in price is approximately eight percent lower on average than the private-sale price (CNW Marketing Research), so many new-car purchasers choose to bear the high transaction costs of selling on the secondhand market. Further, buying a new car and trading-in a used car is associated with significantly more haggling than is leasing a new car and returning it at lease expiration (CNW Marketing Research).}
We focus on Perfect Bayesian Equilibria, where we ignore equilibria in which firms offer terms that are not accepted. Also, because the maintenance decisions of new-car drivers are observable, consumers in the secondhand market revise their beliefs about which types of used cars are being traded based on these maintenance choices. We focus on equilibria in which new-car drivers always invest in maintenance which seems natural given these maintenance choices are publicly observable and investing in maintenance is always efficient. In the proof of Proposition 1, we show that there are beliefs that ensure such drivers indeed always choose \( m = 1 \) in equilibrium. Also, when there are multiple equilibria we focus on the one with the highest level of trade for pre-owned used cars.

B) Equilibrium With and Without Leasing

This subsection describes equilibrium with and without leasing. But first, to simplify the discussion we impose some restrictions. First, we assume
\[
\nu_1 q^N - c + \nu_2 (q - \Delta) + \delta^{-1} \kappa > \nu_1 q.
\]
This assumption ensures that the optimal leasing contract involves some cars not being bought back. Second, \( \nu_2 q^N - c + \delta \nu_2 E(q) - \kappa < 0 \). This assumption ensures that group-2 consumers never buy or lease new cars. Third, we assume \( x_2 > x_1 \) which ensures that secondhand market prices are strictly positive. Fourth, we assume that some leasing occurs in equilibrium. A condition that ensures this is \( \tau \) is sufficiently large.

Suppose leasing is not an option. First, every group-1 consumer purchases a new car in period 1 and maintains the car, while group-2 consumers do not drive cars in period 1. Second, in period 2 group-1 consumers who own used cars where \( q^U \) is high drive the cars while group-1 consumers who own used cars where \( q^U \) is low sell them to group-2 consumers and buy new cars. Also, the overall volume of trade is below the socially efficient level.

Note that the inefficiency in the volume of trade is due to adverse selection. The logic is the same as in Akerlof’s classic analysis. Because of asymmetric information, the price a used car sells for on the secondhand market is not a function of the realization of \( q^U \). As a result, at
the beginning of period 2, group-1 consumers who own higher quality used cars face a price that does not reflect the car’s actual quality, so fewer cars are traded than is socially efficient.

Now suppose firms can both sell and lease. In this case there is a mix of selling and leasing where group-1 consumers with low values for $z_i$ choose to lease new cars in period 1 while those with high values choose to purchase. For consumers who purchase new cars, behavior in equilibrium is the same as described above. That is, there is an adverse-selection inefficiency, but note that purchasing a new car avoids the leasing cost which is why it is chosen when $z_i$ is high.

Now consider group-1 consumers who lease. For these consumers adverse selection is reduced because the buyback price is chosen in a manner that increases the probability the car is returned at lease expiration. This probability is also increased because of the reduced transaction costs associated with leasing. But because consumers receive no return to maintenance when a leased car is returned, there is a moral-hazard problem which means leased cars that are returned are not maintained. In addition, when a group-1 consumer leases in period 1 the consumer bears the leasing cost which is why leasing is chosen only when $z_i$ is small.

C) Testable Predictions

Here we present and discuss testable predictions of the model. We begin with predictions that follow from the moral-hazard component of the model. See the Appendix for formal proofs.

Proposition 1: In period 1 the maintenance level for leased cars that are subsequently kept in period 2 (buybacks) is strictly higher than the maintenance level for leased cars that are subsequently returned. Also, in period 1 the maintenance level for purchased cars that are subsequently sold on the secondhand market in period 2 is strictly higher than the maintenance level for leased cars that are subsequently returned.
Higher used-car quality does not benefit a new-car driver who leases the car and then returns it. Hence, when a consumer in period 1 with a leased car anticipates returning it at lease expiration, the driver does not maintain the car (or under the interpretation $m = 0$ is the minimum maintenance level specified in the lease contract, the driver chooses this minimum maintenance level). So maintenance in period 1 is lower for leased cars that are subsequently returned in period 2 than for leased cars that are subsequently kept in period 2. Similarly, moral hazard lowers the period-1 maintenance level for leased cars that are subsequently returned in period 2 while there is no similar moral-hazard problem for cars purchased in period 1 that are subsequently sold on the secondhand market.\footnote{We assume that maintenance choices are observable but not verifiable, which is why there is a moral-hazard problem for leased cars in period 1 that are subsequently returned in period 2 but not for cars purchased in period 1 that are subsequently sold on the secondhand market. An alternative approach explored theoretically in Johnson and Waldman (2010) is that maintenance choices are neither observable nor verifiable in which case there would also be a moral-hazard problem for cars purchased in period 1 that are subsequently sold on the secondhand market. In empirical tests not reported here we considered the possibility of moral hazard for cars purchased when new that are subsequently sold on the secondhand market and found no evidence for this.} As a result, maintenance levels are lower in the former case relative to the latter.

The next proposition concerns how equilibrium varies with a change in $\Delta$, i.e., a change in the amount used-car quality increases due to maintenance. As discussed below, this proposition is central for our explanation for why new-car leasing has grown over time.

*Proposition 2*: Holding all else fixed, a decrease in $\Delta$ increases the proportion of group-1 consumers who lease rather than purchase new cars in period 1.

In our model the cost of moral hazard is the reduced quality of used cars when maintenance is not performed. So a reduction of $\Delta$ means that the moral-hazard problem associated with leasing is smaller and the result is an increase in the proportion of consumers who lease.

Note that we interpret a decrease in $\Delta$ as an increase in new-car reliability. The idea is that one of the roles of maintenance is to identify and address problems that arise with the car,
some of which might not be observable in the absence of maintaining the car. If the new-car defect rate, which is our measure of reliability in later sections, falls, then there are fewer problems to discover and address through maintenance. This reduces the cost, in terms of the effect on future car quality, of the lower maintenance.

As mentioned briefly in the Introduction, this feature of the equilibrium provides a possible explanation for the substantial growth in new-car leasing over time. Consumer Reports (2003, 2005), based on its own survey data, reports a significant increase in new-car reliability during the same time period in which new-car leasing grew. According to Proposition 2, such an increase in reliability reduces the moral-hazard cost associated with leasing a new vehicle and should thus increase the percentage of new cars that are leased. In Section IV we empirically investigate this explanation for the growth over time in new-car leasing.

We now turn to predictions that follow from adverse selection.

**Proposition 3:** Restricting attention to used cars in period 2 that are pre-owned, used cars purchased on the secondhand market in period 2 are lower quality, on average, than continuously-held used cars.

Asymmetric information means the secondhand-market price for a used car does not reflect the car’s actual quality. As a result, just as initially modeled in Akerlof’s paper, at the beginning of period 2, used-car owners with high quality used cars keep and drive their used cars while used-car owners with low quality used cars sell them. So, if we restrict attention to cars purchased rather than leased in period 1, the average quality of cars purchased on the secondhand market should be below the average quality of continuously held used cars. Note that this is the

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12 Note that Johnson and Waldman (2010) consider a related theoretical model in which increases in new-car reliability can increase the proportion of new-car transactions that are leases. The main difference between the models is that in the earlier paper maintenance is neither observable nor verifiable while here it is assumed that it is observable but not verifiable. As a result, in the earlier paper there is moral hazard for leased new cars and for purchased new cars which is inconsistent with the evidence (see footnote 11). Also, in the earlier paper increased reliability increases leasing only given additional restrictions that are not required to to derive the result here.
same prediction investigated in many earlier tests of adverse selection such as Bond (1982,1984).13

Our next result, which follows from both adverse selection and transaction costs, concerns the probability a used car is sold on the secondhand market.

Proposition 4: At the beginning of period 2, the probability an off-lease used car is returned and then sold on the secondhand market is greater than the probability a pre-owned used car is sold on the secondhand market.

One role of leasing is to reduce or avoid adverse selection. The logic is that, when a new car is leased rather than sold, adverse selection is reduced because the lessee sets the buyback price in a manner that increases the probability of trade. Further, this logic is reinforced by the transaction-cost component of the model. That is, since the transaction cost associated with secondhand-market trade is lower for cars returned at lease expiration, holding all else fixed, the incentive for a group-1 consumer to purchase a new car in period 2 and dispose of his or her used car is higher when that car was leased rather than purchased in period 1.

Our final prediction follows strictly from the transaction-cost component of the model.

Proposition 5: Consider any two values for \( v_1, v_1', v_1'' \), \( v_1'' > v_1' \). If \( \tau \) is sufficiently large and \( v_1' \) is sufficiently small, then a higher proportion of consumers of type \( v_1'' \) lease than consumers of type \( v_1' \).1415

13 The result can also hold in the absence of asymmetric information because of efficient sorting of new and used cars among drivers with heterogeneous valuations on quality. We discuss this issue in detail in Section IV.
14 We also restrict \( \tau \) not to be so large or \( v_1' \) so small that any of our earlier parameter restrictions is violated. Typically, it is possible in our model to make \( \tau \) sufficiently large and \( v_1' \) sufficiently small that the proportion leasing is higher when \( v_1 = v_1'' \) rather than \( v_1' \) and no earlier restriction is violated.
15 Johnson and Waldman (2010) derive a similar prediction without assuming transaction costs but rather assuming there is a moral-hazard problem for cars purchased when new. As discussed in footnote 11, however, our data do not support a moral-hazard problem for cars purchased in period 1.
When $v_1$ is high the benefit to a group-1 consumer of driving a higher quality new car in period 2 and disposing of his or her used car is higher and therefore so is the probability these events occur. We also know leasing reduces the transaction costs associated with secondhand-market trade. This suggests that leasing should rise with $v_1$ since there is a larger return to reducing the costs of secondhand-market trade when the probability of secondhand-market trade is higher. Proposition 5 shows that, if the reduction in transaction costs associated with leasing is sufficiently large, then indeed this reduced transaction cost causes leasing to be positively related to the size of $v_1$.$^{16}$

III. DATA DESCRIPTION AND EMPIRICAL TESTS OF MORAL HAZARD AND ADVERSE SELECTION

In this section we provide tests focused on whether each of two of the core components of our model – moral hazard and adverse selection – is an important factor in the market. We start by describing the data we use in our empirical tests.

A) The Data

Our tests employ US data. Much of the data come from the interview portion of the Consumer Expenditure Survey (CES), which is a rolling panel data set in which households enter and exit every five quarters, from the years 1991 through 2006.$^{17}$ The unit of observation in most tests is a vehicle in a specific quarter. The CES data do not identify specifically which leased cars are bought back. We manually identify a leased car as being bought back when a

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$^{16}$ The reason that Proposition 5 cannot be guaranteed to hold without an additional restriction beyond transaction costs being large is that an increase in $v_1$ generally has two effects on the relative attractiveness of leasing versus buying. First, higher $v_1$ means fewer cars will be kept and hence more transaction costs avoided. Second, fewer cars kept also means the adverse-selection problem associated with purchasing becomes less pronounced, and because one benefit of leasing is that it partially resolves the adverse-selection problem, this second effect tends to lower the relative attractiveness of leasing.

$^{17}$ Specifically, we use data from the Consumer Unit Characteristics and Income file (the FMLY file) and various Detailed Expenditure files (the LSD, OVB, OVC, VEQ, and VOT files). Pre-1991 surveys contain far less information about vehicle leasing and hence cannot be used. Up to four quarters of car expenditure data are available per household, with an average of 2.6 quarters of data per household due to non-responses.
household has a leased car in one quarter and a car with the same characteristics (including similar odometer reading) appears as a used purchase in the subsequent quarter.

The CES data do not identify specifically which cars received the recorded maintenance and repairs, but only whether the expenditure was for a car or truck. We thus restrict the sample for our repair and maintenance analyses to vehicle-quarters where the household had only one car and/or one truck, which allows us to match expenditures to individual cars or trucks. This restriction excludes approximately 23 percent of households and 50 percent of vehicle-quarters. We also exclude cars driven less than 588 miles per year or more than 35,000 miles per year (the bottom and top one percent) to limit the influence of outliers. For the maintenance and repair regression models, we exclude data points in which the car was purchased or disposed during the quarter to avoid the problem that less than a full quarter of information is available for these data points. Note that below we use the term “car” to refer to both cars and trucks.

Many of our tests employ the fraction of new-car transactions (sales or leases) that are leased vehicles. We have data on this variable for the US as a whole for most models and vintages between 1996 and 2000. The data are from CNW Marketing Research and are based on insurance company records and vehicle registration data from Departments of Motor Vehicles.

We also employ a reliability variable for some tests. We constructed this variable from data reported in the 1996 to 2004 issues of Consumer Reports. The magazine surveys its readers on their experiences with their new cars and reports defect probabilities across 13 parts, such as

18 If, for example, the household has one car and two trucks, then only the car is included because we do not know how maintenance expenditures are divided across the two trucks. Also, we do not exclude observations where the household had more than one car and/or one truck in the tests that do not use maintenance or repair data.

19 The fraction of excluded vehicle-quarters is larger than the fraction of excluded households because the restriction tends to exclude cars from households with many cars. Also, before 1996, the data only identify that the household disposed of a car but not which car was disposed. For these years, we identify the disposed car by matching the disposal identifier to a car that appears in the data in one quarter but not the subsequent quarter.

20 We additionally exclude cars that are used for business purposes since the driver may not pay for maintenance and repairs. We also exclude cars received as a gift or purchased for someone outside of the household, or that were disposed of through a gift, through a car accident, or theft. We additionally exclude from the maintenance and repair analyses cars where a household reports an expenditure on a car service policy, and cars of nameplates and vintages with free maintenance warranties. Cars with odometer records that are missing or erroneous are excluded. This excludes approximately 18 percent of cars. For purchased or leased cars, car age equals the difference between the survey interview month and the car-acquisition month (for leased cars, the acquisition month is inferred from the month of the first lease payment, while for purchased cars, the acquisition month is reported directly).
engine and transmission. As our reliability measure, we use the fraction of vehicles of a model, vintage, and age that have at least one serious problem in a year, so a higher number reflects worse reliability.\textsuperscript{21} Until 2005, \textit{Consumer Reports} reported defect probability for a model, vintage, age, and repair category as being in one of five specified probability ranges and we use the midpoint of the reported range as our measure of the defect probability.\textsuperscript{22} Also, for each CES interview quarter we assign reliability values using data from the closest-in-calendar-time \textit{Consumer Reports} survey (each \textit{Consumer Reports} survey period starts on April 1 two years before the magazine publication date and ends March 31 the year before the publication date).\textsuperscript{23}

We construct a maintenance indicator variable from the CES data that is equal to one when there is an expenditure on an alignment, oil change, or tune-up occurring during the quarter, where oil changes represent the most common type of maintenance, and zero otherwise.\textsuperscript{24} We also construct a repair indicator variable from the CES data. We would like our CES repair indicator variable to be consistent with the \textit{Consumer Reports} reliability measure which asks respondents to report car problems “deemed serious on account of cost, failure, compromised safety, or downtime.” Towards that end, we construct our CES indicator variable to reflect repairs that we expect drivers to consider as serious reliability issues. These are repairs above one hundred dollars (in 2008 dollars) in CES repair categories that are due to car

\[ R_{it} = \sum_{j=1}^{13} p_{ij} - \sum_{j<k}^{13} p_{ij}p_{ik} + \sum_{j<k<l}^{13} p_{ij}p_{ik}p_{il} - \sum_{j<k<l<m}^{13} p_{ij}p_{ik}p_{il}p_{im} + \ldots + \prod_{j=1}^{13} p_{ij} \]

where \( p_{ij} \) is the probability that model-vintage-age \( i \) in year \( t \) has a defect in part \( j \). Note that this formula is just the general addition rule of probability (applied to independent events). The measure is calculated in this way to match the dependent variable in Table 4, which is an indicator for whether the CES respondent had at least one repair in that quarter.

\textsuperscript{22} Starting in 2005, \textit{Consumer Reports} changed its reliability ratings such that each category no longer corresponds to a pre-defined probability range.

\textsuperscript{23} \textit{Consumer Reports} data were previously used by Desai and Purohit (1999) to construct a reliability measure.

\textsuperscript{24} Do-it-yourself maintenance is excluded from our measure, but results are similar when we include household expenditures on vehicle fluids, including oil not purchased from a service provider. Because there are many potential problems with this measure of do-it-yourself maintenance, we do not include it in our reported results.
malfunctions rather than to accidents, routine maintenance, or discretionary types of repair.\footnote{25} See Table 1 for descriptive statistics for the variables used in this study.\footnote{26}

B) Tests of Moral Hazard and Adverse Selection

In this section we provide tests for the presence of moral hazard and adverse selection which are basic building blocks of our theoretical model. We begin with moral hazard and, in particular, the first test captured in \textit{Proposition 1}. That is, focusing on leased new cars, maintenance should be higher for those subsequently kept at lease expiration than for those subsequently returned. To investigate this prediction we look at leased cars and test whether maintenance frequency is negatively related to whether the car was returned during the sample period. Further, we restrict this test to cars up to five years old – most cars coming off lease are five years old or less.

In our linear probability model, the dependent variable is an indicator for whether there were positive maintenance expenditures during the quarter.\footnote{27} The regressor of interest is an indicator for whether the car was returned during the sample period, where the omitted category for lease type is buyback. Control variables include mileage, vehicle age, and household income.

\footnote{25} Included CES repair categories are “Air Conditioning,” “Battery Purchases and Installation,” “Brake Work,” “Engine Cooling System Work,” “Electrical System Work,” “Engine Repair or Replacement,” “Steering or Front End Work,” and “Clutch or Transmission Work.” Excluded categories are those a \textit{Consumer Reports} respondent would typically not consider a serious reliability issue. These categories are maintenance (“Oil Change, Lubrication, and Oil Filter,” “Motor Tune-up,” and “Front End Alignment, Wheel Balancing, and Wheel Rotation”), “Bodywork and Painting,” which includes various items not related to reliability such as crash repairs, window replacement, and rust proofing, “Other Vehicle Services, Parts and Equipment,” which includes items such as hub caps, tire pressure gauges, jacks and windshield wipers, “Tire Purchases and Mounting” and “Tire Repairs,” “Video Equipment and Installation,” “Audio Equipment and Installation,” “Vehicle Accessories and Customizing,” and “Vehicle Cleaning and Cleaning Supplies.”

\footnote{26} In the table, note that the low value of 0.06 for the fraction of “cars obtained new by lease” reflects that the sample period includes vintages both before and after leasing became popular, that leased cars turn over more frequently than owned cars and hence are in the sample for fewer quarters on average, and that the summary statistics are unweighted (as opposed to the lease fraction statistics in Tables 5 and 6).

\footnote{27} A linear probability model provides unbiased and consistent estimates of coefficients in binary response models, and we correct the standard errors for heteroskedasticity. For ease of interpretation, especially with respect to the models with fixed effects (the fixed-effects probit model is inconsistent for fixed number of groups but increasing number of observations, while the fixed-effects logit model is consistent but does not allow for simple-to-interpret marginal effects), we only report results from linear probability models throughout when the dependent variable is binary response. Also, we have run all of our maintenance and repair regressions using expenditures rather than a binary indicator variable and results are qualitatively unchanged, although statistical significance is generally lower.
Results are reported in Table 2. Column 1 reports results given no fixed effects, while columns 2 and 3 add model-vintage fixed effects. Further, in column 3 we distinguish between cars returned in the next quarter versus two to four quarters in the future. All three regressions are consistent with a strong moral-hazard problem. In each regression the coefficient (or coefficients) on the lease return variable is negative and statistically significant at the ten percent level or better, where three of the four relevant coefficients are significant at the one percent level. Another prediction is that the coefficient on the lease continuously held variable should be negative but closer to zero than the coefficient on the lease return variable since leased cars continuously held during the sample period are a mix of cars that are eventually bought back and cars eventually returned. In each of the three regressions, consistent with this prediction, the coefficient on the lease continuously held variable is negative but closer to zero than the coefficient on the lease return variable.28-29

Columns 4 and 5 of Table 2 provide two robustness checks. Column 4 adds as an explanatory variable the consumer’s per day expenditure on gas in the prior quarter. This controls for the possibility that the car’s recent usage simultaneously predicts both the maintenance and the disposal decision. In column 5 we add as an explanatory variable the consumer’s expenditure on maintenance in the prior quarter. This controls for the possibility that car owners shift the timing of maintenance in response to planning to sell their cars. In each case there is no change in the qualitative nature of the results.

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28 Table 2 also exhibits what might best be described as a negative income effect, i.e., the probability of a positive maintenance expenditure is lower for the highest income levels. We suspect this result arises because the lease return and continuously held variables do not completely control for the probability a car will be returned at lease expiration. In other words, moral hazard concerning leasing suggests that maintenance should be negatively related to the probability a car will be returned at lease expiration, so explanatory variables positively related to this probability are predicted to have negative coefficients in our Table 2 test. One such variable is the lease return variable, which is the focus of the table. But, consistent with the discussion that accompanies Proposition 5, the highest income levels may also be associated with higher probabilities of lease return in which case they are also predicted to have negative coefficients in the Table 2 test. Note that we have investigated the sample analyzed in Table 2 and the probability of return for those leasing is indeed positively related to the income level.

29 One might argue that there should be a similar prediction concerning repairs in addition to maintenance, but this is incorrect. Lessees required to do significant repairs could decide to return or sell their cars because the repairs do not completely resolve the problem, so it is unclear what moral hazard predicts concerning the correlation between repairs and whether the car is eventually returned.
Next we consider the second part of Proposition 1 which is that maintenance levels should be lower for leased new cars that are subsequently returned than for purchased new cars that are subsequently sold on the secondhand market. In Table 3 we investigate this prediction by looking at a sample that consists of cars up to five years old that were either leased when new and returned during the sample period or purchased when new and sold or traded-in during the sample period. The dependent variable is an indicator for a positive maintenance expenditure during the quarter, while the regressor of interest is an indicator for whether the car was owned and then disposed during the sample period (where the omitted category is leased and returned).

Results are reported in columns 1 and 2, where column 1 does not include fixed effects and column 2 includes model-vintage fixed effects. In each column the coefficient on the own disposed variable is positive and in column 1 this coefficient is also statistically significant at the five percent level. These results are consistent with a moral-hazard problem for leased new cars and no moral-hazard problem for purchased new cars.

We now turn to adverse selection. The basic adverse selection prediction is that used cars purchased on the secondhand market should be lower quality on average than similar cars that are continuously held. To test whether this is the case we use a linear probability model to compare repair rates across these two types of cars.\(^{30}\)

The unit of observation is a vehicle-quarter and the dependent variable is an indicator for whether the vehicle received at least one hundred dollars in repairs that quarter. We control for car age, mileage, consumer income, and reliability for cars of that age, model, and vintage. Because the prediction concerns comparing used cars purchased on the secondhand market with similar cars continuously held, in conducting this test we would like to control for the average repair rate for each car’s specific model-vintage-age in the overall population. The explanatory variables of interest in the column 2 regression of Table 4, however, are based on model-vintage.

\(^{30}\) Though not part of our model, one may wonder if used-car buyers conduct fewer repairs conditional on the presence of a defect relative to the repairs conducted by new-car buyers. If so, a finding that used cars purchased on the secondhand market have the same repair rate as used cars continuously held would be inconclusive about adverse selection. Regardless, a higher repair rate for used cars purchased on the secondhand market would be evidence in favor of adverse selection.
lease fractions, which do not vary within model-vintage or model-vintage-age and hence preclude us from including model-vintage or model-vintage-age fixed effects. Instead, we control for this average repair rate by including the Consumer Reports reliability or defect measure for each car’s model-vintage-age.\textsuperscript{31}

Results are reported in the first column of Table 4. In this test we look at all used cars seven years old or less (seven years old is the highest age for which reliability data are available) where we exclude cars purchased when they were greater than zero but less than one year old because it is unclear whether these cars should be classified as new or used (though including these cars in either category does not affect the results meaningfully). Here we find no support for adverse selection, i.e., the coefficient on the purchased used variable is approximately zero. Note, however, that it is possible that there is adverse selection for this sample of cars but the test is biased against finding evidence in favor of adverse selection. Specifically, consistent with the discussion in footnote 30, our test may be biased because used-car buyers have lower valuations for quality than new-car buyers who hold onto their used cars, so used-car buyers may be less likely to perform repairs when problems arise.

In summary, two standard theoretical predictions concerning durable goods markets are that leasing is associated with a moral-hazard problem and that the possibility of secondhand market trade will result in an adverse-selection problem. Our empirical analysis in this section provides clear support for the moral-hazard prediction but no evidence of an adverse-selection problem.

IV. THE RETURNS AND GROWTH OF LEASING

In the previous section we showed that leasing in the new-car market results in a moral-hazard problem so the obvious next question is why is a substantial proportion of new cars leased? Building on earlier analyses such as Hendel and Lizzeri (2002), Johnson and Waldman

\textsuperscript{31} Results are similar when we use model-vintage fixed effects instead of reliability in the column 1 specification.
(2003,2010), and Gavazza (2011), our theoretical model suggests two reasons – leasing reduces adverse selection and reduces transaction costs. In this section we first investigate these issues and then turn to an analysis of why leasing has grown.

A) Returns to Leasing

In the previous section we found no evidence of adverse selection focusing on a sample of used cars that include both pre-owned used cars and off-lease used cars. But, as captured in Proposition 4, our theoretical model predicts that leasing reduces the adverse-selection problem. With this in mind, in column 2 of Table 4 we rerun the column 1 test but interact the purchased used variable with indicator variables capturing different intervals for the model-vintage lease fraction. If there is adverse selection for pre-owned used cars and leasing substantially reduces it, then the coefficient on the purchased used variable should be positive when it is interacted with the indicator variable for the lowest model-vintage lease-fraction interval, while the relationship should be weaker when the interaction is with the indicator variables for the other model-vintage lease-fraction intervals. The results are consistent with the prediction. That is, the coefficient on the purchased-used variable interacted with the indicator variable for the lowest model-vintage lease fraction interval is positive and statistically significant at the five percent level, while the coefficients on the other purchased-used variables are statistically insignificant. In other words, our results are consistent with adverse selection in the absence of leasing and leasing reducing the adverse-selection problem.

Concerning the results found in the second column of Table 4, since for the high lease-fraction intervals it is still the case that many new cars are purchased, it would seem that on average there should be adverse selection for cars in those categories. But the table indicates no evidence of adverse selection except for cars in the lowest lease-fraction interval. One factor that

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32 In our model whether secondhand market quality rises with leasing depends on the relative sizes of a positive effect due to reduced adverse selection, a positive effect due to reduced transaction costs, and a negative effect due to the introduction of moral hazard. In the model the net effect can be positive or negative depending on the parameterization.
may help explain this result is that, even for moderate lease-fractions, more used cars in our sample (cars of ages 1 through 7) are likely off-lease cars rather than pre-owned. This is consistent with Figure 1 below that shows that off-lease used cars turn over much more frequently than pre-owned used cars. Also, consistent with an earlier discussion, used-car buyers may be less likely to perform repairs than the owners of continuously held used cars, which suggests that our results may be biased against finding an adverse-selection problem.\footnote{Another possibility not captured in our theoretical analysis that might contribute to this result is that when leased cars are returned, repairs of observable problems are made before the cars are sold on the secondhand market.}

A related question of interest is whether used cars purchased on the secondhand market that are off-lease are higher or lower quality than secondhand market used cars that are pre-owned. We cannot test this directly because we do not know whether any specific used car is off-lease. However, the results in column 2 of Table 4 suggest that the off-lease cars are higher quality. The logic is that the coefficient on the purchased-used variable interacted with the indicator variable for the lowest model-vintage lease fraction interval is positive and statistically significant. This suggests that secondhand market used cars that are pre-owned are lower quality. So, since the coefficients on the other interaction variables are small and insignificant, this is likely because the off-lease used cars in these categories are higher quality than the secondhand market used cars that are pre-owned. Note that this finding is consistent with a discussion in Hendel and Lizzeri (2002) where they suggest that the benefits to leasing of reducing adverse selection outweigh the costs to leasing associated with moral hazard (see footnote 32 for a related discussion).

Note that our tests for adverse selection above are based on the classic prediction first investigated in Bond (1982,1984) that used car owners should sell lower quality used cars, so used cars purchased on the secondhand market should on average be lower quality than similar used cars continuously held. One drawback of this approach to testing for adverse selection is that, even with full information, efficient sorting of new and used cars to heterogeneous drivers can result in lower quality used cars being the cars traded on the secondhand market.
But it is of interest to note that this efficient sorting argument does not explain our findings in Table 4. If there is no adverse selection in the used-car market, then obviously leasing cannot reduce adverse selection. So, in the absence of adverse selection, it is not clear why in Table 4, for car models with the lowest lease fractions, repair rates are higher for used cars purchased on the secondhand market rather than continuously held, while this relationship does not hold for other car models. In other words, although Bond’s basic test does not distinguish between efficient sorting and adverse selection, our enhanced test which includes the additional prediction that leasing reduces adverse selection does distinguish between the theories.\(^{34}\)

We now turn to the transaction-cost component of the model. In the model a second reason for leasing is that it reduces the transaction costs of secondhand trade. As captured in Proposition 5, the prediction that follows from this aspect of the model is that high-valuation consumers lease more because they replace their cars more frequently and so benefit more from the reduced transaction costs.\(^{35}\) If, as seems likely, high income typically means a high valuation for new-car quality, then the literature already contains evidence consistent with this prediction. Specifically, Aizcorbe and Starr-McCluer (1997) and Mannering, Winston, and Starkey (2002) both find a positive relationship between leasing and income. For example, in an analysis of the CES, Aizcorbe and Starr-McCluer found that in 1992, 1.0%, 1.0%, 1.6%, 4.1%, and 11.4% of households with incomes below $10,000, between $10,000 and $25,000, between $25,000 and $50,000, between $50,000 and $100,000, and above $100,000 leased, respectively. In terms of our prediction, however, these results have some drawbacks. Specifically, the Aizcorbe and Starr-McCluer finding that the percentage of households with a leased car rises with income need not be due to the percentage of new-car transactions that are leases rising with income. Rather,

\(^{34}\)Peterson and Schneider (2014) provide evidence for adverse selection in the used-car market employing a test not subject to the efficient sorting argument discussed above. Their test focuses on the idea that some used-car problems are more likely to be unobservable to potential buyers than other problems and the adverse-selection and efficient sorting arguments can be distinguished in the data by focusing on these differences in observability.

\(^{35}\)To be precise, in our theoretical model there is a single type of new-car driver so taken literally the model does not make any prediction concerning how leasing varies across different types of new-car drivers. But we could add multiple consumer groups that drive new cars and formally derive the result.
the finding is potentially explained by lower income households possessing fewer cars and more of these cars being used cars that are infrequently leased.\textsuperscript{36}

To investigate the relationship between leasing and income, we employ the CES to calculate lease percentages for new-car vintages between 1990 and 2005, where we avoid the drawbacks of the Aizcorbe and Starr-McCluer findings by having the unit of observation be a newly purchased or leased car as opposed to a household. Table 5 looks at raw lease percentages by income group at both three-year intervals and over the whole period and finds that leasing generally increases with income. In addition, except for the 1990-1993 time period, the results are not consistent with the Aizcorbe and Starr-McCluer finding that the increase is particularly pronounced for the highest income groups.

Another approach for proxying for high-valuation consumers is to consider how leasing varies with new-car price. That is, consumers with high valuations on car quality should purchase more expensive new cars on average so the prediction is that new-car lease percentage rises with new-car price. In Table 6 we investigate this prediction by looking at raw lease percentages by new-car price at both three-year intervals and over the whole period. The results are consistent with the prediction that leasing rises with new-car price. Overall, Tables 5 and 6 strongly support the prediction that leasing rises with consumer valuation for new-car quality.

The final return to leasing in our model that we investigate in this subsection is that lessees return cars at lease expiration more frequently than cars of the same age that were purchased when new are sold on the secondhand market. In our model the return to this behavior is that it both reduces adverse selection and reduces the transaction costs associated with trading on the secondhand market. Figure 1 shows hazard rates for the disposal of leased and owned cars. That is, the figure shows the fraction of leased (owned) cars that are not disposed prior to age $T$ that are disposed at age $T$, where a leased car that is bought back is considered as not disposed (note that the curve for leased cars ends at age seven because there were virtually no

\textsuperscript{36} The Mannering, Winston, and Starkey (2002) finding of a positive correlation between income and leasing is not subject to this drawback, but it does not provide detailed evidence concerning how leasing varies with income.
leased cars past this age).\textsuperscript{37} The figure is consistent with our theoretical model. Specifically, leasing is associated with a higher frequency of secondhand market trade which, in turn, is consistent with leasing reducing both adverse selection and transaction costs associated with secondhand-market trade.\textsuperscript{38}

B) Growth in Leasing

As discussed earlier, there has been substantial growth over time in the amount of leasing in the US new-car market. Our model provides an explanation for this growth which is focused on the moral-hazard aspect of the model. Specifically, since moral hazard concerning maintenance is the cost of leasing in our model, the percentage of new cars leased should rise if the cost of moral hazard falls. In turn, in our model improvements in new-car reliability reduce the cost of moral hazard, so as captured in Proposition 2 a potential explanation for the growth of leasing over time is improvements in new-car reliability which have been reported in various sources including Consumer Reports (2003, 2005).

There is already evidence in the literature consistent with the Proposition 2 prediction that the new-car lease percentage should increase with new-car reliability. For example, Desai and Purohit (1999) develop a measure of reliability using information reported in Consumer Reports and then show in a cross-sectional analysis that more reliable car models have higher lease percentages. Another study is Mannering, Winston, and Starkey (2002) which reports similar results in their empirical study of the probability a household leases rather than purchases a new car as a function of consumer attributes.

\textsuperscript{37} The data for the figure is the sample of cars that were obtained new and entered the sample period still in the possession of the original driver. For cars of each age, we calculated the fraction of cars that entered the sample period still in the possession of the original driver that was disposed during the one-year sample period. For respondents with less than one year of data (a non-response in at least one quarter), we annualized the disposal rate by multiplying the quarterly disposal indicator by four and dividing by the number of available quarters which is between one and four. Note that the results are similar if we limit the sample to respondents with all four quarters of data.

\textsuperscript{38} Controlling for driver and car characteristics, either individually or together, in hazard regression models yields similar results.
We extend these previous analyses by considering whether over time a model’s new-car lease percentage is correlated with the model’s reliability. The dependent variable is the percentage lease rate by model and vintage and the explanatory variable of interest is our reliability measure, where in this test we use average reliability over the first three years the car was on the road. When we include fixed effects for model we are measuring the within-model-over-time relationship and we also include year fixed effects to control for trends in leasing and reliability over time. Results are reported in Table 7, where column 1 does not include model fixed effects while column 2 does. The results strongly support the prediction that leasing is positively related to reliability (remember that for our measure of reliability a higher value means lower reliability). Specifically, the coefficient on the reliability variable has the predicted sign in both columns, where the column 1 coefficient is statistically significant at the five percent level and the column 2 coefficient is statistically significant at the one percent level.39

These results are consistent with the large increase in new-car leasing that has occurred during the last few decades being at least partly due to the substantial increases in new-car reliability that has also occurred during this period.40 As just discussed, even after controlling for the time trends in reliability and leasing percentages, we find that within-model changes in leasing over time are correlated with within-model changes in reliability.41

39 One concern with this test is that the consumer types who lease or the act of leasing may affect the reliability measure given it is based on driver reports of new-car defects concerning various parts of the cars. So at least theoretically the correlation we find between leasing and reliability could be due to reverse causation, i.e., more leasing leads to higher reliability rather than the reverse. But this seems unlikely. Earlier results show that, on average, leasing results in decreased maintenance, so any causal connection between leasing and reliability that starts with the leasing decision should result in a negative correlation between leasing and reliability rather than the positive correlation that we find.

40 Starting around 2002 there was a decline in new-car leasing in the US, although not in Europe. One possible reason for the decline in the US is that lease terms in the late 1990s and early 2000s in the US were overly generous because manufacturers systematically overestimated residual values, and starting around 2002 lease terms became less generous as manufacturers realized their mistakes. See Global Vehicle Remarketing 2003: North American Markets (2003) for a related discussion.

41 One alternative explanation for the Table 7 results is that, consistent with Proposition 5, individuals with high valuations on car quality lease more, while they also value reliability more. In this alternative explanation there is no causal link between leasing and reliability but they are correlated nevertheless because both are correlated with driver valuations concerning car quality. Potentially one could distinguish between the explanations by including a measure of average income of new-car drivers by model-vintage. Unfortunately, we are unable to construct a measure of average driver income by model-vintage with sufficient precision to conduct this test. Another alternative explanation is that more reliable new cars have higher residual values, which lowers monthly payments
V. ALTERNATIVE EXPLANATIONS

There are a number of alternative theoretical explanations for why products are leased and, in particular, the role of leasing in the new-car market. Here we discuss the main alternatives. One classic explanation for leasing is that it is a response to a lack of ability to commit. The basic argument found initially in Coase (1972) is that a durable-goods monopolist that sells its output will not internalize how its actions in one period affect the value of units sold previously.\(^{42}\) The result is that the monopolist has an inefficiently high incentive to take actions such as increasing output that lower the value of previously sold units. In turn, if consumers anticipate this behavior, then consumer willingness to pay falls in early periods which reduces overall monopoly profitability. Leasing avoids the problem because when the monopolist leases it owns the used units so it internalizes actions that affect the value of units previously produced.

There are a number of reasons why a lack of ability to commit is unlikely to be the correct explanation for new-car leasing. First, this is a monopoly explanation but there are many producers in the automobile market and it is unlikely that any producer has sufficient market power to make the lack of ability to commit argument a significant issue (see footnote 6). Second, according to Bond and Samuelson (1984), commitment problems are significantly reduced in markets characterized by replacement sales and in the car market replacement sales are standard. Third, if leasing is employed to avoid problems due to an inability to commit, then new-car production should have fallen during the period leasing grew. But the evidence is inconsistent with this prediction. For example, according to Tables 5 and 6 the fraction of new cars leased in the US grew steadily during the 1990s, but there was no corresponding shrinkage in the size of the new-car market.\(^{43}\)


\(^{43}\) Another monopoly explanation for leasing is put forth in Waldman (1997) and Hendel and Lizzieri (1999). In that argument leasing is used by a durable-goods monopolist as a way of reducing used-unit availability. However, there is an important problem with this argument in terms of it serving as an explanation for new-car leasing which is that  

and consequently increases leasing either because of credit market constraints or consumer myopia. As we discuss in Section V, however, the evidence overall does not seem to support the credit market constraint or consumer myopia arguments for new-car leasing.
A second classic explanation for leasing is that leasing is associated with tax advantages as argued, for example, in Myers, Dill, and Bautista (1976) and Franks and Hodges (1987). Further, as discussed by Crocetti (1988) and Auster (1990), these tax advantages grew in the US after the Tax Reform Act of 1986 so the tax argument is consistent with the growth in leasing in the US after the mid-1980s. But there are a number of reasons for believing that the tax argument is not a major factor in the long-term growth in new-car leasing. First, the tax argument predicts growth in leasing in the US market starting in 1986 and a leveling off of the percentage of new cars leased soon afterward. But in fact the growth in US new-car leasing started prior to 1986 and continued for over ten years after the change in the tax laws (see Tables 5 and 6). Second, new-car leasing has also increased in many European countries over the same time period and we know of no change in tax rates or tax policies in these other locations that would explain this growth (in contrast, our argument that leasing has grown because of increased new-car reliability is consistent with leasing increasing in both the US and Europe). Third, the tax argument does not explain other patterns found in the data such as that leasing rises with new-car reliability and that leasing affects the relationship between used-car repair rates and whether the car was purchased on the secondhand market or continuously held.

Two other related explanations follow. First, as argued by Wyman (1973) and Copeland and Weston (1982) amongst others, leasing can be used to transfer risk from risk-averse lessees to risk neutral or at least less risk-averse lessors. The argument is that, if there is uncertainty concerning the residual value of the product at the time of lease expiration, leasing can be a way of more efficiently allocating that risk. Note, however, that absolute risk aversion is likely to fall with consumer income which, according to this explanation, suggests that leasing should be more common among low-income consumers. The problem is that empirical results reported here and elsewhere indicate that leasing is more common among high-income consumers.

the argument predicts the durable-goods producer will scrap some or all of the used units returned to the firm, but this is inconsistent with standard behavior in this market.
Second, a popular explanation in the business press is that leasing is popular because it lowers monthly payments (see Woodruff (1994) for an early discussion of this argument). The argument is that, because of either consumer myopia or limited access to capital markets, consumers perceive that leasing is more affordable. But it should be low-income rather than high-income consumers who are most likely to be myopic and most likely to have limited access to capital markets. So, as was the case with the previous explanation, this explanation predicts that leasing should be more popular among low-income consumers. Hence, the fact the evidence does not support this prediction suggests that the affordability argument is not what is driving most real-world lease decisions.44-45

In summary, there are a number of alternative explanations for the role of leasing in the new-car market, but none of the major alternatives fit the evidence very well.

VI. CONCLUSION

There are many possible reasons for why a product is leased. We began by constructing and analyzing a model that combines the adverse-selection and moral-hazard arguments of Hendel and Lizzeri (2002) and Johnson and Waldman (2003,2010) with the transaction-cost argument of Gavazza (2011). In our model, the main cost of leasing is moral hazard, while the main returns are reduced adverse selection and transaction costs. As argued by a number of previous authors, leasing results in moral hazard concerning consumer maintenance. That is, because with high probability the consumer returns the product at lease expiration, the incentive for consumers to perform maintenance is inefficiently low. Leasing also reduces adverse

44 One could argue that this argument should hold even for high-income consumers if leasing allows such consumers to drive even more expensive new cars. We have conducted a regression analysis where an indicator for whether the car was leased is the dependent variable and the explanatory variable of interest is household income. We find that, even when model-vintage fixed effects are included, household income has a statistically significant positive coefficient. This further rules out the argument that leasing is used because it makes new cars more affordable.

45 Another related argument appears in Pierce (2012). That paper provides theory and evidence consistent with the idea that, either because of the need to “move” unpopular cars or because of an agency problem across divisions, a manufacturer serving as its own lessor may increase residual values written into lease contracts above the true expected residual values. That argument, however, does not explain most of the patterns we identify.
selection because appropriately setting the buyback price allows the lessor to control the frequency of secondhand-market trade. Finally, leasing reduces transaction costs associated with secondhand trade due to economies of scale on the selling side of the market. Using our model, we derive a number of testable predictions and then provide an empirical analysis. We find strong support for our model and the joint role of these factors for understanding how leasing works in the new-car market.

In terms of our empirical results, we believe there are two findings that are of particular interest. The first is our finding concerning our test of adverse selection. Starting with Bond (1982,1984), a number of papers have tested for adverse selection by investigating whether used cars sold on the secondhand market are lower quality than similar used cars continuously held as predicted by the adverse-selection argument. The results in this literature are mixed. We conduct a similar test but, consistent with an argument first made in Hendel and Lizzeri (2002) and Johnson and Waldman (2003), allow for the possibility that leasing reduces the adverse-selection problem. We find results consistent with adverse selection for pre-owned used cars and that leasing serves to reduce the adverse-selection problem.

The second finding we think is of particular interest concerns the growth of leasing in the last few decades in the new-car market. A number of explanations for this growth have been suggested such as changes in the tax laws, but in general these explanations do not match the evidence very well. We argue that this growth is due to improvements in new-car reliability, where in our argument such improvements lead to increased leasing because improved reliability reduces the severity of the moral-hazard problem associated with the leasing decision. We find clear evidence that more reliable new cars have higher lease rates as our argument predicts. That is, even after controlling for differences in average lease rates across car models and time trends concerning the leasing decision, there is still a statistically significant positive correlation between new-car reliability and leasing. We believe this is strong evidence that improvements in new-car reliability do result in increased leasing and thus strong evidence that improvements in new-car reliability are in fact an important factor in the growth in leasing in the new-car market.
APPENDIX

Proof of Proposition 1: To prove the first part of this proposition, note that all leased cars that are returned have zero maintenance. The reason is that if a lessee does not plan to return the car, choosing \( m = 1 \) requires bearing the cost \( \kappa > 0 \) in period 1 but generates no return in period 2, given that the contractual terms do not depend on \( m \).

Thus, the first part of the proposition follows. However, to show that it is not a vacuous claim, we show that some leased cars are indeed returned and sold on the used-car market in equilibrium. To this end, we derive the features of the optimal lease contract. Because the equilibrium maintenance decisions are determined solely by whether a consumer intends to keep the used vehicle or not, to determine the optimal contract it is sufficient to determine which realizations of \( q \) are kept; let \( \tilde{q}_L \) denote the threshold such that consumers keep all cars of higher quality.

We begin by confirming \( \tilde{q}_L \) is a choice variable at the contract-design stage that can be enforced by selecting an appropriate buyback price \( p^B \). To see this, note that in period 1 a consumer is marginally willing to choose \( m = 1 \) for a car of quality \( \tilde{q}_L \) and plan to drive it in period 2 after paying \( p^B \), as opposed to choosing \( m = 0 \) and planning on buying a new car in period 2, so long as \( \delta(v_i\tilde{q}_L - p^B) - \kappa = \delta(v_iq^N - c) \). This determines the required \( p^B \), given a target value of \( \tilde{q}_L \). To confirm that in period 2 the consumer would indeed keep exactly these cars, note that it is optimal to keep cars of \( \tilde{q}_L \) or higher if maintenance has indeed already been spent on these cars (because the above equality becomes an appropriate inequality once \( \kappa \) is sunk). To show that any car of quality less than \( \tilde{q}_L \) for which \( m = 0 \) will not be kept, consider the marginal case of the car of quality exactly \( \tilde{q}_L \) under the hypothetical \( m = 0 \). Keeping the car generates utility for the lessee of \( v_i(\tilde{q}_L - \Delta) - p^B < v_i\tilde{q}_L - p^B - \delta^{-1}\kappa = v_iq^N - c \), where the inequality between the first and second expressions follows from the assumption \( \delta v_i\Delta > \kappa \), and the equality between the second and third expressions follows from the construction of \( p^B \) as indicated just above. Because the term on the right is the payoff to buying a new car in period 2, it follows that \( p^B \) can always be chosen to enforce any desired \( \tilde{q}_L \).
Now, because a competitive market ensures that lessees capture all the social surplus from leasing, the gross surplus in period 1 is fixed at \( v_i q^N - c \), and a leased car has \( m = 1 \) if and only if the lessee drives it in period 2, the optimal \( \tilde{q}_L \) maximizes second period social surplus,

\[
\int_{\tilde{q}} q^N - c + v_2(q - \Delta) dF(q) + \int_{\tilde{q}} q^N (v_i q - \delta^{-1} \kappa) dF(q),
\]

with a first derivative equal to the following (neglecting a term involving the density that does not influence the sign): \( v_1 q^N - c + v_2 (\tilde{q}_L - \Delta) - v_i \tilde{q}_L + \delta^{-1} \kappa \). Evaluated at \( q \), this gives \( v_1 q^N - c + v_2(q - \Delta) - v_1 q + \delta^{1} \kappa > 0 \), by an assumption in the text. Instead evaluating at \( q^N \), we get \( v_2 q^N - c - (v_2 \Delta - \delta^{-1} \kappa) < v_2 q^N - c < 0 \), again by an assumption in the text. Thus, the optimal contract exhibits \( \tilde{q}_L \in (q, q^N) \), and the first part of the proposition is (non-vacuously) true.

To prove the second part of the proposition, it is enough to show \( m = 1 \) for purchased new cars. This is sufficient because we just showed that \( m = 0 \) for leased cars that are returned. It is straightforward to show that there are indeed beliefs that purchased cars always have \( m = 1 \). Simply specify that \( m = 0 \) leads to a used car price of \( v_2(q - \Delta) \), as is the case if group-2 consumers believe that a car owner who has selected \( m = 0 \) has a car of quality \( q - \Delta \). In contrast, the price of a used car with \( m = 1 \) can never be lower than \( v_2 q \), so that, because \( \delta v_2 \Delta > \kappa \), it is profitable for consumers to choose \( m = 1 \). Hence, choosing \( m = 0 \) is a zero probability event, so beliefs may indeed be assigned as suggested.

\[\blacksquare\]

**Proof of Proposition 2:** To prove this result, we first show that the payoff to purchasing a new car in period 1 does not depend on \( \Delta \), and then show that the payoff associated with leasing decreases with \( \Delta \). It follows that leasing becomes more attractive as \( \Delta \) falls.

To show that the payoff to purchasing a new car is independent of \( \Delta \), recall that we are restricting attention to equilibria in which consumers who purchase new cars always choose \( m = 1 \). It follows that any second-period equilibrium in the used-car market for such cars is comprised of a market price \( p \) and threshold \( \overline{q} \) such that owners keep their used cars if and only if \( q \geq \overline{q} \).
The quantities \( p \) and \( \tilde{q} \) satisfy the following conditions: \( p = v_2 E(q \mid q \leq \tilde{q}) \) and \( v_1 q^N - c + p - \tau = v_1 \tilde{q} \). The first says that \( p \) reflects average quality given the threshold \( \tilde{q} \), and the second indicates that consumers indeed choose threshold \( \tilde{q} \) given \( p \). As these expressions do not involve \( \Delta \), \( p \) is invariant to \( \Delta \) (recall that we are selecting the equilibrium with the largest \( p \) if there are multiple equilibria) and hence the return to buying a new car is also invariant.

Now consider leasing. As discussed in the proof of Proposition 1, in the optimal lease contract the threshold rule for returning used cars, \( \tilde{q}_L \), is chosen by the lessor to maximize the social surplus, subject to the constraint that \( m = 0 \) when \( q \leq \tilde{q}_L \). This surplus is given by

\[
v_1 q^N - c + \delta \left\{ \int_{\tilde{q}}^{\tilde{q}_L} [v_1 q^N - c + v_2 (q - \Delta)]dF(q) + \int_{\tilde{q}_L}^{\tilde{q}} (v_1 q - \delta^{-1} \kappa) dF(q) \right\}.
\]

Applying the envelope theorem, a small decrease in \( \Delta \) changes surplus by \( \partial v_2 F(\tilde{q}_L) > 0 \), using the fact (derived in the proof of Proposition 1) that \( \tilde{q}_L < q \). The proposition follows.

**Proof of Proposition 3**: This follows from the facts that owners of cars always invest in maintenance in period 1 and always keep cars of higher rather than lesser quality.

**Proof of Proposition 4**: The statement of the proposition is equivalent to the claim \( \tilde{q} < \tilde{q}_L \), so that the thresholds for which cars are kept (in terms of realizations from \( F(q) \)) are thusly ranked. There are three steps to showing this. The first is showing that this condition is equivalent to \( p^B + \delta^{-1} \kappa > p - \tau \), where \( p^B \) is the buyback price and \( p \) is the price for used cars purchased when new. This follows because the marginal car \( \tilde{q}_L \) that a lessee keeps satisfies

\[
\delta(v_1 \tilde{q}_L - p^B) - \kappa = \delta(v_1 q^N - c) \iff v_1 \tilde{q}_L = v_1 q^N - c + p^B + \delta^{-1} \kappa,
\]

and the marginal car \( \tilde{q} \) that a new car buyer keeps satisfies \( v_1 \tilde{q} = v_1 q^N - c + p - \tau \). Inspection reveals that, as claimed, \( \tilde{q}_L > \tilde{q} \) if and only if \( p^B + \delta^{-1} \kappa < p - \tau \). The second step is showing \( p^{LU} < p^B \), where \( p^{LU} \) is the price of used cars leased when new. To see this, use the condition just derived on \( \tilde{q}_L \) along with the first-order condition on \( \tilde{q}_L \) (derived in the proof of Proposition
1), \( q_1 \tilde{q}_L = v_1 q^N - c + v_2 (\tilde{q}_L - \Delta) + \delta^{-1} \kappa \), to conclude that \( p^B = v_2 (\tilde{q}_L - \Delta) \). Now, because \( m = 0 \) for leased cars that are returned, we know that \( p^{LU} = v_2 [E(q \mid q \leq \tilde{q}_L) - \Delta] < v_2 (\tilde{q}_L - \Delta) = p^B \), where the strict inequality follows because the optimal \( \tilde{q} \) exceeds \( \underline{q}_L \), as shown in the proof of Proposition 1.

Because \( p^{LU} < p^B \), the condition \( p^B + \delta^{-1} \kappa > p - \tau \) is implied if it is the case that \( p^{LU} + \delta^{-1} \kappa \geq p - \tau \). Hence, if we can show that \( p^{LU} + \delta^{-1} \kappa \geq p - \tau \), the proposition follows.

Consider a lessee. Because the leasing market is competitive so the lessee extracts all social surplus associated with lease contracts and since \( m = 0 \) for returned cars, the implicit expenditure on a new car leased in period 1 is \( c - \delta p^{LU} F(\tilde{q}_L) + \kappa (1 - F(\tilde{q}_L)) \). Now suppose this consumer purchased a car in period 1 rather than leasing, but that he kept the same cars as if he were leasing and also chose \( m = 1 \) for all \( q \) rather than just for \( q > \tilde{q}_L \). This consumer would drive cars of exactly the same quality in both periods as if he had instead leased, and would have the same total expenditures on new cars in period 2 as well. However, this consumer’s implicit expenditure on the car purchased in period 1 would be \( c - \delta (p - \tau - \delta^{-1} \kappa) F(\tilde{q}_L) + \kappa (1 - F(\tilde{q}_L)) \). Now, if \( p^{LU} + \delta^{-1} \kappa < p - \tau \), then the implicit expenditure on this car would be less than when the consumer leased, which would mean no leasing in equilibrium. Since our parameter restrictions require leasing, the proposition follows.

**Proof of Proposition 5:** Because some consumers always lease, in particular for any given \( v_1'' \), all that remains to show is that the number who lease becomes small as \( v_1 \) becomes small (but not so small as to violate any assumption in the text). By Proposition 4 we know that \( \tilde{q}_L > \tilde{q} \). This means the gain to leasing rather than buying (which equals the change in second-period social surplus) is proportional to

\[
F(\tilde{q})[\tau - v_2 \Delta + \delta^{-1} \kappa] + \int_{\tilde{q}}^{\tilde{q}_L} [v_1 q^N - c - v_1 q + v_2 (q - \Delta) + \delta^{-1} \kappa]dF(q).
\]

The first term captures that leasing avoids the transaction cost \( \tau \) on \( q < \tilde{q} \), and also saves the maintenance cost \( \kappa \) (borne in period 1), but choosing \( m = 0 \) lowers the value of those cars to group-2 consumers by \( v_2 \Delta \).
The second term measures the change in payoff from buying more new cars and hence selling more used cars in period 2 when one leases rather than buys. In particular, for each vehicle in this quality range, the lessee gains directly utility $v_i q^N - c - v_i q$ by driving a new car rather than a used one, and also gains the surplus generated by the group-2 consumer who ends up driving this vehicle, $v_2 (q - \Delta)$, and finally saves the maintenance cost term involving $\kappa$ that would have been borne if this vehicle had been purchased when new.

Because $\tilde{q}_L > \tilde{q}$, the above expression converges to zero as $\tilde{q}_L$ converges to $q$. Thus, it is sufficient to show that $\tilde{q}_L$ converges to $q$ as $v_i$ becomes small. But as shown in the proof of Proposition 1, $v_i q^N - c + v_2 (q - \Delta) - v_1 q + \delta^{-1} \kappa$ is the marginal incentive for increasing $\tilde{q}_L$ above $q$. By assumption, this expression is positive. We will now show that there is some value of $v_i$, call it $v_i^*$, such that this expression is equal to zero. This ensures that for values of $v_i$ slightly larger than $v_i^*$, the expression just written is positive (as required by assumption) but that $\tilde{q}_L$ is arbitrarily close to $q$, so that the proposition follows. To see that there exists such a value, observe that if $v_i$ were replaced with $v_2$ in this expression, then this expression would equal $v_2 q^N - c - v_2 \Delta + \delta^{-1} \kappa < v_2 q^N - c < 0$, where the first inequality follows from the fact that $\delta^{-1} \kappa < v_2 \Delta$, and where the second inequality follows from the assumption that it is never optimal for a group-2 consumer to buy a new car in period 1. Hence, there must be some value $v_i^*$ as claimed, and the result follows. ■
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Political Economy*. 112, pp. 1157-1180.


Political Economy*. 110, pp. 113-143.


Economics*. 34, pp. 247-265.


Table 1: Descriptive statistics

<table>
<thead>
<tr>
<th></th>
<th>Non-missing observations</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Min/Max</th>
</tr>
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<tbody>
<tr>
<td>Vintage</td>
<td>79,618</td>
<td>1996.2</td>
<td>4.5</td>
<td>1986/2005</td>
</tr>
<tr>
<td>Age</td>
<td>79,618</td>
<td>2.91</td>
<td>1.50</td>
<td>0/5</td>
</tr>
<tr>
<td>Odometer (x10⁴)</td>
<td>79,618</td>
<td>4.14</td>
<td>2.79</td>
<td>0/18</td>
</tr>
<tr>
<td>Household in 0-39 income percentile</td>
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<td>0.23</td>
<td>0.42</td>
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<td>Household in 40-79 income percentile</td>
<td>68,719</td>
<td>0.47</td>
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<td>Household in 80-94 income percentile</td>
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<td>0.22</td>
<td>0.41</td>
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<td>Household in 95-98 income percentile</td>
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<td>0.06</td>
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<td>0/1</td>
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<tr>
<td>Household in 99 income percentile</td>
<td>68,719</td>
<td>0.02</td>
<td>0.12</td>
<td>0/1</td>
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<td>Fraction cars of model-vintage-age with problems (Consumer Reports)</td>
<td>35,004</td>
<td>0.51</td>
<td>0.16</td>
<td>.12/.78</td>
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<td>Fraction cars of model-vintage leased when new (CNW Marketing Research)</td>
<td>25,946</td>
<td>0.31</td>
<td>0.11</td>
<td>.00/.84</td>
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<tr>
<td>Maintenance</td>
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<tr>
<td>Repair</td>
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<td>0/1</td>
</tr>
<tr>
<td>Gas per day ($)</td>
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<td>2.63</td>
<td>2.38</td>
<td>0/49.32</td>
</tr>
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<td>Car obtained new by lease</td>
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<td>0.06</td>
<td>0.23</td>
<td>0/1</td>
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<tr>
<td>Bought back in sample period</td>
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<td>0.04</td>
<td>0.20</td>
<td>0/1</td>
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<tr>
<td>Continuously-held in sample period</td>
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<td>0.90</td>
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<tr>
<td>Returned in sample period</td>
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<tr>
<td>Car obtained new by purchase</td>
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<td>0.68</td>
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<td>0/1</td>
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<tr>
<td>Traded-in or sold in sample period</td>
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<td>0/1</td>
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<td>Car obtained used by purchase</td>
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<td>2.13</td>
<td>1.06</td>
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</table>

Notes: The unit of observation is vehicle-quarter such that up to four observations per car are included. Observations for cars up to age five are included since most of the analysis is limited to this age range. Note that Consumer Reports data are available only for 1990 to 2003 vintages while CNW Marketing Research data are available only for 1996 to 2000 vintages. Only vehicles from households with one car and/or truck are included to allow maintenance and repair occurrences to be matched to individual cars. Data points where odometer is missing or contains original data entry are excluded since most of the analysis requires odometer. Only cars that are purchased new and continuously held, sold, or traded-in; cars leased new and continuously held, bought back, or returned during the sample period; or cars purchased used are included since other cars are not included in the analysis. Quarters in which the car was purchased or disposed are excluded since data for a full quarter of maintenance or repairs are unavailable. See the text for additional details about the data.
Table 2: Maintenance of leased cars that are bought back versus returned or continuously-held

<table>
<thead>
<tr>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
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<tbody>
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<td>Lease return</td>
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<td>-0.349***</td>
<td>-0.352***</td>
<td>-0.464**</td>
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<tr>
<td></td>
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<td>[0.100]</td>
<td>[0.100]</td>
<td>[0.187]</td>
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</tr>
<tr>
<td>1 Q before return</td>
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<td></td>
<td>-0.368***</td>
<td>[0.103]</td>
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<tr>
<td>2-4 Q's before return</td>
<td></td>
<td></td>
<td>-0.307***</td>
<td>[0.110]</td>
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<tr>
<td>Continuously held</td>
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<td>-0.256***</td>
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<td>Log of odometer (x10^4)</td>
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<td>0.050**</td>
<td>0.050**</td>
<td>0.044*</td>
<td>0.054</td>
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<td>[0.024]</td>
<td>[0.025]</td>
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<tr>
<td>Income 40-79%</td>
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<td>-0.048</td>
<td>-0.048</td>
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<td>[0.058]</td>
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<tr>
<td>Income 80-94%</td>
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<tr>
<td>Income 95-98%</td>
<td>-0.127***</td>
<td>-0.117**</td>
<td>-0.117**</td>
<td>-0.126**</td>
<td>-0.095</td>
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<td>[0.088]</td>
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<tr>
<td>Income 99%</td>
<td>-0.115**</td>
<td>-0.173**</td>
<td>-0.172**</td>
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<td>[0.083]</td>
<td>[0.083]</td>
<td>[0.115]</td>
<td></td>
</tr>
<tr>
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<td></td>
<td>0.011**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[0.005]</td>
<td></td>
</tr>
<tr>
<td>Lag maintenance</td>
<td></td>
<td></td>
<td></td>
<td>-0.078**</td>
<td>[0.031]</td>
</tr>
<tr>
<td>Constant</td>
<td>0.591***</td>
<td>0.758***</td>
<td>0.757***</td>
<td>0.733***</td>
<td>0.827***</td>
</tr>
<tr>
<td></td>
<td>[0.054]</td>
<td>[0.107]</td>
<td>[0.107]</td>
<td>[0.106]</td>
<td>[0.182]</td>
</tr>
</tbody>
</table>

Notes: The unit of observation is vehicle-quarter. The sample is limited to vehicles up to age five that were leased when new and continuously-held, returned to the dealer, or bought back during the sample period. The dependent variable is an indicator for positive maintenance expenditures. “Continuously held” indicates that the leased vehicle was not returned or bought back during the sample period, while “Lease return” indicates that the car was returned to the dealer during the sample period (the omitted category is buyback). The models are estimated as linear probability models. Heteroskedasticity-robust standard errors clustered at the car level are reported in brackets. See the text for additional details about the data. *, **, and *** indicate significance at the 10, 5, and 1 percent levels respectively.
Table 3: Maintenance of owned versus leased cars prior to disposal

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own dispose</td>
<td>0.075**</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>[0.037]</td>
<td>[0.073]</td>
</tr>
<tr>
<td>Log of odometer (x10^{-4})</td>
<td>0.119***</td>
<td>0.208***</td>
</tr>
<tr>
<td></td>
<td>[0.025]</td>
<td>[0.053]</td>
</tr>
<tr>
<td>Car age</td>
<td>-0.059***</td>
<td>-0.077***</td>
</tr>
<tr>
<td></td>
<td>[0.016]</td>
<td>[0.027]</td>
</tr>
<tr>
<td>Income 40-79%</td>
<td>-0.053</td>
<td>-0.089</td>
</tr>
<tr>
<td></td>
<td>[0.041]</td>
<td>[0.073]</td>
</tr>
<tr>
<td>Income 80-94%</td>
<td>-0.009</td>
<td>0.048</td>
</tr>
<tr>
<td></td>
<td>[0.046]</td>
<td>[0.093]</td>
</tr>
<tr>
<td>Income 95-98%</td>
<td>0.090</td>
<td>0.036</td>
</tr>
<tr>
<td></td>
<td>[0.065]</td>
<td>[0.120]</td>
</tr>
<tr>
<td>Income 99%</td>
<td>-0.063</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>[0.085]</td>
<td>[0.146]</td>
</tr>
<tr>
<td>Constant</td>
<td>0.449***</td>
<td>0.401***</td>
</tr>
<tr>
<td></td>
<td>[0.052]</td>
<td>[0.095]</td>
</tr>
</tbody>
</table>

Model-vintage fixed effects  No  Yes
Number of model-vintage groups  559
Observations  1151  1151
Observed mean of dependent variable  0.47  0.47

Notes: The unit of observation is vehicle-quarter. The sample is limited to vehicles up to age five that were purchased new and traded-in or sold, or leased new and returned, during the sample period. The dependent variable is an indicator for positive maintenance. “Own dispose” indicates that the vehicle was purchased new and disposed during the sample period (the omitted category is vehicles that were leased new and returned during the sample period). The models are estimated as linear probability models. Heteroskedasticity-robust standard errors clustered at the car level are reported in brackets. See the text for additional details about the data. *, **, and *** indicate significance at the 10, 5, and 1 percent levels respectively.
Table 4: Repair of cars that are purchased new and continuously-held versus purchased used

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased used</td>
<td>-0.005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.006]</td>
<td></td>
</tr>
<tr>
<td>Purchased used x model-vintage lease fraction &lt;5%</td>
<td>0.182**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.083]</td>
<td></td>
</tr>
<tr>
<td>Purchased used x model-vintage lease fraction 5-14%</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.037]</td>
<td></td>
</tr>
<tr>
<td>Purchased used x model-vintage lease fraction 15-24%</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.012]</td>
<td></td>
</tr>
<tr>
<td>Purchased used x model-vintage lease fraction 25+</td>
<td>-0.010</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.007]</td>
<td></td>
</tr>
<tr>
<td>Fraction vehicles of model-vintage-age with problems</td>
<td>0.081***</td>
<td>0.075***</td>
</tr>
<tr>
<td></td>
<td>[0.017]</td>
<td>[0.017]</td>
</tr>
<tr>
<td>Car age</td>
<td>0.009***</td>
<td>0.009***</td>
</tr>
<tr>
<td></td>
<td>[0.002]</td>
<td>[0.002]</td>
</tr>
<tr>
<td>Log of odometer (x10^-4)</td>
<td>0.032***</td>
<td>0.033***</td>
</tr>
<tr>
<td></td>
<td>[0.004]</td>
<td>[0.004]</td>
</tr>
<tr>
<td>Income 40-79%</td>
<td>0.015***</td>
<td>0.015***</td>
</tr>
<tr>
<td></td>
<td>[0.005]</td>
<td>[0.005]</td>
</tr>
<tr>
<td>Income 80-94%</td>
<td>0.020***</td>
<td>0.021***</td>
</tr>
<tr>
<td></td>
<td>[0.007]</td>
<td>[0.007]</td>
</tr>
<tr>
<td>Income 95-98%</td>
<td>0.027**</td>
<td>0.028**</td>
</tr>
<tr>
<td></td>
<td>[0.012]</td>
<td>[0.012]</td>
</tr>
<tr>
<td>Income 99%</td>
<td>0.045**</td>
<td>0.045**</td>
</tr>
<tr>
<td></td>
<td>[0.023]</td>
<td>[0.023]</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.036***</td>
<td>-0.032***</td>
</tr>
<tr>
<td></td>
<td>[0.008]</td>
<td>[0.008]</td>
</tr>
<tr>
<td>Observations</td>
<td>13682</td>
<td>13682</td>
</tr>
<tr>
<td>Observed mean of dependent variable</td>
<td>0.08</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Notes: The unit of observation is vehicle-quarter and the vintage range for the sample used in this table is 1996-2000 because this is the time period for which lease-fraction data is available. The dependent variable is an indicator for whether the vehicle received at least $100 (2008 dollars) in repairs that quarter. The sample consists of vehicles up to age seven (Consumer Reports data are available through age seven) that were either purchased new and continuously held, or purchased used. The models are estimated as linear probability models. “Fraction vehicles of model-vintage-age with problems” is the fraction of vehicles of that model-vintage-age with at least one serious problem over a year (from Consumer Reports). Heteroskedasticity-robust standard errors clustered at the car level are reported in brackets. See the text for additional details about the data. *, **, and *** indicate significance at the 10, 5, and 1 percent levels respectively.
Table 5: Fraction of new cars that are leased, by household income

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0-39%</td>
<td>0.05</td>
<td>0.13</td>
<td>0.14</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>40-79%</td>
<td>0.05</td>
<td>0.16</td>
<td>0.19</td>
<td>0.10</td>
<td>0.13</td>
</tr>
<tr>
<td>80-94%</td>
<td>0.07</td>
<td>0.24</td>
<td>0.23</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td>95-98%</td>
<td>0.17</td>
<td>0.28</td>
<td>0.25</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>99%</td>
<td>0.18</td>
<td>0.26</td>
<td>0.33</td>
<td>0.14</td>
<td>0.22</td>
</tr>
<tr>
<td>All incomes</td>
<td>0.07</td>
<td>0.19</td>
<td>0.21</td>
<td>0.11</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Notes: For households in the specified income percentile range, the table shows the fraction of new vehicles that were obtained through leasing. Observations are weighted using the U.S. population representative CES weights.

Table 6: Fraction of new cars that are leased, by new-car price

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0-39%</td>
<td>0.04</td>
<td>0.16</td>
<td>0.17</td>
<td>0.09</td>
<td>0.12</td>
</tr>
<tr>
<td>40-79%</td>
<td>0.09</td>
<td>0.21</td>
<td>0.21</td>
<td>0.10</td>
<td>0.15</td>
</tr>
<tr>
<td>80-94%</td>
<td>0.08</td>
<td>0.22</td>
<td>0.27</td>
<td>0.15</td>
<td>0.18</td>
</tr>
<tr>
<td>95-98%</td>
<td>0.12</td>
<td>0.25</td>
<td>0.27</td>
<td>0.19</td>
<td>0.21</td>
</tr>
<tr>
<td>99%</td>
<td>0.29</td>
<td>0.33</td>
<td>0.38</td>
<td>0.23</td>
<td>0.29</td>
</tr>
<tr>
<td>All new prices</td>
<td>0.07</td>
<td>0.19</td>
<td>0.21</td>
<td>0.11</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Notes: For vehicles in the specified new-price percentile ranges, the table shows the fraction of new vehicles that were obtained through leasing. Observations are weighted using the U.S. population representative CES weights.
Table 7: Car reliability versus lease fraction when new

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction vehicles of model-</td>
<td>-0.171**</td>
<td>-0.223***</td>
</tr>
<tr>
<td>vintage with problems</td>
<td>[0.076]</td>
<td>[0.078]</td>
</tr>
<tr>
<td>Constant</td>
<td>0.386***</td>
<td>0.417***</td>
</tr>
<tr>
<td></td>
<td>[0.037]</td>
<td>[0.029]</td>
</tr>
<tr>
<td>Model fixed effects</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of model groups</td>
<td></td>
<td>142</td>
</tr>
<tr>
<td>Vintage fixed effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of vintage groups</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Observations</td>
<td>472</td>
<td>472</td>
</tr>
<tr>
<td>Obs. mean of dep. variable</td>
<td>0.35</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Notes: The unit of observation is model-vintage and the vintage range for the sample used in this table is 1996-2000 because this is the time period for which lease-fraction data is available. The dependent variable is the fraction of vehicles from a model-vintage that were obtained new via lease (as opposed to purchase). The model is estimated using OLS. The regressor of interest is “Fraction vehicles of model-vintage with problems,” which represents the fraction of vehicles of that model-vintage with at least one serious problem per year, averaged over the first three years of the vehicle’s life (from Consumer Reports). Standard errors are reported in brackets. See the text for additional details about the data. *, **, and *** indicate significance at the 10, 5, and 1 percent levels respectively.
Figure 1: Car disposal hazard rates – leased versus owned cars

Notes: The figure shows the fraction of cars obtained new that were continuously held until the indicated age and disposed at that age (the hazard rate) for leased cars and for owned cars. The curve for “Leased” cars ends at age seven because there are virtually no leased cars in the data set beyond this age.